National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes

Results of the second MonNO3 workshop, 10-11 June 2009

National Institute for Public Health and the Environment
Ministry of Health, Welfare and Sport

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes

Results of the second $MonNO_3$ workshop, 10-11 June 2009

RIVM Report 680717019/2011

NATIONAL ENVIRONMENTAL RESEARCH INSTITUTE
AARHUS UNIVERSITY

GEUS
GEOLOGICAL SURVEY OF DENMARK AND GREENLAND

LEI
WAGENINGEN UR

Colophon

© RIVM 2011
Parts of this publication may be reproduced, provided acknowledgement is given to the 'National Institute for Public Health and the Environment', along with the title and year of publication.

B. Fraters, National Institute for Public Health and the Environment (RIVM)
K. Kovar, PBL Netherlands Environmental Assessment Agency
R. Grant, Danish National Environmental Research Institute (DMU)
L. Thorling, Geological Survey for Denmark and Greenland (GEUS)
J.W. Reijs, LEI, part of Wageningen University and Research Centre

Contact:
Dico Fraters
Centre of Environmental Monitoring
dico.fraters@rivm.nl

This investigation has been performed by order and for the account of the Dutch Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs, Agriculture and Innovation, within the framework of the Minerals Policy Monitoring Programme (LMM), project number 680717.

Abstract

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes
Results of the second MonNO_3 Workshop, 10-11 June 2009

Member States of the European Union are obliged both to monitor the quality of their waters and the effect of their Action Programmes on these waters and to report the results to the European Commission. These monitoring obligations have been interpreted differently by the various countries due to the lack of specific guidelines. Most countries, however, have increased their efforts to monitor water quality the last six years, primarily as a consequence of the discussion between the Member States and the European Commission on how the fertiliser policy should be designed and implemented. Member States try to underpin their position on monitoring with the results from additional monitoring efforts. Another factor contributing to the increase in monitoring is the requirement for Member States that recently joined the EU to adapt their monitoring systems to comply with the obligations of the European Directives.

These are the findings of an International Workshop ('MonNO_3' workshop) organised in 2009 by the RIVM together with the Danish National Environmental Research Institute (DMU), the Geological Survey for Denmark and Greenland (GEUS) and LEI, part of Wageningen University and Research Centre. Twelve countries from Northwest and Central Europe participated in the second MonNO_3 workshop. The focus was on developments since 2003, the year that the first MonNO_3 workshop was held.

Similar to the first 'MonNO_3' workshop, the second one has also contributed to the exchange of knowledge and information – at the international level – on monitoring the effects of the fertiliser policy. Attention was also paid to the use of monitoring data for purposes other than providing information on the status of and trends in water quality; for example, to use data for underpinning measures to be included in the fertiliser policy. In closing, the participants discussed possible amelioration and expansion of the monitoring networks.

Keywords:
minerals policy, water quality, agricultural practices

Rapport in het kort

Ontwikkelingen in het monitoren van de effectiviteit van de Nitraatrichtlijn Actieprogramma's
Resultaten van de tweede MonNO$_3$-workshop, 10-11 juni 2009

Lidstaten van de Europese Unie zijn verplicht om de waterkwaliteit en de effecten van hun mestbeleid daarop te monitoren en hierover te rapporteren aan de Europese Commissie. Uit een internationale workshop blijkt dat landen hun monitoringsverplichting verschillend invullen doordat voorschriften ontbreken. Een andere bevinding is dat de meeste landen de afgelopen zes jaren hebben geïnvesteerd in een uitbreiding van de monitoring van de waterkwaliteit. Deze uitbreiding kwam voort uit een discussie tussen de lidstaten en de Commissie over de wijze waarop het mestbeleid moet worden vormgegeven. Lidstaten proberen hun standpunten hierover te onderbouwen met aanvullende monitoring. Een andere reden voor een uitgebreidere monitoring is dat lidstaten die pas recentelijk bij de Unie zijn aangesloten, hun monitoringssysteem moeten aanpassen aan de richtlijnen.

Het RIVM heeft de workshop in 2009 met het Deense Milieuonderzoeksinstituut (DMU), de Geologische Dienst voor Denemarken en Groenland (GEUS) en het LEI, onderdeel van Wageningen UR, georganiseerd. Aan deze tweede MonNO$_3$-workshop namen twaalf landen uit Noordwest- en Midden-Europa deel. De workshop richtte zich vooral op de ontwikkelingen sinds 2003, het jaar dat de eerste MonNO$_3$ workshop heeft plaatsgevonden.

De tweede workshop heeft, net als de eerste, eraan bijgedragen dat landen kennis en informatie over het monitoren van effecten van het mestbeleid uitwisselen. De workshop stimuleerde bijvoorbeeld de discussie over voor- en nadelen van gebruikte benaderingen van de waterkwaliteitsmonitoring. Daarnaast was er aandacht voor het gebruik van de monitoringgegevens voor andere doeleinden dan de waterkwaliteitsmonitoring, bijvoorbeeld om maatregelen voor het mestbeleid te onderbouwen. Ten slotte stonden de deelnemers stil bij verbeteringen en uitbreidingen van meetnetten.

Trefwoorden:
mestbeleid, waterkwaliteit, landbouwpraktijk

Resumé

Udviklinger i overvågningen af resultaterne af Nitratdirektivets indsatsplaner
Resultater fra den 2. MonNO$_3$ workshop, 10-11 Juni 2000

Medlemsstaterne i EU er forpligtigede til at overvåge kvaliteten af overfladevand og grundvand og effekten af deres indsatsplaner/vandmiljøplaner. Resultaterne af overvågningen skal rapporteres til EU kommissionen. Resultaterne af en international workshop viste, at landene havde deres egne fortolkning af, hvorledes overvågningen skal gennemføres, idet der ikke er nogen retningslinjer for, hvorledes overvågningen skal udføres, hverken i direktivet eller som EU-guidelines. En anden konklusion var, at de fleste lande inden for de sidste seks år havde øget deres overvågningsindsats over for vandkvaliteten. Denne forøgelse er en konsekvens af diskussioner mellem medlemsstaterne og EU kommissionen om hvorledes næringsstof politikken skulle defineres, herunder harmonikravene. Medlemsstaterne prøver således at understrege deres synspunkter ved hjælp af resultaterne fra en ekstra overvågningsindsats. Et andet incitament for en øget overvågning relaterer til den kendsgerning at de medlemsstater, der for nylig har tilsluttet sig EU, har haft et behov for at tilpasse deres overvågningssystemer for at opfylde kravene i relevante EU direktiver.

Det hollandske overvågningsinstitut, RIVM, organiserede denne workshop sammen med DMU, Århus Universitet og GEUS, begge fra Danmark, samt landbrugsøkonomisk institut LEI, der er en del af Wageningen Universitet i 2009. Tolv lande fra Nordvest - og Centraleuropa var involveret i den 2. MonNO$_3$ workshop. Workshoppen fokuserede på udviklingen siden 2003, hvor den første MonNO$_3$ workshop fandt sted.

Den anden workshop har, i lighed med den første, bidraget til udveksling af viden og fakta om overvågningen af effekten af den førte politik. Derudover blev der fokuseret på brugen af overvågningsdata til andre formål end at skaffe viden om status og trends for vandkvaliteten, for eksempel data der kan understøtte valget af indsatsprogrammer. Endelig diskuterede deltagerne forbedringer og udvidelserne af overvågningen.

Nøgleord:
vandmiljøplaner, vandkvalitet, landbrugspraksis

Preface

This report, prepared in close co-operation with the participants, is the ultimate, tangible result of the second MonNO_3 workshop held in the Netherlands in June 2009. However, we consider the intangible results to be probably just as important. A very informal atmosphere at the workshop stimulated a free exchange of information and knowledge. During the two workshop days in one location, where we not only worked hard but also enjoyed our trip through the canals of Amsterdam, bonds of co-operation were forged. The process of updating the Member States' contribution, coupled with writing and commenting on the synthesis after the workshop, strengthened the bonds that had been built during the workshop.

The success of the workshop is also the result of all the preparatory work done in advance. All participating Member States provided a pre-workshop paper before the workshop. We had pre-workshop meetings in Brussels, Copenhagen, London and Vienna. In Vienna we met not only with our Austrian colleagues but also with experts from the Czech Republic and the Slovak Republic.

We would like to thank Brian Kronvang from the Danish National Environmental Research Institute (DMU), who did a marvellous job as chairman of the workshop plenary sessions. We also wish to thank Simon Dawes from the English Department of Environment, Food and Rural Affairs (DEFRA), Ralf Eppinger from the Flemish Environment Agency (VMM), Johannes Grath from the Environment Agency Austria, Rüdiger Wolter of the German Federal Environment Agency (UBA), and Manon Zwart from the Dutch National Institute for Public Health and the Environment (RIVM), who all chaired parallel sessions and/or were rapporteur and helped us tremendously. Finally, we thank our colleagues from RIVM, especially Sylvia Baggerman and Christine Blikman, who helped with the administration before and during the workshop, Bea Blauwdraad who took the photos, Gert Boer who took care of reproduction of the pre and post workshop report, and the participants for their suggestions and critical comments on the draft version of the synthesis of this report.

28 March 2011
Dico Fraters, Karel Kovar, Ruth Grant, Lærke Thorling, Joan Reijs

Contents

Summary

The contributions of the participants to the second $MonNO_3$ workshop are assembled in this report. Specifically, this report provides a synthesis of the workshop discussions and findings. The workshop took place in Amsterdam, the Netherlands on 10 and 11 June 2009, and was held six years after the first $MonNO_3$ workshop in 2003. The workshop was organised by the Dutch National Institute for Public Health and the Environment (RIVM), the Danish National Environmental Research Institute (DMU), the Geological Survey for Denmark and Greenland (GEUS), and LEI, part of Wageningen University and Research Centre in the Netherlands. The second workshop focused on the scientific and methodological aspects of the developments in monitoring the effects of Nitrates Directive Action Programmes on the environment. Twelve EU Member States − Austria, Belgium, the Czech Republic, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, the Slovak Republic, Sweden and the United Kingdom − participated, with each of these countries delivering a paper. For Belgium delegates from the Flemish region and the Walloon region were present and for the United Kingdom representatives from England and Wales, Northern Ireland and Scotland attended the workshop.

Countries show large differences with respect to both use of surface waters and groundwater, and in the intensity and structure of agriculture. However, there does not seem to be a relationship between the intensity of agriculture and whether Member States have either designated nitrate vulnerable zones (NVZs) or applied their Nitrates Directive Action Programmes to their entire territory. Six Member States have been granted derogation for the maximum allowable nitrogen application rate of 170 kg of nitrogen per hectare with animal manure; among the Member States that applied for derogation were even ones that have on average a low livestock density.

Eight Member States have increased their monitoring efforts during the six years (2003-2009), because they had to refine NVZ designation (in particular Belgium, France, Sweden and the United Kingdom), to underpin a request for derogation or as a consequence of requirements in the derogation decision (in particular Belgium, Ireland, the Netherlands and the United Kingdom), and/or to comply with Nitrates Directive requirements in general (in particular the new Member States the Czech Republic and the Slovak Republic). Some countries are still extending their networks because of one of the above mentioned reasons, for example, the Flemish region of Belgium.

The three main topics discussed during the workshop were:

1. the two different effect monitoring approaches, namely upscaling and interpolation, as defined during the first workshop;
2. the additional use of monitoring data, for example, for underpinning specific measures in Action Programmes; and
3. the need for special monitoring networks for designation of NVZs and/or the underpinning of the derogation in addition to existing groundwater and surface water monitoring networks.

Monitoring approaches

The main advantage of the upscaling approach is that it provides a better insight into processes that play a role in leaching of nutrients to groundwater and surface waters, as compared to the interpolation approach. This insight can be used by farmers to adapt and therefore is a driver for participation. This insight

can also be used by researchers to improve process models and to make estimations and predictions more reliable. A second advantage of the upscaling approach is that it is cheaper than the interpolation approach, in particular in the initial phase. Thirdly, with this approach it is easier and cheaper to extend the number of monitoring parameters. The main advantage of the interpolation approach is that it is less sensitive to changes in the network, which is important for networks that are assumed to operate for more than ten years, and that it is easier to show 'representativeness' of the network with this approach. This is due to the large number of locations, which ensures the presence of many different combinations of farming practices and environmental conditions within the network. Consequently, the loss of a specific location, for example, a location that is no longer accessible or suitable, is less important for the results. A second advantage of the interpolation approach is that there is a smaller chance the farmers adapt to the system in place, which would bias the results. Thirdly, it is postulated that the interpolation approach results might have a higher acceptability for stakeholders than the results of the upscaling approach for its robustness and simplicity, as the interpretation of the former is less depending on difficult to grasp assumptions in process models used in the upscaling approach.

However, the discussion on pros and cons of the two approaches will be difficult if one does not take into account the four different types of monitoring networks: firstly, general networks and surveys for agriculture, groundwater, and surface waters, secondly, quick response networks, thirdly, investigative monitoring, and finally, compliance checking surveys.

Additional use of monitoring data
Monitoring data from national networks can be used and are used to underpin new or additional policy measures, but there are certain restrictions regarding the details of underpinning depending on the type of monitoring approach used.

Additional monitoring
The extent of the increase in monitoring effort needed to comply with the requirement of the European Commission depends on many factors, such as the extent of the agricultural area designated as NVZ (in case of designation), the extent of the area under derogation and the level of the derogation, that is, the manure nitrogen application limit (in case of derogation), the intensity of agriculture (N surplus, livestock density), the monitoring approach used and the existing monitoring effort, the measures included in the Action Programme, and the pressure exerted on the government by stakeholders and interest groups (farmers unions, environmental pressure groups).

Recommendations
Considering future activities, it was thought to be advantageous to initiate an intercalibration project for models used in the framework of effect monitoring and to develop tools to convince farmers that (specific) measures are useful and in their own interest. Also it might be helpful to make a comprehensive overview of the use of data from national monitoring networks in the underpinning of more or less specific Action Programme measures and the manner in which they are used, for example, in combination with research data and/or models. This topic could also be a subject for a next $MonNO_3$ workshop.

Samenvatting

De bijdragen van de deelnemers aan de tweede MonNO$_3$-workshop zijn opgenomen in dit rapport. Dit rapport bevat tevens een synthese van de workshopdiscussies en -bevindingen. De workshop heeft plaatsgevonden in Amsterdam op 10 en 11 juni 2009, en vond plaats zes jaar na de eerste MonNO$_3$-workshop, gehouden in 2003. De workshop was georganiseerd door het Rijksinstituut voor Volksgezondheid en Milieu (RIVM), het Deense Milieuonderzoeksinstituut (DMU), de Geologische Dienst voor Denemarken en Groenland (GEUS), en het LEI, onderdeel van Wageningen University en Research Centrum. De tweede workshop richtte zich op de ontwikkelingen in met name de wetenschappelijke en methodologische aspecten van het monitoren van de effecten van de Nitraatrichtlijnactieprogramma's op het milieu. Twaalf EU Lidstaten, te weten België, Denemarken, Duitsland, Frankrijk, Ierland, Luxemburg, Nederland, Oostenrijk, Slowakije, Tsjechië, het Verenigd Koninkrijk en Zweden, hebben deelgenomen, waarbij elke Lidstaat een bijdrage op papier heeft geleverd. Voor België waren vertegenwoordigers aanwezig van zowel de Vlaamse als de Waalse regio en voor het Verenigd Koninkrijk namen vertegenwoordigers uit Engeland en Wales, Schotland en Noord-Ierland deel aan de workshop.

Er waren grote verschillen tussen landen voor wat betreft zowel het gebruik van grond- en oppervlaktewater als wat betreft de intensiteit en de structuur van de landbouw. Er leek echter geen verband te zijn tussen de intensiteit van de landbouw en de keuze van een Lidstaat voor het aanwijzen van nitraatgevoelige gebieden (NVZs) of het toepassen van een Actieprogramma voor het gehele grondgebied. Zes Lidstaten maakten in 2009 gebruik van derogatie voor het afwijken van de maximale toegestane hoeveelheid stikstof van 170 kg per hectare die met dierlijke mest mag worden aangewend, onder de aanvragers waren zelfs Lidstaten met een gemiddeld lage veedichtheid.

Acht Lidstaten hadden hun monitoringinspanningen vergroot in de afgelopen zes jaren (2003-2009), omdat zij de NVZ-aanwijzing moesten verfijnen (met name België, Frankrijk, Verenigd Koninkrijk en Zweden), omdat zij een aanvraag voor derogatie moesten onderbouwen of als gevolg van de verplichtingen die voortvloeiden uit een derogatiebeschikking (met name België, Ierland, Nederland en het Verenigd Koninkrijk), en/of omdat dit nodig was om te voldoen aan de Nitraatrichtlijnverplichtingen in het algemeen (met name de nieuwe Lidstaten Slowakije en Tsjechië). Sommige landen waren in 2009 nog bezig met het (verder) uitbreiden van meetnetten vanwege een van de bovengenoemde redenen, bijvoorbeeld de Vlaamse regio van België.

De drie belangrijkste onderwerpen voor de workshopdiscussies waren:

1. de twee verschillende benaderingen voor het monitoren van effecten, te weten opschalen en interpolatie, zoals deze tijdens de vorige workshop zijn gedefinieerd;
2. het gebruik van monitoringgegevens voor andere doeleinden, bijvoorbeeld voor het onderbouwen van specifieke maatregelen in de Actieprogramma's; en
3. het gebruik van speciale monitoringnetwerken voor het aanwijzen van nitraatgevoelige gebieden (NVZs) en/of het onderbouwen van de derogatie, in aanvulling op de bestaande meetnetten voor het monitoren van grondwater- en oppervlaktewaterkwaliteit.

Benaderingswijze

Het belangrijkste voordeel van de opschalingsbenadering is dat het een beter inzicht verschaft in de processen die een rol spelen bij uit- en afspoeling van nutriënten naar grond- en oppervlaktewater dan de interpolatiebenadering. Dit inzicht kan door landbouwers worden gebruikt om hun handelen aan te passen en is daarom een drijfveer voor deelname. Dit inzicht kan door onderzoekers worden gebruikt om hun modellen te verbeteren en om meer betrouwbare schattingen te maken en voorspelling te doen. Een tweede voordeel van de opschalingsbenadering is dat deze benadering goedkoper is dan de interpolatiebenadering, vooral in de beginfase. Ten derde, is het met deze benadering gemakkelijker en goedkoper om het aantal te monitoren parameters uit te breiden dan met de interpolatiebenadering. Het belangrijkste voordeel van de interpolatiebenadering is dat deze minder gevoelig is voor veranderingen in het netwerk, hetgeen van belang is voor een netwerk dat geacht wordt operationeel te zijn voor meer dan tien jaar, en dat het makkelijker is met deze benaderingswijze om aannemelijk te maken dat het netwerk ‘representatief’ is. Dit komt door het grote aantal meetlocaties dat de aanwezigheid van vele verschillende combinaties van landbouwpraktijk en omgevingsomstandigheden in het meetnet verzekeren. Als gevolg hiervan heeft het verlies van een bepaalde meetlocatie, bijvoorbeeld een locatie die niet langer toegankelijk of geschikt is, minder gevolgen voor het onderzoek. Een tweede voordeel van de interpolatiebenadering is dat de kans dat de deelnemende landbouwers zich aanpassen aan het meetnetactiviteiten, wat de resultaten zou beïnvloeden, kleiner is dan bij de opschalingsbenadering. Ten derde, wordt ingeschat dat de resultaten van een interpolatiebenadering mogelijk op een groter draagvlak kunnen rekenen dan de resultaten van de opschalingsbenadering, vanwege de eenvoud en robuustheid van de interpolatiebenadering aangezien deze benadering minder afhankelijk is van soms weinig inzichtelijke aannamen in de procesmodellen gebruik bij de opschalingsbenadering.

Desalniettemin zal de discussie over de voor- en nadelen van de twee benaderingen moeilijk te voeren zijn als men geen rekening houdt met het bestaan van vier verschillende typen van monitoringnetwerken: ten eerste algemene netwerken en meetprogramma’s voor landbouw, grondwater en oppervlaktewater, ten tweede snelleresponsnetwerken, ten derde onderzoeksnetwerken en programma’s en tot slot controlenetwerken en programma’s.

Aanvullend gebruik van monitoringgegevens

Monitoringgegevens van nationale meetnetten kunnen en worden gebruikt om nieuwe of aanvullende beleidsmaatregelen te onderbouwen. Er zijn echter bepaalde beperkingen aan het gebruik met betrekking tot de mate van detail van een onderbouwing, welke mede afhangt van de gebuikte monitoringsbenadering.

Aanvullende monitoring

De mate waarin een uitbreiding van de monitoringinspanning noodzakelijk is om te voldoen aan de verplichtingen van de Europese Commissie, hangt af van vele factoren, zoals de grootte van het deel van het landbouwareaal dat is aangewezen als nitraatgevoelig gebied (in geval van aanwijzing), de grootte van het areaal waarvoor derogatie is verkregen en de hoogte van de derogatie, dat wil zeggen de stikstofgebruiksnorm voor dierlijke mest (in geval van derogatie), de intensiteit van de landbouw (N-overschot, veedichtheid), de gebruikte monitoringsbenadering en de huidige monitoringinspanning, de maatregelen die zijn opgenomen in het Actieprogramma en de druk die wordt uitgeoefend op de nationale overheid door belangengroeperingen en actiegroepen (land- en tuinbouworganisaties, vakbonden en milieugroeperingen).

Aanbevelingen
Kijkend naar toekomstige waardevolle activiteiten werd gedacht aan het initiëren van een interkalibratieproject voor de modellen die gebruikt worden bij het monitoren van effecten en aan het ontwikkelen van gereedschappen die kunnen helpen om landbouwers te overtuigen dat (specifieke) maatregelen nuttig en in hun eigen belang zijn. Het kan ook waardevol zijn een gedegen overzicht te maken van het gebruik van gegevens uit nationale meetnetten voor de onderbouwing van meer of minder specifieke maatregelen in de Actieprogramma's en de wijze waarop ze gebruikt zijn, bijvoorbeeld in combinatie met onderzoeksgegevens en/of modellen. Dit onderwerp kan ook een discussiepunt zijn voor een volgende MonNO$_3$-workshop.

Sammenfatning

Skriftlige bidrag fra deltagerne i den 2. MonNO_3 workshop er samlet i denne rapport. Denne rapport er således en syntese af diskussioner og resultater fra workshoppen. Workshoppen fandt sted i Amsterdam, Holland fra 10. til 11. juni 2009 og blev afholdt seks år efter den første MonNO_3 workshop i 2003.

Det hollandske rigsinstitut for folkesundhed og miljø (RIVM) organiserede i 2009 denne workshop sammen med Danmarks og Grønlands nationale geologiske undersøgelser (GEUS) og Danmarks miljøundersøgelser (DMU), Århus Universitet, samt det landbrugsøkonomiske institut (LEI), der er en del af Wageningen Universitet. Den anden workshop fokuserede på de videnskabelige og metodiske aspekter af udviklingen i effektovervågningen af indsatplaner/vandmiljøplaner iværksat i henhold til Nitratdirektivet. Der deltog tolv EU medlemslande – Belgien, Danmark, Frankrig, Holland, Irland, Luxembourg, Slovakiet, Storbritannien, Sverige, Tjekkiet, Tyskland og Østrig. For hvert af disse lande er der udfærdiget et bidrag. Fra Belgien var der delegerede fra Den Flamske region og den Wallonske region, ligesom der fra Storbritannien var delegerede fra England, Wales, Nordirland og Skotland.

Der er stor forskel indbyrdes mellem landenes anvendelse af overfladevand og grundvand, samt landbrugets intensitet og struktur. Der er dog ingen sammenhæng mellem landbrugsintensiteten og spørgsmålet om, hvorvidt medlemsstaterne har udpeget Nitratfølsomme områder (NFO) i en del af landet eller lader Nitratdirektivets krav til indsatplaner gælde hele statens areal.
I seks medlemslande er der en undtagelsesbestemmelse mht. den maximale tilladelige kvælstof tildeling fra husdyr på 170 kg-N/år. Således var der blandt de medlemslande, der havde ansøgt om undtagelse, også enkelte med en meget lav gennemsnitlig husdyrtæthed

I otte medlemslande har der været en øget overvågningsindsats de seneste seks år (2003-2009), idet de skulle forfine udpegningen af nitratfølsomme områder (i særdeleshed Belgien, Frankrig, Sverige og Storbritannien), havde behov for at understøtte en ansøgning om undtagelse eller som konsekvens af bestemmelserne for at få tildelt en undtagelse (specielt Belgien, Irland, Holland og Storbritannien), og/eller for helt generelt at leve op til nitratdirektivets krav (specielt nye medlemsstater, Tjekkiet og Slovakiet). Nogle lande er fortsat igang med at udvide deres overvågning som følge af en af ovennævnte grunde fx den Flamske region.

De tre væsentligste temaer for workshoppens diskussioner er:

1. De to forskellige overvågningstrategier, opskalering og interpolation, således som det er defineret ved den første workshop.
2. Andre anvendelser af overvågningsdata, fx som understøttelse af specifikke indsatsprogrammer.
3. Behovet for specielle overvågningsnetværk for udpegning af Nitratfølsomme områder, eller understøttelse af undtagelsesbestemmelsen, ud over de eksisterende grundvands og overfladevands overvågning.

Overvågningsstrategier
Fordelen ved opskalering er, at den giver en bedre indsigt i de processer, der spiller en rolle for udvaskningen af næringsstoffer til grundvand og overfladevand, sammenlignet med interpolationsovervågning. Denne forståelse

kan anvendes af landmændene, når de skal tilpasse sig indsatsplanerne, og kan således give et vist medejerskab for resultaterne. Den øgede indsigt kan anvendes af forskere til at forbedre modellering med en mere pålidelig vurdering af miljøeffekten til følge. En anden fordel er, at opskalering er billigere end interpolation, ikke mindst i starten. For det tredje er det nemmere og billigere at øge programmets analyseomfang. Hovedfordelen ved interpolationsstrategien er, at den er meget lidt sensitive overfor ændringer i stationsnettet, hvilket er meget vigtigt, når overvågningen forventes at være operativ i mere end 10 år, og det er også nemmere at vise, at resultaterne er repræsentative. Dette skyldes det meget store antal lokaliteter, som sikrer inddragelse af mange forskellige kombinationer af landbrugspraksis og miljømæssige forhold. Derfor har det mindre betydning for resultatet, hvis en specifik lokalitet udgår, fordi den ikke længere er tilgængelig eller funktionsdygtig. En anden fordel ved interpolation, således som det sker i Holland, er at der er en mindre risiko for at landmændene tilpasser sig overvågningen, hvilket kunne skævvride resultaterne. For det tredje kan man postulere, at resultaterne fra interpolation overvågning måske kan være nemmere at acceptere for intressenterne, idet den enkelte og robuste tilgang kan være lettere at forstå, og ikke afhænger af systemforståelsen, der forudsættes i opskaleringsstrategien.

Diskussionen om fordele og ulemper ved de to overvågningsstrategier er dog vanskelig, hvis man ikke tager i betragtning de fire typer af overvågning, der er behov for: for det første generel overvågning og kortlægning af landbrug, grundvand og overfladevand, for det andet, 'early warning' netværk, for det tredje undersøgelsesovervågning og for det fjerde undersøgelser af graden af målopfyldelse.

Øvrig brug af overvågningsdata
Overvågnings data fra de nationale overvågningsprogrammer kan bruges og bliver brugt til at understøtte nye og supplerende politiske indsatser, men der er væsentlige begrænsninger i, hvilken detaljeringsgrad data kan levere afhængig af overvågningsdesignet.

Øget overvågning
Overvågningen er øget afhængig af behovet for at opfylde EUkommisionens krav. Væsentlige faktorer for forøgelsen er andelen af landbrugsarealerne, der er udpeget som Nitratfølsomt (i tilfælde af at undtagelsesbestemmelsen er i kraft), hvor store arealer undtagelsesbestemmelserne gælder for, størrelsen af undtagelsen, dvs hvor meget ekstra husdyrgødning må der tilføres, kvælstof overskud, husdyrtæthed, overvågningsstrategi og omfang, de valgte virkemidler i indsatsplanerne, og hvilken pression, der kan forventes fra interessegrupper og intresenter (landbrugsorganisationer, miljøgrupper mv).

Anbefalinger
I forhold til fremtidige aktiviteter, fandt man, at det kunne være hensigtsmæssigt at igangsætte en interkalibrering af de modeller, der anvendes som ramme for effektovervågningen og at udvikle redskaber, der kan overbevise landbruget om, at (specifikke) virkemidler er såvel nyttige og i landbrugets egen interesse. Ligeledes kunne det være formålstjenstligt, at få et omfattende overblik over, hvorledes data fra de nationale overvågningsprogrammer understøtter de mere eller mindre specifikke virkemidler, og hvorledes data er brugt, fx i forbindelse med videnskabelige data og/eller modeller. Dette kunne være emner for den næste $MonNO_3$ workshop.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Introduction

B. Fraters[1], K. Kovar[2], R. Grant[3], L. Thorling[4], J.W. Reijs[5]

[1] *National Institute for Public Health and the Environment (RIVM), P.O. Box 1, NL-3720 BA Bilthoven, the Netherlands*
e-mail: dico.fraters@rivm.nl

[2] *PBL Netherlands Environmental Assessment Agency (PBL), P.O. Box 303, NL-3720 AH Bilthoven, the Netherlands*
e-mail: karel.kovar@pbl.nl

[3] *National Environmental Research Institute (DMU), Aarhus University, Vejlsøvej 25, DK-8600 Silkeborg, Denmark*
e-mail: rg@dmu.dk

[4] *The Geological Survey of Denmark and Greenland (GEUS), Lyseng Allé 1, DK-8270 Højbjerg, Denmark*
e-mail: lts@geus.dk

[5] *LEI, part of Wageningen University and Research Centre, P.O. Box 29703, NL-2502 LS The Hague, the Netherlands*
e-mail: joan.reijs@wur.nl

Abstract
This contribution describes the general background for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the European Community. The legal requirements for this type of monitoring are set down in the Nitrates Directive, Article 5 (6) (EC, 1991). In 1999 the European Commission published a draft Monitoring Guidelines (EC, 1999) and in 2003 (EC, 2003) they published a revised draft version. The lack of clarity with respect to the monitor obligation in general and effect monitoring more specifically was the driving force behind the organisation of the first workshop on effect monitoring for the Nitrates Directive in 2003, the MonNO_3 workshop (Fraters et al., 2005). Since 2003 the monitoring of the effects of Nitrates Directive Action Programmes on agriculture and the environment has increased due to discussions between Member States and the European Commission about designation of nitrate vulnerable zones (NVZs) and derogation requests with respect to the obligation to restrict the amount of nitrogen to be applied with manure to a maximum 170 kg ha^{-1}. In addition the Water Framework Directive and new Groundwater Directive also oblige monitoring of the effectiveness of measures laid down in river basin management plans. There, the need for an exchange of scientific ideas on monitoring the effects of Action Programmes and developments therein was recognised and this was the driving force behind the second MonNO_3 workshop. This report discusses the outcome of this workshop organised by RIVM, DMU, GEUS, and LEI. The workshop was held 10-11 June 2009 in Amsterdam, the Netherlands.

1 Background and history

In the 1980s it was widely recognised that agricultural practices might have adverse effects on water quality and ecosystems (Strebel et al., 1989; Duynisveld et al., 1988; Baker and Johnson, 1981). Several European countries started to formulate policy measures to counteract these effects and to regulate agricultural practices (Anonymous, 1984, 1985, 1986, 1991; Danish Parliament, 1987). Also on international level initiatives were taken. The initiatives within the European Union resulted in 1991 in a directive that should eventually lead up to an environmentally sound agriculture with respect to nitrogen losses to groundwater and surface waters, the Nitrates Directive (EC, 1991).

The Nitrates Directive requires all Member States to establish a code of Good Agricultural Practice (GAP). Also areas that are vulnerable to nitrate, the nitrate vulnerable zones (NVZs), should be designated. For these areas Action Programmes have to be established. A Member State may choose to not designate NVZs but to apply the Action Programmes to the entire territory. An Action Programme must contain at least the measures prescribed in the Nitrates Directive, such as the obligation for livestock farms to establish enough storage capacity for animal manure and the prohibition for all farmers to apply more nitrogen with animal manure than 170 kg ha^{-1}. With respect to the latter, the Nitrates Directive explicitly offers Member States the possibility to deviate from this manure application maximum of 170 kg ha^{-1}. This derogation has to be approved by the European Commission.

The EU Nitrates Directive also requires all Member States to monitor their groundwater, surface water and the effectiveness of their Action Programmes and to report the findings. In 1999 the European Commission published draft monitoring guidelines (EC, 1999), which outlines how monitoring should be carried out. Reporting guidelines were published in 2000 (EC, 2000b). A new draft version of the monitoring draft guidelines was released in 2003 (EC, 2003). According to these draft guidelines for the monitoring required under the Nitrates Directive, the following three types of monitoring can be distinguished:

- monitoring for the identification of water;
- monitoring for countries applying the Action Programme to the whole of their territory; and
- monitoring to assess the effectiveness of Action Programmes.

Monitoring for the identification of water

Monitoring is required if a number of Nitrate NVZs are to be designated within the country or region. If a country or region decides that Action Programmes will be applied to the entire territory – meaning that NVZs are not designated – then this type of monitoring is irrelevant. Obviously, if this type of monitoring is required, use will be made of other existing networks (see next point), possibly combined with an adapted monitoring programme, for example to focus on specific areas or to obtain a higher observation frequency in time.

Monitoring for countries applying the Action Programme to the whole of their territory

Quoting from the draft guidelines, this embraces ‘baseline monitoring of important water bodies and intensively cropped regions’. Examples are the national monitoring networks for groundwater and surface water, (probably) available in all the relevant countries or regions.

Monitoring to assess the effectiveness of Action Programmes
Quoting from the draft guidelines:

> 'This monitoring, required under the first sentence of Article 5 (6), should be carried out in all areas where Action Programmes apply and should have regard to the objectives of Article 1 of the Directive. Monitoring the effectiveness of the Action Programmes requires baseline information for comparison purposes. Thus, the monitoring described in sections 3 and 4 above must be undertaken in zones subject to Action Programmes and may need to be supplemented. All major river systems should contain sampling points that are representative of the catchment and are sufficiently sensitive to the results expected of the Action Programme measures.'

For effect monitoring some countries will make use of existing networks (identification monitoring, baseline monitoring, or other networks such as those used for agricultural monitoring), while other countries will make use of networks that have been specifically designed for this purpose.

It is clear that countries have given their own interpretation on how the monitoring should be carried out. At the meeting of the EU Nitrate Committee in June 2002 Professor Bjørn Kløve of the Norwegian Centre for Soil and Environmental Research concluded in his presentation that:

> 'The present draft guidelines (1999 version):
> - are very general and somewhat unclear; and
> - do not provide guidelines for monitoring the effects of Action Programmes.'

In the meeting of the EU Nitrate Committee in March 2003 the Commission has issued a new and final draft version of the Nitrates Directive monitoring guideline (EC, 2003). All Member States were asked give their comments before 15 May 2003. The question whether this new 2003 version settles the comments on the 1999 version is not yet answered. Until presently the European Commission has not upgraded the draft monitoring guideline, making it an official EU monitoring guideline.

This lack of clarity with respect to the monitor obligation in general and effect monitoring more specifically was the driving force behind the organisation of a first workshop on effect monitoring for the Nitrates Directive held in 2003, the first MonNO_3 workshop (Fraters et al., 2005).

Since 2003 the monitoring of the effects of Action Programmes on agriculture and the environment has increased due to discussions between Member States and the European Commission about the extent of the area designated as NVZs and/or the request for derogation with respect to the obligation to restrict the amount of nitrogen to be applied with manure to a maximum 170 kg ha^{-1}. For example, the Netherlands was obliged to increase the monitoring effort significantly in 2006 as a consequence of derogation granted by the European Commission. In addition, the consequences of new environmental EU legislation for monitoring have been discussed extensively in EU working groups since 2003; this concerns the Water Framework Directive (EC, 2000a) and new Groundwater Directive (EC, 2006). These directives also oblige monitoring of the effectiveness of measures laid down in river basin management plans. The implementation of the Water Framework Directive and new Groundwater

Directive into national laws has involved a lot of discussion about how to realise an effective monitoring programme.

A second $MonNO_3$ workshop was thought to be instrumental for an exchange of ideas and for optimising the current monitoring networks given the discussion about monitoring for designation of NVZs and for derogation, the monitoring obligations resulting from new EU environmental legislation, and the financial challenges with tightening budgets.

2 Workshop on developments in effect monitoring in EU Member States

2.1 Background

Networks for monitoring of groundwater and surface waters have been in place in several countries for many years. However, for monitoring the effects of Action Programmes on agriculture and the environment, experience, in general, is still limited though steadily increasing. As already mentioned, for the effect monitoring either use will be only made of other existing (identification, baseline, et cetera) networks, or additional networks will be used that have been specifically designed for this purpose. For example, in 2003 only Denmark and the Netherlands had such specific monitoring networks for any length of time. In Denmark, as well as the Netherlands, the effectiveness has been established by simultaneously monitoring agricultural practices and nitrate concentrations in recently formed groundwater and/or surface water. Currently the United Kingdom and the Republic of Ireland have similar networks for some years. The Netherlands has a special derogation monitoring network and Belgium is developing such a network. In the Czech Republic and the Slovak Republic monitoring networks are being extended in order to comply with Nitrates Directive requirements.

The initiative to organise a workshop on effect monitoring was taken by the Netherlands. This is because not only the Dutch Parliament, but also the Dutch agricultural sector, for example, has regularly raised questions with respect to monitoring. The main issue was whether monitoring the quality of water leaching from the agricultural soil – that means the upper metre of shallow groundwater, tile drain water or ditch water – is unique to the Netherlands and on whether co-ordination should be sought with other EU Member States. Hence, there appeared to be a need for a broader exchange of scientific ideas on monitoring the effects of the Action Programmes. A workshop could provide the means for optimising the existing monitoring networks and/or the analytical methods used.

The workshop, called the second $MonNO_3$ workshop, was organised by the National Institute for Public Health and the Environment of the Netherlands (RIVM), in co-operation with the National Environmental Research Institute of Denmark (DMU), the Geological Survey of Denmark and Greenland (GEUS), and LEI, part of Wageningen University and Research Centre of the Netherlands. The workshop was held 10-11 June 2009 in Amsterdam, the Netherlands.

2.2 Goal and focus of the workshop

The second $MonNO_3$ workshop focused on the scientific and methodological aspects within the theme: 'developments in monitoring the effects of Action Programmes on the environment'. This theme is set up in the framework of the EU Nitrates Directive and described in the draft guidelines for the monitoring required under the Nitrates Directive (91/676/EEC); section 5 of the 1999 version (EC, 1999) and sections 6 and 7 of the 2003 version (EC, 2003).

The *workshop goal* was threefold:
1. To give participants insight into and to inform them about the developments in the monitoring network in each other's countries, considering both the strategy behind the design of the monitoring programmes, and the standard analytical methods and techniques (for example, for sampling).
2. To identify common goals, problems and solutions for improving the effectiveness and efficiency of monitoring and data interpretation and, possibly, for extending the comparability.
3. To re-establish a network of experts.

Three *discussion topics* were defined in advance to be discussed during the workshop:
1. What are the pros and cons of two different effect monitoring approaches – the upscaling approach and the interpolation approach – distinguished during the previous workshop?
2. Can monitoring data from national networks be used to underpin new policy (for example, fertilisation standards) or can data be used to show that no new measures are needed?
3. Can existing networks be used or are special networks needed to monitoring for NVZ designation and/or underpinning of derogation?

2.3 Workshop target group

The workshop was intended for those actively concerned with scientific and methodological aspects of the design, operation and reporting of the effect monitoring in relation to the Nitrates Directive Action Programme in their own countries.

This workshop involved all countries that participated in the first $MonNO_3$ workshop, except for France that was not able to participate in 2003: Austria, Belgium (Flemish and Walloon regions), the Czech Republic, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, the Slovak Republic, Sweden, and the United Kingdom (England and Wales, Scotland, and Northern Ireland). Poland has been invited but was not able to participate. Countries were selected because of similarity in climate, soil types and crop.

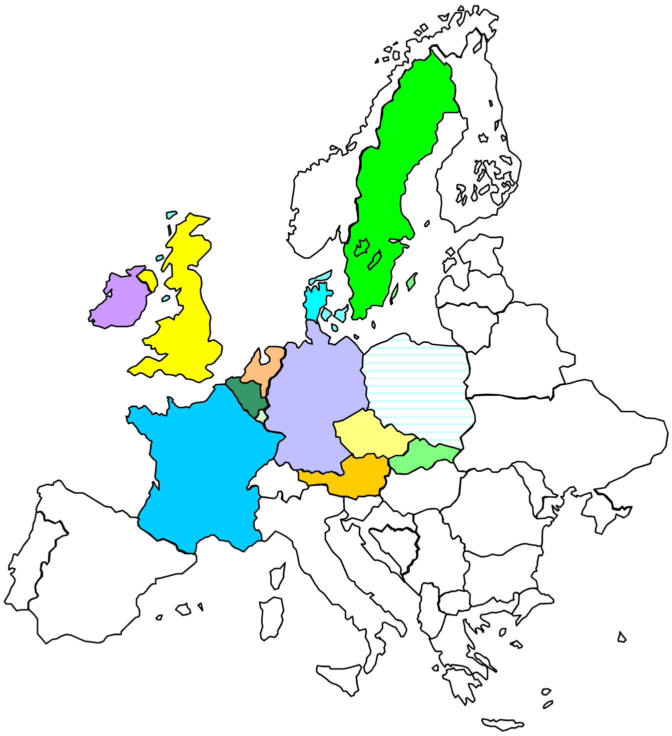


Figure 1 Countries of the European Union invited and participating in the second MonNO$_3$ workshop, held 10-11 June 2009. Poland (hatched) was not able to participate.

Within this group of participating countries a large diversity exists with respect to use and source of water, level of nitrate pollution, extent, intensity and importance of agriculture, and the way and the time frame the Nitrates Directive is implemented. Some countries, like Austria and Denmark, are completely dependent on groundwater as resource, while others, like England and Wales, Northern Ireland, and to a lesser extent, Ireland and Scotland, are almost entirely dependent on surface water as resource. Countries with 'an easy point of departure with respect to nitrate pollution[1]' are represented (Austria and Sweden, and probably the Czech Republic and the Slovak Republic, but these were not classified in 1998), as well as those with 'a difficult point of departure' (Belgium, Denmark, and the Netherlands) and 'intermediate ones' (other countries). In Austria and Sweden the land area under agriculture is much smaller than in Belgium, Denmark and the Netherlands, and, in addition, the use of nitrogen and phosphorus in agriculture is smaller. The entire range of countries and regions is dealing with the Programme's implementation in national legislation. Some countries apply the Action Programmes to their entire territory, other countries apply them to specific areas, which means, they designate nitrate vulnerable zones (NVZ) (Table 1). Differences also exist with respect to the use of derogation (Table 1), that is, an exemption from the rule that the maximum amount of nitrogen to be applied with animal manure is 170 kg nitrogen per hectare of agricultural land.

From a technical viewpoint it is also true that the differences in the monitoring approach will be related to specific soil and groundwater conditions in the

[1] Distinction is based on the report of McKenna (1998) as described in Goodwill (2000).

European countries, such as soil type, depth of groundwater table, and type of aquifer. These aspects have obviously been addressed as well in this workshop.

Table 1 Overview of countries/regions with a similar Action Programme approach and/or use of derogation

Action Programme	With derogation	No derogation
Whole territory approach	Denmark Flemish region (B) Germany Ireland The Netherlands Northern Ireland (UK)	Austria [†] Luxembourg
NVZ designation	England and Wales (UK) Scotland (UK) Walloon region (B)	Czech Republic France Slovak Republic Sweden

[†] Austria used derogation up to 2007, but the extent was negligible.

2.4 Workshop set up and programme

The workshop was prepared by an Organising Committee formed by experts from the organising institutes. The committee was assisted by a group of experts from other countries who were willing to chair and/or report findings of parallel sessions during the workshop (see Appendix 1).

In total 42 experts attended the workshop, representing 15 delegations from 12 EU Member States (for detailed information see Appendix 2). For Belgium experts were present from the Walloon and Flemish regions, for the United Kingdom experts came from England and Wales, Scotland and Northern Ireland.

The two-day workshop combined plenary and parallel group discussion (for details see Appendix 3). During the first morning delegations provided statements regarding each of the three workshop discussion topics (see section 2.2 Goal and focus of the workshop) and experts introduced themselves. The three discussion topics were elaborated upon in three different sessions, one in the afternoon of the first day and the two others in two sessions the next day. Each session started with a general introduction and a 'kick off' presentation by one of the experts in a plenary part of the session. After these presentations, topics were discussed in four parallel groups under guidance of a group chair; the composition of the groups is given in Appendix 4 for all sessions. A rapporteur was present in each group to give an account of discussions in the plenary part of each session. The findings of the different groups were briefly discussed in this plenary part. A photo impression is given in Appendix 5.

The implementation of the Nitrates Directive, designation of the NVZ, notification of derogation from the maximum allowable manure application rate of 170 kg of nitrogen per hectare and reporting are all 'delicate' subjects. For this reason, the Organising Committee paid a lot of attention in this workshop to create an informal atmosphere to stimulate an open discussion on all subjects, including the delicate ones. Considering quality and intensity of the discussions, and reactions of the participants, we concluded that this was a good choice.

3 This workshop report

All participating countries were asked to provide on forehand a paper on their monitoring network(s) for assessing effectiveness of the Nitrates Directive Action Programme. All authors used the same prescribed framework for their contribution, which covers not only effect monitoring but also provides national background information on agriculture, environmental pressure and other monitoring networks. These papers have been published in a pre-workshop report that was only available for the workshop participants.

In order to share the knowledge generated by the workshop with a broader public, all participating countries and regions have provided the final version of their paper after the workshop. Those papers were edited to provide a consistent report, with all papers having a similar structure. Each of the papers usually contains the following sections:
- Abstract;
- Introduction with an overview of (a) the main points in the Action Programmes, (b) trends in nutrient surpluses and nutrient concentrations, and (c) developments in existing monitoring network(s) relevant to the Nitrates Directive (agriculture, surface water, groundwater, effects);
- Effect monitoring, with details about the strategy for effect monitoring, a technical description of networks used for effect monitoring and data interpretation, all with a focus on developments since the previous workshop;
- Discussion, with points of attention for experiences, problems, bottlenecks encountered during the establishment of the ‘effect monitoring networks’ and solutions arising;
- References.

This report also contains a chapter with the synthesis of the workshop findings, including overviews and conclusions. The draft version of this synthesis chapter has been sent to all participants for comments in February 2011.

4 References

Anonymous (1984) (the Netherlands) Temporary Act Restriction Pig and Poultry Husbandry (Interimwet beperking varkens- en pluimveehouderijen).

Anonymous (1985) (Denmark) NPO Action Plan. Miljøstyrelsen.

Anonymous (1986) (the Netherlands) Manure Act (Meststoffenwet).

Anonymous (1991) (Belgium) Decree concerning the protection of the environment against pollution from fertilisers (Decreet inzake de bescherming van het leefmilieu tegen de verontreinging door meststoffen). Belgisch Staatsblad, 28 February 1991.

Baker, J.L. and Johnson, H.P. (1981) Nitrate-N in tile drainage as affected by fertilisation . Journal of Environmental Quality 10(4), 519-522.

Danish Parliament (1987) Report on the Action Plan for the Aquatic Environment. Report given by the environment and planning committee April 30, 1987 with appendix. Folketinget 1986-87, Blad nr. 817 and 1100.

Duynisveld, W.H.M., Strebel O. and Böttcher, J. (1988) Are nitrate leaching from arable land and nitrate pollution of groundwater avoidable? Ecological Bulletins 39, 116-125.

EC (1991) Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Communities, L375, 31/12/1991, 1-8.

EC (1999) Draft guidelines for the monitoring required under the Nitrates Directive (91/676/EEC). Version 2, with annexes 1 through 6. European Commission, Directorate-General XI (Environment, Nuclear Safety and Civil Protection), Directorate D (Environment, Quality and Natural Resources).

EC (2000a) Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. Official Journal of the European Communities, L327, 22/12/2000, 6-72 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF).

EC (2000b) Reporting Guidelines for Member-States (art. 10) Reports. Nitrates Directive, status and trends of aquatic environment and agricultural practice.

EC (2003) Draft guidelines for the monitoring required under the Nitrates Directive (91/676/EEC). Version 3, with annexes 1 through 3. European Commission, Directorate-General XI (Environment, Nuclear Safety and Civil Protection), Directorate D (Environment, Quality and Natural Resources).

EC (2006) Directive 2006/118/EC of the European Parliament and of the Council on the protection of groundwater against pollution and deterioration. Official Journal of the European Communities, L372, 27/12/2006, 19-31 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:372:0019:0031:EN:PDF).

Fraters, B., Kovar, K., Willems, W.J., Stockmarr, J. and Grant, R. (2005) Monitoring effectiveness of the EU Nitrates Directive Action Programmes. Results of the international MonNO3 workshop in the Netherlands, 11-12 June 2003. National Institute for Public Health and the Environment, Bilthoven, the Netherlands, RIVM report 500003007.

Goodwill, R. (2000) Report A5-0386/2000 on Implementation of Directive 91/676/EEC on nitrates, 2000/2110(INI). European Parliament, Committee on the Environment, Public Health and Consumer Policy. Report of 6 December 2000 (http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+REPORT+A5-2000-0386+0+DOC+PDF+V0//EN).

McKenna, P. (1998) Report on the Commission Reports on the Implementation of Council Directive 91/676/EEC. Committee on the Environment, Public Health and Consumer Protection (A4-0284/98), EC, Brussels.

Strebel, O., Duynisveld, W.H.M. and Böttcher, J. (1989) Nitrate pollution of groundwater in western Europe. Agriculture, Ecosystems and Environment 26, 189-214.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Synthesis of workshop

B. Fraters[1], K. Kovar[2], R. Grant[3], L. Thorling[4], J.W. Reijs[5]

[1] *National Institute for Public Health and the Environment (RIVM), P.O. Box 1, NL-3720 BA Bilthoven, the Netherlands*
e-mail: dico.fraters@rivm.nl

[2] PBL *Netherlands Environmental Assessment Agency (PBL), P.O. Box 303, NL-3720 AH Bilthoven, the Netherlands*
e-mail: karel.kovar@pbl.nl

[3] *National Environmental Research Institute (DMU), Aarhus University, Vejlsøvej 25, DK-8600 Silkeborg, Denmark*
e-mail: rg@dmu.dk

[4] *The Geological Survey of Denmark and Greenland (GEUS), Lyseng Allé 1, DK-8270 Højbjerg, Denmark*
e-mail: lts@geus.dk

[5] *LEI, part of Wageningen University and Research Centre, P.O. Box 29703, NL-2502 LS The Hague, the Netherlands*
e-mail: joan.reijs@wur.nl

Abstract
This contribution provides a synthesis of the discussions at the second $MonNO_3$ workshop on developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the European Community. The legal requirements for this type of monitoring are set down in the Nitrates Directive, Article 5 (6) (EC, 1991). The three main topics discussed were (1) the two different effect monitoring approaches of upscaling and interpolation, (2) the use of monitoring data for other purposes than trend analyses, and (3) the need for special monitoring networks for designation of nitrate vulnerable zones (NVZs) and/or the underpinning of the derogation. It is concluded that the upscaling approach gives more insight into processes involved in leaching of agriculturally used nutrients to groundwater and surface waters and is, in general, a cheaper approach than the interpolation approach. The interpolation approach is less sensitive to changes in a monitoring network and results have a higher acceptability for stakeholders. However, the discussion on pros and cons of the two approaches will be difficult if one does not take into account the four different types of monitoring networks: firstly, general networks and surveys for agriculture, groundwater and surface waters, secondly, quick response networks, thirdly, investigative monitoring, and finally, compliance checking surveys. Monitoring data from national networks can be used and are used to underpin new or additional policy measures, but there are certain restrictions regarding the details of underpinning depending on the type of monitoring approach used. The extent of the increase in monitoring effort needed to comply with the requirement of the European Commission depends on many factors, such as the extent of the agricultural area designated as NVZ (in case of

designation), the extent of the area under derogation and the level of derogation, that is, the manure nitrogen application limit (in case of derogation), the intensity of agriculture (N surplus, livestock density), the monitoring approach used and the existing monitoring effort, the measures included in the Action Programme, and the pressure exerted on the government by stakeholders and interest groups, in particular farmers unions and environmental pressure groups.

1 Introduction

1.1 Workshop focus

The second $MonNO_3$ workshop focused on developments in monitoring the effects of Nitrates Directive Action Programmes on the environment. The main goal was to get insight into the developments in the monitoring approaches and monitoring networks, in countries with similar climates, soil types and crops within the European Union, since the previous $MonNO_3$ workshop held in 2003 (Fraters et al., 2005). However, countries differ in the way and time of implementation of the Nitrates Directive, the use and importance of different sources of water, the extent and intensity of agriculture, and the history of monitoring groundwater, surface water and of effects of the Action Programmes. The differences between countries in these aspects will be discussed below.

To get insight into the developments in the different countries three *discussion topics* were defined in advance to be discussed during the workshop:

1. What are the pros and cons of two different effect monitoring approaches – the upscaling approach and the interpolation approach – distinguished during the previous workshop?
2. Can monitoring data from national networks be used to underpin new policy, for example, fertilisation standards, or can data be used to show that no new measures are needed?
3. Can existing networks be used or are special networks needed to monitoring for NVZ designation and/or underpinning of derogation?

The outcome of the discussion with respect to each topic will be presented in separate sections after this introduction.

1.2 Implementation of Nitrates Directive

Countries represented at the workshop cover EU founder states, states that joined the EU recently in 2004, and Member States that joined earlier, both before (in 1973) and after (in 1995) the adoption of the Nitrates Directive in 1991 (Table 1).

The transposition of the Nitrates Directive into national laws was a slow process. In 1997, the European Commission (EC, 1997) highlighted the significant lack of progress made by Member States in their application of the Directive and the status of legal proceedings against the Member States. The EC reported that 10 out of 15 states had communicated the transposition of the Directive in their national law. Four were in conformity of measures (Denmark, France, Luxembourg, and Spain). In 1997, Austria and Sweden, that joined the EU after 1991, managed to surpass Belgium and the Netherlands, EU founder states, with respect to the extent of the implementation of the Directive (Table 1).

Important, monitoring-relevant aspects of the implementation of the Nitrates Directive are, firstly, the choice to designate nitrate vulnerable zones (NVZs) or to apply an Action Programme to the entire territory and, secondly, the decision to request or not request derogation with respect to the Directive's obligation to restrict the amount of nitrogen to be applied with manure to a maximum 170 kg ha^{-1}. For all four possible combinations – NVZ designation with and without requesting derogation and whole territory approach with and without requesting derogation – countries were represented at the second $MonNO_3$ workshop (Table 2).

Table 1 Overview of implementation of Nitrates Directive with respect to transposition into national law and establishment of a code of Good Agricultural Practice in June 1997 (EC, 1997).
Between brackets year country joined the EU (first) and year of transposition into national law (second).

Transposition into national law (date due 20 Dec 1993)	Code of Good Agriculture Practice (date due 20 Dec 1993)	
	Yes	No
Yes	Austria ‡ (1995; 1996) Denmark (1973; 1993) France (founder; 1993) Germany † (founder; 1996) Ireland † (1973; 1995) Luxembourg (founder; 1994) Sweden ‡ (1995; 1996) United Kingdom † (1973; 1996)	
No	The Netherlands (founder)	Belgium (founder) Czech Republic (2004) Slovak Republic (2004)

† No conformity of measures in 1997.
‡ Conformity check ongoing in 1997.

Six of the 12 countries designated NVZs and do not apply the Action Programme to the whole territory. The extent of the area designated differs between countries; the designated area ranges from 15% in Sweden up to about 70% in Belgium (Table 3). Most countries have about 50-55% of their agricultural area in NVZs. The percentage has increased significantly compared to the first designation. The Flemish region of Belgium and Northern Ireland, which is part of the United Kingdom, changed the 'NVZ designation' to the 'whole territory approach'.

Six of the 12 countries have requested derogation. In 2009, all six were still in their first derogation period, with exception of Denmark that had derogations applicable within the framework of the Danish Action Programmes for the periods 1999-2003 (EC, 2002) and 2004-2008 (EC, 2005a). Recently, both Germany (EC, 2009a) and the Netherlands (EC, 2010a) were granted a renewed derogation for the period 2010-2013. There are large differences between derogations, both in extent of the area under derogation and of the level of derogation, that means, the manure nitrogen application limit (Table 4). Denmark, Germany and the Walloon region of Belgium have less than 5% of the agricultural area under derogation and a maximum of 230 kg of manure N per hectare, while Ireland, the Flemish region of Belgium and the Netherlands have between 8% and 50% of the agricultural area under derogation and a maximum of 250 kg of manure N per hectare. The United Kingdom also has derogation of 250 kg N ha^{-1}, but for only 1.5% of the agricultural area.

Table 2 Overview of countries and regions with similar Action Programme approach and/or use of derogation.
Countries/regions that have indicated to perform additional monitoring for underpinning derogation and/or NVZ designation are in bold.

Action Programme	With derogation	No derogation
Whole territory approach	Denmark **Flemish region (Belgium)** Germany **Ireland** **The Netherlands** **Northern Ireland (UK)**	Austria † Luxembourg
NVZ designation	**England and Wales (UK)** Scotland (UK) **Walloon region (Belgium)**	**Czech Republic** **France** **Slovak Republic** **Sweden**

† Austria used derogation up to 2007, but the extent was negligible.

Table 3 Overview of the extent of area of agricultural land designated as NVZ for countries not using the whole territory approach.
Current (2009) area and area designated initially – year is given between brackets.

	Agricultural area in NVZ (%)	
Country, region	In 2009	First designation
Belgium (B)		
B, Flemish region	100	5 (1995)
B, Walloon region	54	5 (1994)
Czech Republic	48	43 (2003)
France	55	39 (1999)
Slovak Republic	55	n/a
Sweden	60	36
United Kingdom (UK)		
UK, England	70	8 (1996)
UK, Wales	4	4
UK, Scotland	14	14
UK, Northern Ireland	100	0.14

n/a not applicable because 2009 gives percentage of area in NVZ for first designation.

Table 4 Overview of extent of the area and the level of derogation for countries with derogation

Country, region	Area of agricultural land under derogation (%)	Level of derogation (manure N in kg ha^{-1})	Period
Belgium, Flemish region (EC, 2008a)	12†	250	2007-2010
Belgium, Walloon region (EC, 2008b)	0.37	230	2007-2010
Denmark (EC, 2005a)	4.2	230	2008-2012
Germany (EC, 2006)	0.1	230	2006-2009‡
Ireland (EC, 2007a)	8	250	2006-2010
The Netherlands (EC, 2005b)	50	250	2006-2009‡
United Kingdom (EC, 2007b, 2009b)	1.5	250	2009-2012$

† In 2007, the first year of derogation, this was 28%.

‡ In 2010, the derogation is renewed for the period 2010-2013 (EC, 2009a, 2010a).

$ Expiration date for derogation decision for Northern Ireland (EC, 2007b) is 2010.

Another important aspect of the Action Programme is the closed period for fertiliser application and the minimal storage capacity for animal manure. Countries often distinguish different closed periods for different types of manure (liquid manure, or slurry, and farmyard manure), presence or absence of winter cover, and soil type. The closed period for liquid manure varies from two up to five months within the period from 1 September to 28 February. Table 5 gives a simplified overview of closed periods and minimum storage capacity obligations based on data provided by the participants. A more detailed overview is given by Van Dijk and Ten Berghe (2009) for Denmark, France, the Flemish region of Belgium, Germany and the Netherlands.

Most regulations of the countries considered put additional conditions and/or provide options for exemptions. Belgium, Denmark (arable land) and the Netherlands have relative long closed periods (4-5.5 months), while Austria, Germany, the Czech Republic and the Slovak Republic have shorter closed periods (2-4 months). Most countries require a minimum storage capacity of at least six months for slurry, with exception of the Czech Republic (3-4 months) and Ireland (4-5 months).

Table 5 Simplified overview of closed periods and minimal storage capacity obligations in different Action Programmes
Data provided by participants; state of affairs 2009

Country/ Region	Closed period (dd.mm)	Remarks	Storage capacity (month)	Remarks
Austria	15.10-15.02	without cover	6	
	15.11-15.02	with cover		
Belgium/	15.10-15.02	heavy clay soils	6-9	cattle/poultry- pigs
Flemish region	01.09-15.02	other soils	3	farmyard (solid)
Belgium/	15.09-15.01	grassland	6	
Walloon region	15.10-15.02	arable land		
	no closing	FYM †		
Czech Republic	15.11-31.01	slurry/lowlands	3	dung water ‡
	05.11-28.02	slurry/highlands	4	slurry
	01.12-31.01	FYM/all	6	farmyard manure
Denmark	harvest-01.02		6-9	
France §	01.07-15.01	winter/spring crops	-	no data provided
	01.10-15.01	grassland		
Germany	01.11-31.01	arable land	6	
	15.11-31.01	grassland		
Ireland	15.09-31.01	varies across zones	16-22 wks	varies across zones
	15.10-31.01	organic fertilisers		
Luxembourg	-	depending on fertilisers and area	6	liquid manure
Netherlands	15.09-01.02	clay and peat	6	
	01.09-01.02	sand and loess		
	no closing	FYM arable on clay and peat		
Slovak Republic	15.11-15.02		6-12	
Sweden	01.11-28.02	All types of manure	6-10	Type of animal and size of holding
UK/England and Wales	3-5 month	depending on soil and crop type	5-6	pig slurry/poultry manure 6 month, others 5 month
UK/Scotland	-	-	-	-
UK/Northern	15.09-31.01	chemical fertilisers	22 wks	cattle
Ireland	15.10-31.01	organic manures	26 wks	pigs and poultry

† FYM = farmyard manure.
‡ Concerns mixture of urine and water, produced in bedding systems (not produced in deep litter systems).
§ Derived from Van Dijk and Ten Berghe (2009).

1.3 Sources for water production

Differences in monitoring strategy may be related to the importance of the source for drinking water production. Groundwater is the main source for drinking water production in Austria, Denmark, and, to a slightly lesser extent, in France, the Slovak Republic, Walloon region of Belgium, and Germany (Figure 1). Surface water is the main source in Ireland, Sweden and the United Kingdom. The use of drinking water differs between countries and varies between 50 and 150 m^3 per inhabitant per year (Figure 2).

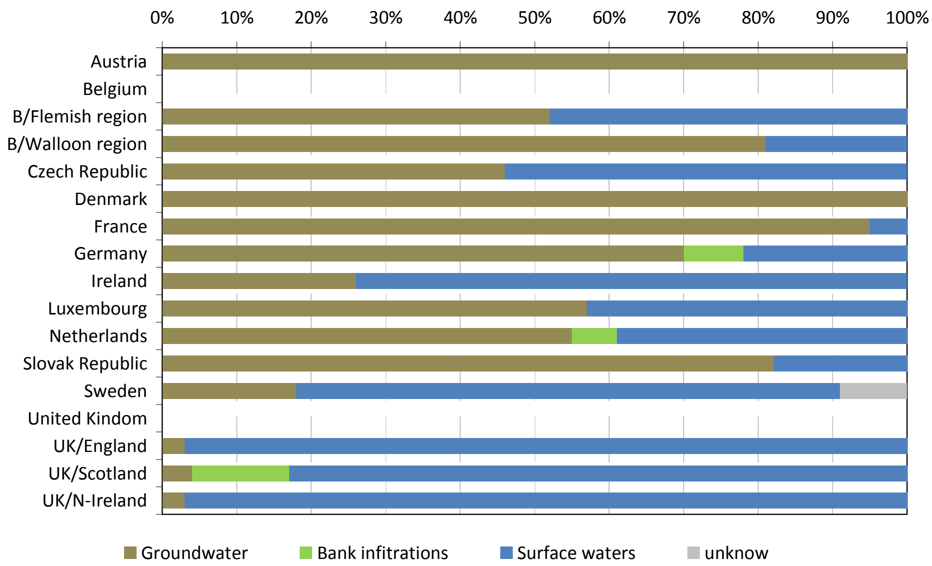


Figure 1 Water sources for production of drinking water.
Data provided by participants, representative for the period 2004-2007.

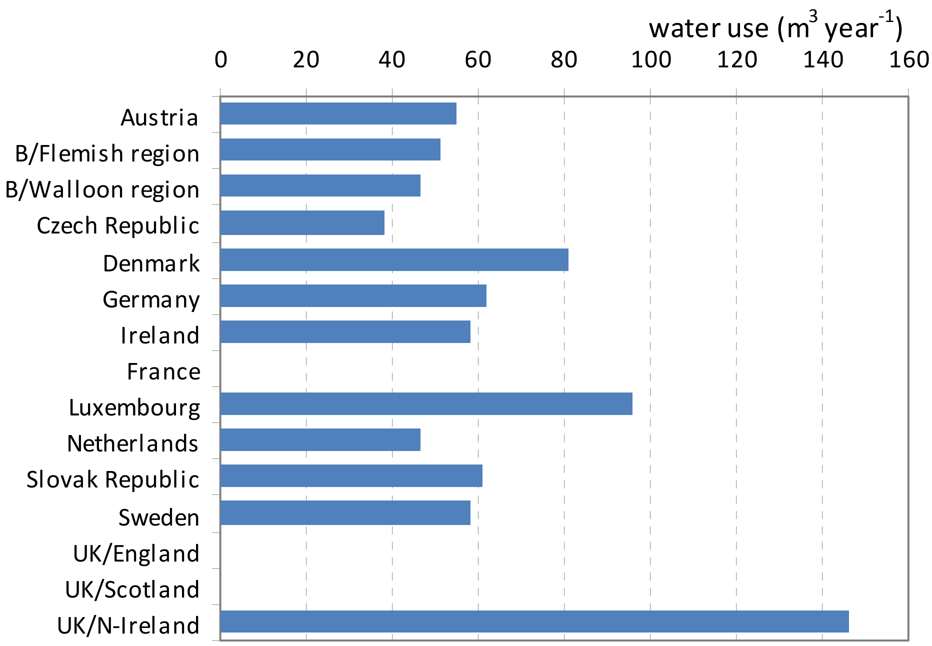


Figure 2 Use of drinking water for households per inhabitant per year in cubic metres.
Data provided by participants, representative for the 2004-2007 period. Data Flemish region for 2003. Data for N-Ireland regards urban use of water.

1.4 Agriculture

The intensity of monitoring may be related to the importance, type and intensity of agriculture. Agriculture uses more than 50% of the land in most of the countries involved in the workshop, only Austria, the Slovak Republic and Sweden, countries with large areas covered by forests, have a lower percentage of land used by agriculture (Figure 3). Arable crop production covers more than

80% of the utilised agricultural area (UAA) in Denmark and Sweden, while grassland covers the major part of the UAA in the United Kingdom and Ireland (Figure 4). Farm holdings tend to be small, average size less than 30 ha, in Austria, Belgium and the Netherlands, and large, more than 60 ha, in the Czech Republic and the United Kingdom (Figure 5).

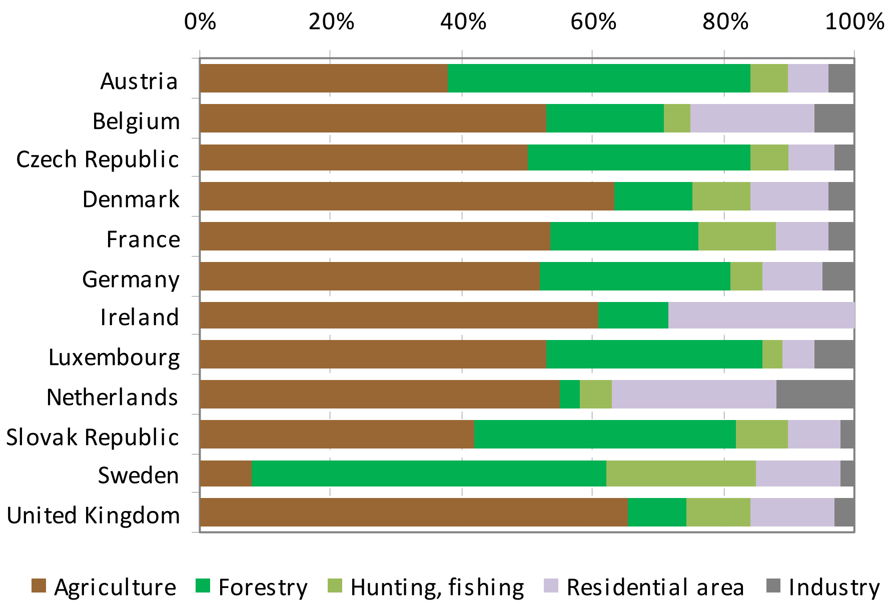


Figure 3 Land use (in % of total area) in 2009.
Data Eurostat, 2010a; CSO, 2010, for Ireland. Hunting and fishing includes land with no visible use; residential area includes commerce and services; industry includes energy, transport and mining. For Ireland all three are included in 'residential area'.

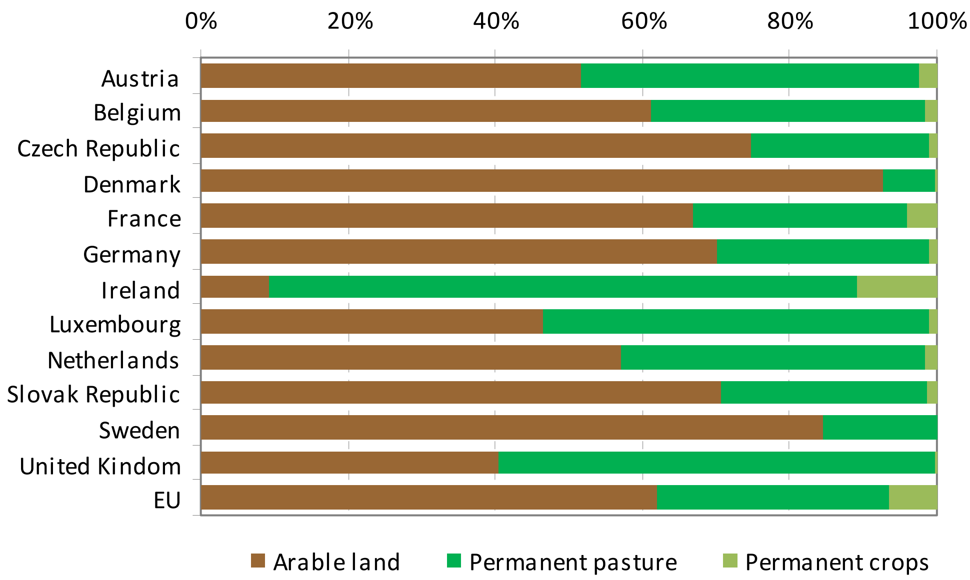


Figure 4 Utilised agricultural area.
Data 2005, source Eurostat (2008); CSO (2010) for Ireland; arable in Ireland includes crops, fruit and horticulture.

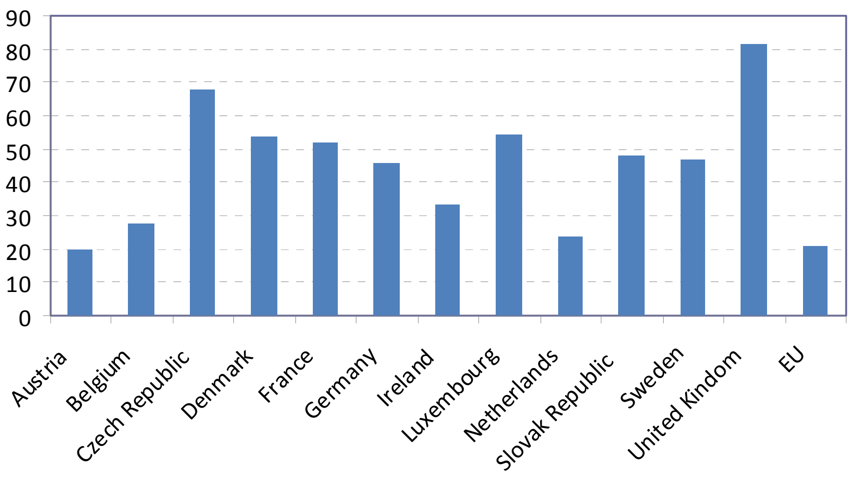


Figure 5 Average size of farms in hectares in 2005.
Source Eurostat (2008). Data for the Czech Republic and the Slovak Republic are provided by the participants.

Livestock densities are high, more than three livestock units (LU) per hectare of UAA, in Belgium, notably in the Flemish region of Belgium and the Netherlands (Figure 6). Livestock densities are low, less than one LU/UAA, in Austria, the Czech Republic, France, the Slovak Republic, Sweden and the United Kindom with the exception of Northern Ireland.

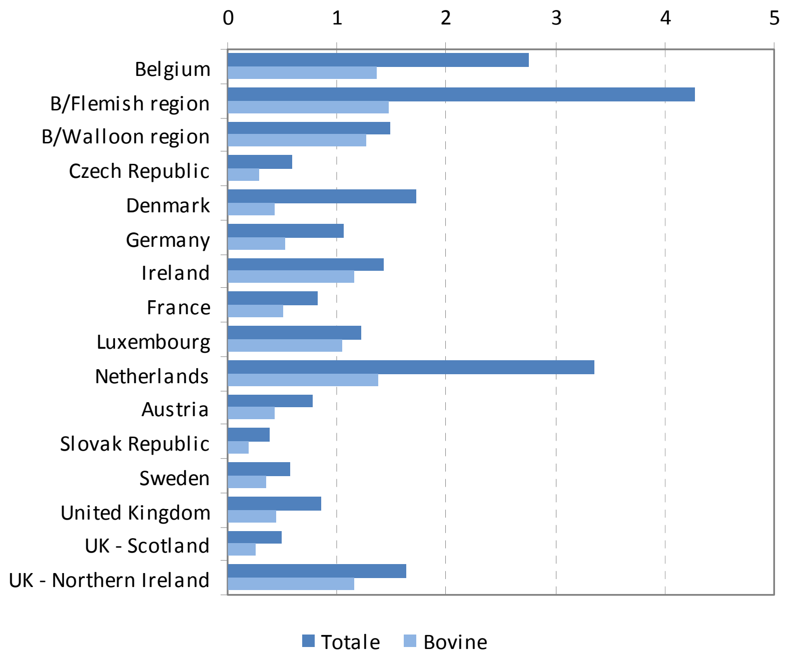


Figure 6 Livestock density: livestock units per hectare of utilised agricultural area for 2007. Source Eurostat (2010b).

Due to the combination of land use, livestock density and use of artificial fertiliser, nitrogen surpluses on the soil balance are high, more than 80 kg N ha^{-1}, in the Netherlands, the Flemish region of Belgium and the northwest of

Germany (Figure 7). Nitrogen surpluses are low, less than 20 kg N ha^{-1}, in large parts of Austria, the Slovak Republic and Scotland.

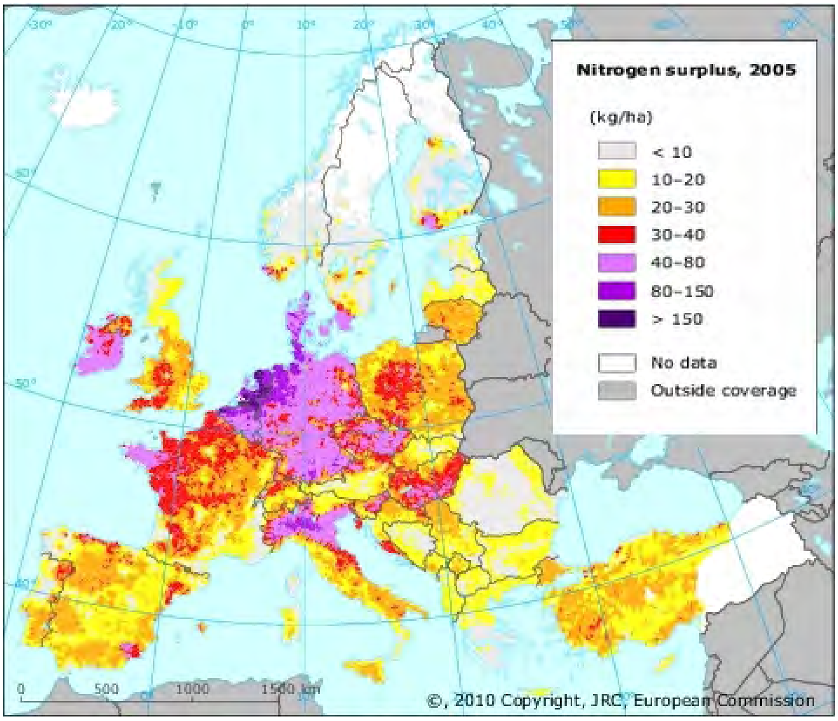


Figure 7 Estimated nitrogen surplus for year 2005 (EEA, 2010).
The surplus is calculated as the difference between inorganic and organic fertiliser application, atmospheric deposition, fixation and uptake by crops.

1.5 Monitoring networks

In all countries there is a long history of monitoring of agricultural practices and the quality of ground- and surface waters. In many countries the intensity of monitoring has increased; this increase as due to either the discussion with the European Commission about the designation of NVZs or as a consequence of the request of derogation (the use of more than 170 kg of manure nitrogen per hectare). An overview is given in Table 6.

Four countries have developed specific quick response effect monitoring networks, in addition to their regular ground and surface water networks, to show the effect of their Action Programmes (Denmark, the Netherlands, Sweden and England). A few other countries have additional programmes to monitor the effects (Walloon Region of Belgium, Germany, France and Luxembourg). Two countries have developed specific networks for monitoring the effect of their derogation (Flemish Region of Belgium and the Netherlands).

Table 6 Simplified overview of monitoring and control networks in the EU Member States participating in the second MonNO$_3$ workshop.
Data provided by participants; state of affairs June 2009.

Country	Agri-culture	Groundwater quality	Surface waters quality	Quick Response Effect	Dero-gation
Austria	Agricultural census concerning all farms, yearly.	National network since 1991, 238 springs + 1,780 porous aquifers; sampling 2-4 times per year, additional investigative monitoring by nine provinces; Drinking water survey by provinces.	National network since 1991, 76 surveillance stations for permanent monitoring with sampling 12-24 times per year; operational monitoring stations with non-permanent monitoring for water bodies at risk (revision every 3 years), additional monitoring by nine provinces.	With existing networks.	
Belgium, Flemish Region	Agricultural census, each year.	Nitrate monitoring network since 1999, around 260 pumping wells of farmers, since end 2003, 2,109 observation wells, 3 depths, sampling twice per year; Primary network, deep groundwater; sampling once per year; Network of drinking water supply companies; Networks of other organisations and private supply wells.	Regional network since 1991, 1,000 sites, sampling 12 times per year; Agricultural network (MAP = nitrate monitoring) since 1999, 266 sites, since end 2002, 800 sites sampling about 12 times per year (9-15).	With existing networks.	Derogation monitoring network since 2009
Belgium, Walloon Region	Soil linkage rate (SL) of each farm in the Walloon region Soil sampling for nitrates residues in 3% of farms in NVZ each year.	Network of 88 drinking-water supply companies since 1994. Present network: 950 sites, including farm wells and surveillance points.	Regional network since 1988, 180 sites, sampling 12-24 per year; In bathing zone lake water monitor, sampling weekly during summer.	With existing networks; Soil profile mineral N measurements for the purpose of Quality Approach (QA) monitor (26 reference farms plus farms involved in QA with high livestock density).	

Country	Agri-culture	Groundwater quality	Surface waters quality	Quick Response Effect	Dero-gation
Czech Republic	Agricultural census of Czech statistical office, each year; sampling of pilot farms; detailed census on selected farms.	National monitoring network of boreholes and springs since 1993 (current network: 271 boreholes and 138 springs), sampling twice per year. Additional network of drinking water supply companies and other abstraction for different purposes (appr. 4,100 points), sampling frequency according abstraction capacity.	Monitoring of small agricultural streams since 1993, revision in 2005 (3 types of locations) – 400 main locations – sampling 12 per year, 681 additional locations – sampling 12 per one year in four year period, appr. 120 investigative locations – sampling monthly in period October-March. Monitoring of main rivers for eutrophication (325 locations), sampling monthly. Additional network of drinking water supply companies and other abstraction for different purposes (875 points), sampling frequency according abstraction capacity.	With existing networks.	
Denmark	Agricultural census concerning all farms, yearly; Sampling of 1,900 farms.	National network since 1988, 70 sites with 1,400 well sampling points, sampling once a year (o/a nitrate) to once per six years. Water supply well monitoring since 1989, 6,400 wells at 3,000 sites, sampling once per 3-5 year.	National fresh water network, 231 locations, sampling 12-26 per year; Lake monitor, 31 lakes with 1-20 samples per year and 58 locations with one sample per year. Marine and coastal water monitor, 96 locations with 3-26 samples per year.	With existing networks; 20 representative catchments with different levels of monitoring since 1990, agriculture and water quality, 32 root zone stations, 7 drain-water stations, 100 upper groundwater stations and 5 stream stations.	
France	Agricultural census.	National network of 2,625 sites (2004-2005; 1,242 sites at start in 1992-1993); campaigns take place once every four years. Two-third of locations within NVZs.	National network of 1,719 sites (2004-2005; 1,047 sites at start in 1992-1993), mainly water courses; campaigns take place once every four years. Two-third of locations within	Use of existing networks. Additional research and monitoring is organised by regional authorities (département).	

Country	Agri-culture	Groundwater quality	Surface waters quality	Quick Response Effect	Dero-gation
			NVZs.		
Germany	Agricultural census; complete farms surveys every four years since 1991.	National network since 1999, 800 sites, sampling at least once a year; Networks of Bundesländer.	National fresh water network since (LAWA) 1984, 152 sites; National coastal water network, 10 sites.	with existing networks; Nitrate groundwater network, 180 sites specially selected based on occurrence of nitrate in groundwater.	
Ireland	Agricultural census.	National network of ~275 sites, sampling four times per year; Drinking water supply networks operated by local authorities.	~2,700 river locations with chemical and biological sampling; Lake monitoring at ~225 sites; Estuary, coastal and marine water monitoring. Sampling frequency varies year on year.	With existing networks.	To be re-assessed and finalised towards end of 2009.
Luxem-bourg	Agricultural census.	actual national groundwater network established in 2005: 21 sites, sampling at least 2 times per year.	Actual national surface water network established in 2005: 16 sites, sampling 6 or 12 times per year.	With existing networks; For some groundwater protection pilot projects soil profile mineral N measurements are taken to monitor agricultural practices.	
The Nether-lands	Agricultural census concerning all farms, yearly; FADN (Farm Accountancy Data Network) representati ve samples of 1,500 farms, yearly.	National Groundwater Quality Network (LMG), since 1984, about 360 locations, two depths (10 and 25 m below surface), sampling once per year – once per 4 years; Drinking water production sites (220), sampling 4-times per year; Provincial Groundwater Quality Network (PMGs). KRW groundwater quality network is under construction,	Monitoring Water Status of the Country (MWTL), about 30 locations in main fresh waters (large rivers and lakes), and 39 locations in marine and coastal waters, sampling frequency 12-24 times per year; Regional Water Status Networks, about several thousands locations in regional fresh waters, about 650 used for national reports, sampling	Minerals Policy Monitoring Programme (LMM), about 540 representative farms, monitoring both agricultural practices and water quality (root zone leaching and ditch water), sampling every year, 1-4 times per year; National Soil Monitoring Network (LMB), about 180 farms and 20 forest locations, monitoring soil	LMM includes a Derogation Monitoring Network of 300 derogation farms, sampling every year, 1-4 times per year.

Country	Agri-culture	Groundwater quality	Surface waters quality	Quick Response Effect	Dero-gation
		consists of well from national (LMG) and provincial (PMG) networks.	frequency once every four weeks.	quality. Sampling once every 5-6 years. Upper Groundwater Acidification Network (TMV), about 150 nature locations, monitoring shallow groundwater. Sampling once every two years.	
Slovak Republic		National network since 1982, 373 sites Drinking water supply 1,534 sites Special monitoring network for nitrates – 700 sites since 2008, 2 times a year.	National surface water network 397 locations.		
Sweden	Agricultural census, yearly; Survey of fertiliser and manure practice, every second year.	National groundwater network since 1968, 100 reference sites, sampling 4 times a year.	River mouth network, 50 sites, sampling 12 times per year; Lakes network, 4 large and 80 medium an small size; regional networks; Inventory of lakes (3,000) and watercourses (1,500) since 1975, every 5 year; Marine and coastal water monitor programme.	With existing networks; Network of 35 small agricultural catchments started in 1975, since 2002 8 intensive and 15 extensive areas; Agricultural observation fields, 13.	
United Kingdom England and Wales	Farm Practice Survey; British Survey of Fertiliser Practice, since 1983; Agricultural Census.	Groundwater Network since 1990, 3,700 sites, sampled approx. 4 times per year, currently under revision to meet requirements of the WFD.	General Quality Assessment network (GQA) and SWAD network; over 7,000 sites; sampling 12 times per year.	Specific project established in 2004, 16 study micro-catchments representative of a range of environmental and agricultural conditions, farm practices and water quality monitoring data collected and used to validate N loss models; use national-scale change in agricultural practice	

Country	Agri-culture	Groundwater quality	Surface waters quality	Quick Response Effect	Dero-gation
				to describe effects on water quality at national level.	
United Kingdom Northern Ireland	Agricultural Census; Ad-hoc surveys to meet specific needs.	Groundwater Network since 2000, 80 sites. Since 2004, 85 sites, sampling 4 times per year. Network currently under revision to meet requirements of the WFD.	River and lake monitor network since 1970's, GQA and SWAD network since 1999, 540 sites. Since 2004, 683 sites, sampling 12 times per year. Network currently under revision to meet requirements of the WFD.	With existing networks; Programme is being developed.	
United Kingdom Scotland	Agricultural Census; British Survey of Fertiliser Practice, since 1983.	Groundwater Network since 2000, 150 sites, since 2002 220 sites, sampling 4 times per year; Private water supply sites.	Fresh surface water network of 233 sites, sampling 12 times per year.	With existing networks; Programme is being developed.	

1.6 Environmental goals and quality standards

The way countries deal with environmental quality standards and objectives given in the Nitrates Directive (eutrophication and 50 mg l^{-1} nitrate) depends chiefly on:

- the manner and stage of implementation of the Nitrates Directive;
- the manner and stage of implementation of the Water Framework Directive; and
- the political constellation and the degree of pressure exerted on the politicians by public opinion and the stakeholders.

Some countries have very detailed sets of quality standards for surface waters, like Austria, Belgium, and the Czech Republic (Table 7), while some other have worked out the quality standards for nitrate in groundwater in more detail, like Ireland and the Netherlands. Both the Flemish and the Walloon region of Belgium have standards for soil mineral N in autumn to minimise leaching of nitrate from agricultural land. Denmark and Sweden, on the other hand, have set goals for the reduction of leaching of nitrate from the root zone. The Netherlands uses a quality standard for the nitrate concentration (sand and loess soils) or nitrogen concentration (clay and peat soils) in the leachate from the root zone to derive environmental sound fertilisation standards. Germany, Luxembourg, the Slovak Republic and the United Kingdom have a simple system of environmental standard for nutrients which states that the nitrate concentrations should not exceed the 50 mg l^{-1} standard.

Table 7 Overview of the use of water quality standards, in the EU Member States participating in the second MonNO$_3$ workshop.
Data provided by participants; state of affairs June 2009.

Country	**Soil**	**Groundwater**	**Surface waters**
Austria		NO_3 < 45 mg l^{-1}, if > 50% of monitoring sites have a higher average value additional remediation measures have to be taken for the entire groundwater body; all groundwater bodies with more than 30% exceeding the threshold value were kept under surveillance (two stages).	Surface waters: NO_3 < 50 mg/l Lakes: Transparency: < 0.5-1.5 m (minimum in summer season) Ptot: < 40 µg/l (< 75-350 µg/l for shallow lakes) → annual average conc. (average max. conc. for shallow lakes); Chlorophyll-α: < 7-30 µg/l (< 15-40 µg/l for shallow lakes) → as annual average; Listed water quality standards for lakes relate to lower class boundary of eutrophic status. Ranges of class boundaries result from classification of lakes.
Belgium Flemish region	NO_3-N residue in upper 90 cm of soil in autumn < 90 kg ha^{-1}.	All sample locations: NO_3 < 50 mg l^{-1}.	Sum of NO_3-N+NO_2-N < 10 mg l^{-1}; orthophosphate: < 0.3 mg l^{-1} as P (running waters); < 0.05 mg l^{-1} as P (stagnant waters); maximum allowable exceedance of 50% for N and P in at most 10% of measurements; chlorophyll-α < 100 µg l^{-1} (mean value). Use for drinking water: NO_3 < 50 mg l^{-1} in 95% of samples, always <75 mg l^{-1}.
Belgium Walloon region	Soil linkage rate (SL) of each farm < 1; Respect of mix of basic and chosen rules for farm involved in QA to reduce nitrate leaching; NO_3-N residue in upper 90 cm of soil in autumn < annual standards established for 8 crop groups.	Drinking water: annual average NO_3 < 50 mg l^{-1}; Average value for groundwater body < 37.5 mg l^{-1} (not legally binding).	Drinking water NO_3: < 50 mg l^{-1} in 95% of samples, always < 75 mg l^{-1}; total P < 1 mg l^{-1} (not legally binding); chlorophyll-α < 75 µg l^{-1} (not legally binding).
Czech Republic		*For designation and revision of vulnerable zones (springs and boreholes):* < 50 mg l^{-1} NO_3 in 95% of samples or maximum value.	*For designation and revision of vulnerable zones (small agricultural streams):* < 50 mg l^{-1} NO_3 in 95% of samples or maximum value for profiles with less than 12 samples

Country	Soil	Groundwater	Surface waters
			per year. *For all waters (legally binding):* < 7 mg l^{-1} NO_3-N in 90% of samples For water body status according WFD (not legally binding): < 1.6-3.4 mg l^{-1} NO_3-N (median value) according different water body types – high WB status. < 3.4-4.5 mg l^{-1} NO_3-N (median value) according different water body types – good WB status. Criteria for designation of the eutrophic vulnerable zones (N and P from agriculture) under development.
Denmark	50% reduction goal for nitrate leaching from root zone (1 m below surface level).	Drinking water: annual average NO_3 <50 mg l^{-1}.	Average annual target values set by counties.
France	No information.	No information.	No information.
Germany		NO_3 < 50 mg l^{-1}.	Total N ≤ 2.5 mg l^{-1} (not legally binding).
Ireland		Groundwater Directive: Water Quality Standard NO_3 < 50 mg l^{-1}. Groundwater Directive: Threshold Value NO_3=37.5 mg l^{-1}; MRP = 35 μgl^{-1}; NH_4 = 65 μgl^{-1}. Drinking Water: Maximum Admissible Concentration NO_3 < 50 mg l^{-1}.	Molybdate Reactive Phosphorus (MRP) (P) EQS = 35 μgl^{-1} (mean) Ammonium (N) EQS = 65 μgl^{-1} (mean). EQS = environmental quality standard
Luxem-bourg		NO_3 <50 mg l^{-1}.	Quality criteria under revision.
The Nether-lands		General NO_3 <50 mg l^{-1} *root zone leaching (for deriving fertiliser standards):* sand, upper metre of ground-water, and loess, soil moisture below root zone: NO_3 < 50 mg l^{-1} clay, tile drain water or upper metre of groundwater, and peat, ditch water: total N <11.3 mg l^{-1}.	*Lakes – Brooks (upstream):* Total N < 2.2 – 4.0 mg l^{-1} ; total-P < 0.15 mg l^{-1} ; chlorophyll-α <100 µg l^{-1} (lakes).
Slovak Republic		Value for groundwater body NO_3 < 50 mg l^{-1}.	Drinking water N-NO_3 < 11 mg l^{-1}.
Sweden	Reduction of nitrate leaching from root zone with 8,000 tonnes until 2010 (goal for	NO_3 < 50 mg l^{-1}.	Quality criteria for total N is under revision. total P < 0.025 mg l^{-1}.

Country	Soil	Groundwater	Surface waters
	national action programme).		
United Kingdom		$NO_3 < 50$ mg l^{-1}.	$NO_3 < 50$ mg l^{-1} at least 95% of the time (used for designation).

2 Pros and cons of different effect monitoring approaches

2.1 Introduction

The main characteristics of effect monitoring of Nitrates Directive Action Programmes are that, first, the effects of the Action Programmes on the environmental quality can be linked to changes in agricultural practices due to policy measures, and secondly, the effects of changes in agricultural practices on water quality can be separated from the influence of changes in environmental factors such as precipitation (Figure 8; for details we refer to Fraters et al., 2005).

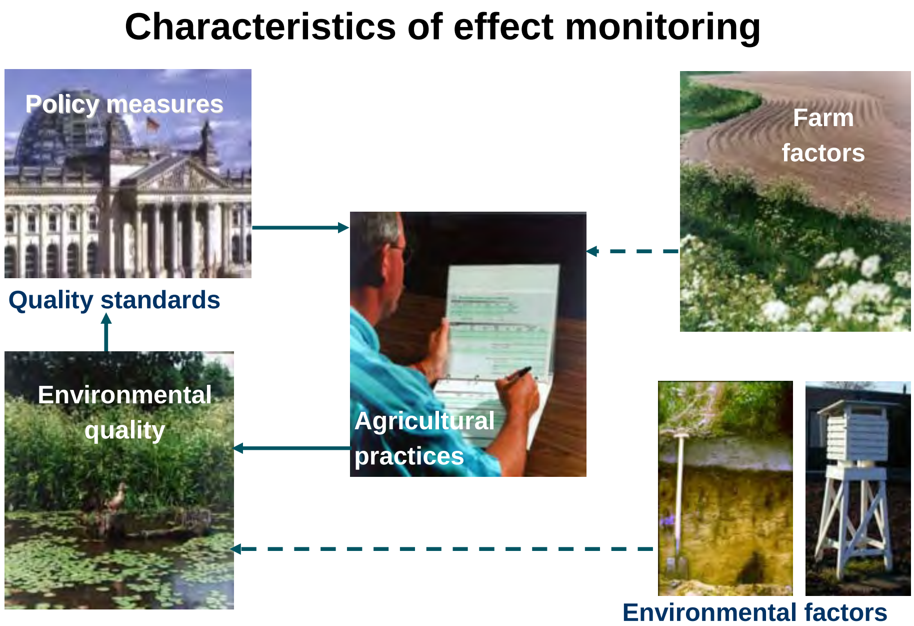


Figure 8 General outline of monitoring the effects of policy measures.
Solid lines indicate the relationships between entities that should be monitored according to the draft guidelines (EC, 1999, 2003), that is, policy measures, agricultural practice and environmental quality. Dashed lines indicate relationships between the entities that have to be monitored and factors needed to underpin claims that policy measures have led to changes in agricultural practices, and thereby to an amelioration of environmental quality.

In the previous MonNO_3 workshop, held in 2003, two main approaches of effect monitoring were distinguished: upscaling and interpolation (Fraters et al., 2005).

The *upscaling approach* uses the results of studies carried out on experimental sites, for example, plots or parcels, to quantify the effects of changes in agricultural practices on nitrate leaching (and water quality). Process models and data on national-scale changes in agricultural practices are used to upscale the experimental-sites results to describe the effect of the Action Programme on nitrate leaching and water quality on the national scale. Countries that, in 2003, employed an approach that could be classified as upscaling included Denmark, Sweden and the United Kingdom.

The *interpolation approach* uses the results of monitoring carried out on a random sample of locations, for example, farms, to quantify the effects of changes in agricultural practices on nitrate leaching (and water quality). Statistical models and national-scale monitored changes in agricultural practices are used to describe the effect of the Action Programme on nitrate leaching and water quality on the national scale. Countries that, in 2003, employed an approach that could be classified as interpolation included Austria, Belgium, Germany, Ireland and the Netherlands.

In short, the main difference between the two approaches was defined as follows:

- the upscaling approach concerns collecting a lot of data on a few locations; and
- the interpolation approach concerns collecting a few data on a lot of locations.

It was beyond the scope of the first MonNO_3 workshop to compare both approaches in detail. In general the upscaling approach has the advantage of gaining an insight into effects of specific measures on water quality, while the interpolation approach has the advantage that it provides an unbiased estimation of the changes in water quality on the national scale.

For both approaches the major focal points with respect to effect monitoring are:

- Accounting of confounding factors, that is to say accounting for the factors that 'complicate' the analyses of the relationship between measure and effect, the environmental factors such as weather, soil type, and so forth. For interpretation of the actually measured water quality in relation to measures one should be able to quantify the effects of the confounding factors on water quality.
- Choice of the type of water to be monitored, in other words soil water, upper groundwater, tile drain water, and so on. This choice deserves attention because it influences the strength of the relationship between measures and effects, due to the lag time, resolution power and interfering processes. Lag time is the time between measure and effect; resolution power is ability to discriminate between sources of measured nitrate in waters; and interfering processes are natural processes along the pathway, for example, denitrification.
- Choice of the level of scale used for research, for example, plot, parcel, field, catchment, farm. There has to be a balance between the levels of scale for which different types of data are available. The latter means that, preferably, the scale on which data on agricultural practices, water quality and confounding factors are collected is the same for all three data sets. Or, in case the scales are different, that upscaling or downscaling of the data from different data sets to the same scale for analyses does not lead to large uncertainties in the results.

For the second MonNO_3 workshop we asked the participants to look into:

- similarities and differences between networks based on an upscaling and networks based on an interpolation approach;
- similarities and differences between networks with the same approach, in other words to look into differences between networks using the upscaling approach and at differences between networks using the interpolation approach.

We asked the participants to consider, for example, the collection of agricultural data, the sampling of water, the strategy and methods of accounting for environmental factors, and the use of models for monitoring design and data interpretation.

With respect to the collection of agricultural data, questions arise like: 'Are agricultural data collected at the same scale as water quality and environmental data?', 'Which agricultural data are needed?', and 'Which problems are encountered and how are they solved?'.

When talking about sampling of water, the factors should be considered that influence interpretation of measurements as lag time, resolution power, and interfering processes, but also scale dependency of representativeness of samples, goals of sampling, and costs of sampling.

Other points of attention that could be considered in the discussion are:
- How to define and monitor effects on eutrophication?
- How to monitor effects of Nitrates Directive Action Programme measures for phosphorus?
- How to use the same Nitrates Directive monitoring networks for monitoring for other EU directives?
- Is stakeholder involvement important, and if so, do farmers participate or are they consulted?

2.2 Discussion

Types of monitoring

The participants struggled with the concepts of upscaling and interpolation approach. The struggle is probably due to the different types of monitoring used for effect monitoring by the countries involved in the workshop. Four different types of monitoring can be distinguished (see Textbox 1 for details):
1. General monitoring networks and surveys for agriculture, groundwater, and surface waters;
2. Quick response monitoring networks;
3. Investigative monitoring;
4. Compliance checking surveys.

Ad. i. General monitoring networks
All countries have general monitoring networks to show the status and trend in the quality of their waters. These are commonly designed and set up as stratified random networks of observation points. For interpretation of the data statistical approaches are used either in combination with or without a process model. So, it could be argued that (almost) all countries will use the interpolation approach.

Countries like Austria, Flemish region of Belgium, the Czech Republic, France, Germany, Luxembourg, and the Slovak Republic consider (parts of) their general monitoring networks, sometimes in combination with investigative monitoring and/or their compliance checking surveys, to be sufficient for quick response monitoring. Therefore, these countries did not design a special network. The Flemish region, for example, extended its groundwater and surface water monitoring networks in 2002 to ensure that the number of wells and, in particular, the number of screens in the upper part of aquifers would be sufficient to monitor the effect of the Action Programmes.

Ad. ii. Quick response networks
In some countries there is a need for additional monitoring to prove the effect of agriculture and changes in agricultural practice on water quality. These specially designed quick response networks – sometimes called early warning networks – are commonly designed using the upscaling approach; this is the case in the Walloon region of Belgium, Denmark, England, Ireland, and Sweden. An exception is the Netherlands that used the interpolation approach to set up a quick response network in the early 1990s.

Ad. iii. Investigative monitoring
Most countries carry out investigative monitoring in addition to other types of monitoring. Investigative monitoring or research projects should not be confused with quick response networks. Investigative monitoring is commonly used to show the effects of specific measures. The knowledge gained is usually built into process models. For example, in France and Germany research projects are used to develop models that are used in combination with agricultural information from surveys at the catchment scale for upscaling and calculating effects of Action Programmes on water quality.

Ad. iv. Compliance checking surveys
All countries perform compliance checking surveys, but Austria, Flemish region of Belgium, and the Czech Republic use soil mineral nitrogen analyses in their compliance checking surveys. In Germany the residual mineral nitrogen is also used for compliance checking in co-operation projects between farmers and drinking water companies within several Federal States.

Type of monitoring and monitoring approach

Most countries use combinations of different types of monitoring and different approaches to show the effectiveness of their Action Programme (Table 6, column 5); not all combinations are expected to occur (Table 8).

The set up many of the general groundwater and surface water monitoring networks (type i; see Textbox 1), often dating back to the 1980s, is based on the interpolation approach. That means, these networks consist of a large number of 'more or less' randomly selected monitoring sites. Only the Danish groundwater monitoring network approach could be classified as upscaling, as 70 monitoring sites were selected in the past, with – at each site – a large number of wells along the groundwater flow path to a groundwater abstraction well.

Quick response networks (type ii; see Textbox 1) are of more recent date, and only a handful of countries have set up such a network (Denmark, England, the Netherlands and Sweden) or are developing them (Ireland, Northern Ireland and Scotland) (Table 6). The set up in all countries is based on the upscaling approach, except for the Netherlands that used the interpolation approach for designing and setting up a quick response network.

Textbox 1 Different types of monitoring

i) General monitoring networks and surveys
All countries have networks for monitoring the trends in quality of their aquifers and surface waters. These networks are useful to get a general picture of the water quality in the country. Due to several factors these networks cannot always be used to show the effect of Action Programmes on water quality within a four-year period. The main factors are lag time, resolution power and interfering processes (Fraters et al., 2005). Often a lot of time will pass between the moment that agricultural practices are changed and the moment that the effects of these changes on the water quality can be measured at the observation points (well screens in groundwater at a depth usually well below the surface level) (lag time). In addition groundwater observation points may receive water that infiltrated at field level at another place, for example, neighbouring nature or urban areas. For surface waters direct discharge by waste water treatment plants, industry, or overflow of sewage systems in case of heavy rainfall may influence water quality at observation points. Therefore, it will be sometimes difficult to distinguish between agricultural and other sources of nutrients (low resolution power). To conclude, effects of measures may be masked by soil processes such as denitrification (nitrate), fixation (phosphor), upward seepage in combination with mineralisation of soil organic matter (nitrogen and phosphor). Monitoring of agricultural practices by, for example, farm accountancy data networks or a census, are seldom directly linked to the locations of these general water quality networks. Therefore there is no direct relationship between observed changes in agricultural practices and observed changes in water quality.

ii) Quick response monitoring networks
Several countries have developed a special purpose monitoring network in addition to their general monitoring networks and surveys. These networks have as common goal to show the effects of policy on water quality in relation to changes in agricultural practices, and to prove these effects within a four-year period, the duration of an Action Programme. Both agricultural practices and water quality are monitored in the sampling units to enable a direct relationship between agricultural practices and water quality. The sampling unit considers agricultural land used by farmers applying common agricultural practices. Water quality monitoring focuses on monitoring water leaching from the agricultural fields, for example, by monitoring water leaching from the root zone or monitoring small surface waters next to the field. This way lag time is short, other sources of pollution are absent and soil processes masking trends are minimal.

iii) Investigative monitoring
Most countries have research projects to investigate the effects of specific measures or the combinations of measures in agriculture on water quality. Investigative monitoring is quite similar to quick response monitoring. The main difference is that quick response networks monitor on agricultural land in use by farmers applying common agricultural practices; practices not influenced by monitoring practices. Investigative monitoring may use similar monitoring and modelling methods, but the agricultural practices used in the fields are determined or, at least, influenced by the researchers.

Textbox 1 Different types of monitoring (continued)

iv) Compliance checking surveys
All countries check compliance of their Action Programme. This generally concerns both administrative controls of farmers and observations of compliance of rules like those related to manure application as respecting the closed period and way of application. Compliance checking is usually not random; for efficiency reasons sampling is based on risk analyses. Farmers with farming practices with a high environmental risk are controlled more often than those with a low risk of not complying. Some countries use environmental information for compliance checking. For example, the amount of residual soil mineral nitrogen in the root zone in autumn which is considered as the potentially leachable nitrogen.

Investigative monitoring (type iii) and compliance checking surveys (type iv) are beyond the scope of this study. Because of its goals, investigative monitoring will probably always be set up using the upscaling approach. The set-up of compliance checking surveys, on the other hand, should normally be based on the interpolation approach, even in case the survey is focused on subsets of farmers defined on the basis of a risk analysis.

Table 8 Overview of occurring combinations of monitoring approaches and types of monitoring[†]

Approach	Type of monitoring			
	i. General	ii. Quick response	iii. Investigative	iv. Compliance
Upscaling	(x)	X	X	-
Interpolation	X	(x)	-	X

[†] X = common combination; (x) = infrequent combination; - = combination not expected

Comparison of different approaches

As often both of two monitoring approaches, namely upscaling and interpolation, are used in each country and the types of monitoring networks used for effect monitoring differ between countries, it was difficult for the participants to discuss the pros and cons of the two approaches. The discussions were clouded by these different frames of reference, in particular at the beginning of the workshop.

The main similarity between the two monitoring approaches is that both approaches seek for a representative assessment of agricultural practices. Governments put in much effort to work out policy measures. However, often it is not known how the policy measures are implemented by farmers in the first place. Therefore it is just as important to get information about the way farmers translate policy measures into agricultural practices as it is to monitor water quality. It was stated that a lot of information could be derived from agricultural data and modelling based on experimental studies. An important question with respect to the development of future policy measures is ‘What is the baseline for farming practices?’; keeping in mind that there is a large variation in farming practices between farmers having a similar farm type, for example, a dairy farm.

For both monitoring approaches similar agricultural and water quality parameters are monitored, but they are monitored at different spatial and temporal scales. Many other characteristics are considered by some to be different between the two approaches, such as network design (selection of sites), methods and models for accounting for the effects of environmental factors on water quality, the number of sampling points per km^2, the frequency of sampling, and the methods used for sampling.

There are differences in methodology between monitoring networks that are designed and set up based on the same approach. Most countries use fixed monitoring sites independent of their approach. The Netherlands makes use of temporary wells in the quick response networks. These temporary wells are per definition never in exactly the same location in consecutive sampling campaigns. Countries like Austria and Belgium sample soil mineral nitrogen (SMN) during inspection visits and these locations are not fixed either.
Pros and cons will always be assessed from the perspective of the overall layout of networks used (history) and information available in a country. The choice by a country for a certain monitoring approach or a combination of approaches and types of monitoring, perhaps with emphasis on one of the approaches, is – in addition to monitoring history and available information – determined by the physical setting in a country, the level of problems as experienced by society, and the available budget. The latter is influenced by the pressure on the government exerted by politicians, farmers unions, and environmental pressure groups. The choice for a certain monitoring approach does not seem to relate to the choice for designating NVZ or applying the Action Programme on the whole territory.

Despite all complexities and complications, some general statements can be made about the pros and cons:

– The main advantage of the *upscaling approach* is that it provides a better insight into processes than the interpolation approach. This insight can be used by farmers to adapt and therefore is a driver for participation. This insight can also be used by researchers to improve process models and to make estimations and predictions more reliable. A second advantage of the upscaling approach is that it is cheaper than the interpolation approach, in particular in the initial phase. Thirdly, with this approach it is easier and cheaper to extend the number of monitoring parameters.
– The main advantage of the *interpolation approach* is that it is less sensitive to changes in the network, which is important for networks that are assumed to operate for more than ten years, and that it is easier to show ‘representativeness’ with this approach. This is due to the large number of locations, which ensures the presence of many different combinations of farming practices and environmental conditions. Consequently, the loss of a specific location, for example, a location that is no longer accessible or suitable, is less important. A second advantage of the interpolation approach is that there is a smaller chance the farmers adapt to the system in place, which would bias the results. Thirdly, by some of the participants the interpolation approach results are expected to have a higher acceptability for stakeholders than the results of the upscaling approach. This is because of the robustness and simplicity of the interpolation approach, were the interpretation is less dependent on difficult to grasp assumptions such as assumption inherent to process models used in the upscaling approach.

To summarise the main difference, using the words of one of the participants: 'the interpolation approach delivers an impact while the upscaling approach delivers an indication on how it works'.

Network developments

It became clear during the $MonNO_3$ workshop that the system for effect monitoring in place has developed organically in each country. These systems generated time series of data sometimes for over two decades or more. Replacing such a system by another one would without doubt – because of discontinuity in observed series – cause enormous problems for trend analyses. Systems did adapt in the past as a consequence of changing circumstances, and will adapt in future. Systems for effect monitoring should be adapted or extended organically to ensure that a change in the monitoring system does not result in an insurmountable loss of information.

The general feeling at the workshop was that there is no reason why effect monitoring networks for the Nitrates Directive (ND) cannot be used for Water Framework Directive (WFD) purposes. ND effect monitoring networks are considered to be complementary for the WFD, but they are not necessarily sufficient to fulfil all monitoring and reporting requirements of WFD.

The possibility of a common EU approach was discussed. The conclusion was that no common approach is feasible because of the different drivers, such as monitoring networks in operation and research traditions and experience. However it might be helpful to initiate an intercalibration project for models used in the framework of effect monitoring, as well as to develop tools for convincing farmers about the usefulness of measures in their own interest.

2.3 Conclusions and recommendations

Conclusions

The upscaling approach gives more insight into processes involved in leaching of agriculturally used nutrients to groundwater and surface waters and is, in general, a cheaper approach than the interpolation approach.

The interpolation approach is less sensitive to changes in a monitoring network and results may have a higher acceptability for stakeholders.

For comparing effect monitoring systems between countries not only the monitoring approach is relevant, but also the type(s) of monitoring in use and the applied working procedures, such as procedures for sampling of groundwater and surface waters.

A common approach for effect monitoring on EU level is not possible. It is not realistic to expect that countries can be required by the EU to change their current approach because of the danger of introducing a discontinuity in observed series.

Recommendations

It might be helpful to initiate an intercalibration project for models used in the framework of effect monitoring and to develop tools to convince farmers that (specific) measures are useful and in their own interest. This topic could be a subject for a next $MonNO_3$ workshop.

3 Additional use of monitoring data from national networks

3.1 Introduction

In the view of the Netherlands, the primary goal of effect monitoring networks is to show that water quality, especially nitrate concentration, improves in relation to changes in agricultural practices, as a consequence of Nitrates Directive Action Programmes. Therefore, networks do not (necessarily) have to show the contribution of individual Action Programme measures or that the 'good status' of water quality is reached (compliance checking).

The main obligatory measures in Action Programmes are:
- fertiliser standards, to reach equilibrium between input and output;
- maximum use of animal manure nitrogen of 170 kg N ha^{-1} or request for derogation;
- closed period for animal manure application, including sufficient storage capacity;
- other limitations to application of fertilisers in relation to:
  - soil conditions: snow cover, frozen soils, and so on;
  - steepness of slope;
- buffer strip near (vulnerable) fresh waters.

The first question is whether data from general monitoring networks can be used to underpin or to show effects of individual measures within the Action Programmes. Or should one use dedicated research projects to underpin or to show effects of individual measures within the Action Programmes?

Target values are not well defined in the Nitrates Directive. Two main points are:
1. Eutrophication, parameters to characterize eutrophication are only given as examples and the levels of these are not prescribed:
   - nutrient concentrations (N, P);
   - chlorophyll-ɑ, duckweed, and so forth.
2. No reference scale – space and time – is given for the nitrate standard of 50 mg l^{-1} nor for the eutrophication parameters. This concerns:
   - spatial aspects:
     a. sample, field, farm, (mini-)catchment, region, water body;
     b. depth: root zone, upper five metre of groundwater;
   - time aspect: day, month, year, average year.

There may be a conflict in choosing the monitoring object. For showing the effect of Action Programmes it would make sense to monitor losses from agriculture fields. However for monitoring for compliance checking it would be logical to monitor objects to be protected (see Figure 9).

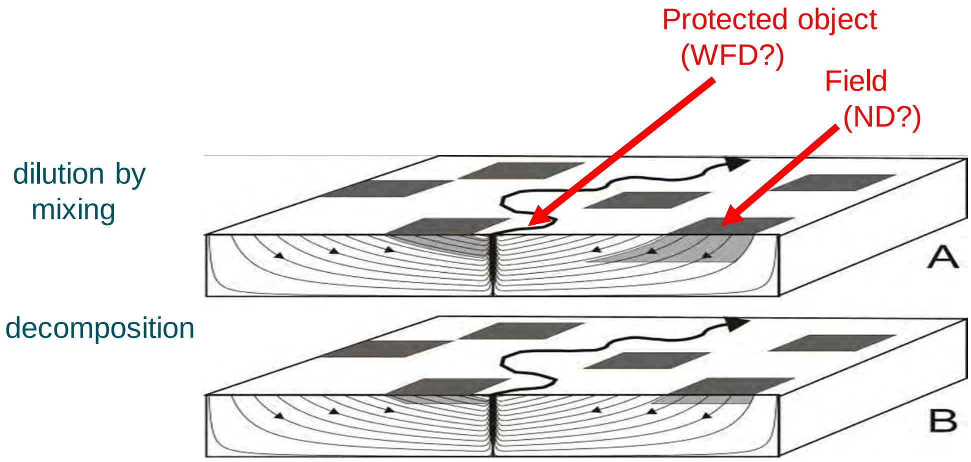


Figure 9 Relationship between monitoring goals and site selection.
Measured nitrate concentrations depend on monitoring goal and selection of locations for monitoring due to the effect of dilution by mixing and decomposition (denitrification) in groundwater (based on figure from EC, 2009c).

The second question is how to decide whether additional measures are needed or not and how to account for a need for compliance checking in (effect) monitoring programmes.

Some questions, with respect to the use of models in combination with monitoring data, are:
- Are models available that can use monitoring data for parameterisation?
- How to use data from monitoring networks in existing models?
  As compared to research projects, in a monitoring network:
  - many factors are not controlled; and
  - many factors are difficult to determine on the scale of the model.
- Are independent data sets available for model validation?

3.2 Discussion

Underpinning new or additional measures

Many of the participating countries have used the results of their effect monitoring network to answer the question whether or not new measures are needed. It was stated that if nitrate concentrations in the national networks decrease, it is sufficient to be able to state that the Action Programme works. However, it was argued that in such a case there is need to investigate whether it was the Action Programme or whether there were other factors that caused this decrease. Also in case of the absence of a trend in nitrate concentrations or with increasing concentrations there is a need to look into factors responsible for this lack of decrease, for example, interfering processes and lag times, or the unexpected increase, for example, changes in weather or soil properties.

It was mentioned that effect monitoring is also needed to be able to communicate that farmers have (or not have) achieved what they were supposed to achieve; there is not only a necessity to communicate this to the European Commission (EC) but to the public and the farmers, as well. One could argue that it might also help to motivate farmers to comply with Action Programme measures. As an example, it was mentioned that data on nitrate from all Member States may lead to a new European nitrogen policy or may be used to convince the EC that all Member States are struggling with complying with a target and it will take some time to achieve this target. In many Article 10 reports it is, for example, stated that nitrate concentrations in groundwater will not change in the short term due to long travel times.

In participants' opinion the WFD will drive countries to 'dig deeper' in the future. Some countries set specific targets, for example, a percentage in the reduction in nitrate leaching, to help to determine whether the Action Programme is working. It was felt not to be effective to separate between the Nitrates Directive and the WFD so strictly, as seems to be the case in some countries; one should benefit from both. Only looking at monitoring from the Nitrates Directive perspective will give a too limited view, for example, limited to the conclusion that there is no increase in concentrations. The WFD gives Member States the means and tools to get a deeper understanding of the system. In other words, the answer to the questions about what causes effects and what is the cost-effectiveness of measures.

The common feeling is that countries collect lots of data that could be useful in assessing effects, but that they do not always make most effective use of this data. Data from monitoring networks can be used to underpin Action Programme measures, to identify agricultural practices that are causing problems and, therefore, could provide information about how the Action Programme should be amended. In addition, in the future, data could be used to identify whether Action Programmes should be tightened in the entire country or only in certain areas. But one should keep in mind that:

- When assessing the effect of Nitrates Directive Action Programmes, lots of other policy issues should be considered too.
- The scale of monitoring and presentation of results is important, for example, the upscaling approach gives detailed information on field level, while the interpolation approach needs data on a higher level of scale and usually yields no deeper understanding.
- Additional (more detailed) information about, for example, climate and hydrogeology, is sometimes needed to support assessment of the cause-effect relationship and to identify further and/or additional measures or new regulations.
- Monitoring data should be used in combination with results of research together with modelling. Typically, models are developed first based on research data, then calibrated on monitoring data.
- Models can be used and have been used for checking whether the effects of measures are sufficient and for predicting what is further needed, whereby it is possible to look at different parts of the hydrological systems.

Examples for underpinning nitrogen use standards

Fertiliser standards for nitrogen are adapted to climatic and soil conditions, in addition to crop type and sometimes level of crop production. Different approaches exist to underpin fertilisation standards, three examples are given below:

- Monitoring data in the Netherlands are used to derive a nitrate leaching fraction (NLF), that means, the fraction of the nitrogen surplus on the soil balance that is leached as nitrate from the root zone. This NLF is used in a model to derive environmental sound nitrogen (N) use standards. The other relationships in this empirical model are mainly based on research data. Current N use standards are a political compromise between environmentally sound standards and economically optimal standards.

- In Denmark, however, N use standards were initially set to 10% below the economic optimum level. Monitoring data are used to supply a model with sufficient input to check if the national goal for reduction of nitrogen leaching is reached.
- In Belgium, residual soil mineral N standards are set in addition to fertilisation standards to control leaching from the root zone.

Compliance checking

Different approaches are used in Member States with respect to compliance checking. With respect to the nitrate target value of 50 mg NO_3 l^{-1} differences exist between compliance checking for soil water, groundwater and surface waters. Eutrophication compliance checking is difficult to handle for most Member States.

The requirements of the WFD and the Nitrates Directive should be considered together, even though the Nitrates Directive does not consider water bodies but NVZs (nitrate vulnerable zones). The WFD requires assessment on water body level for both groundwater and surface waters with particular compliance regimes and target values ≤ 50 mg NO_3 l^{-1}. However, for both directives trend assessment is important; water quality should be at least stable, that means, show no increasing trend in pollution. Similarly, both directives make use of the concept of Protected Areas, Nitrates Directive NVZs are to be treated as Protected Areas under WFD – targets have to be met. Some state that the Nitrates Directive data will become a subset of the WFD data.

For Nitrates Directive compliance and reporting to the European Commission different 'spatial scales' are used for compliance checking, ranging from individual monitoring sites to regions and from water leaving the root zone (the Netherlands and Denmark) to drinking water abstraction (Luxembourg). Sometimes depth is depending on the groundwater body under consideration (France).

For WFD compliance threshold values are well-defined as regards the level of the threshold value and the lateral scale (water body). It is by some considered to be more stringent, because WFD demands a clear improvement of water quality and regional differences are explicitly taken into consideration.

The question was raised how to link regional threshold values to the national Action Programme in case the whole territory approach is used for the Nitrates Directive. The following remarks were made:
- regional differences may need local Action Programmes;
- efforts should be put into the communication about different approaches to farmers;
- large efforts are needed to underpin regional differences in Action Programmes (specific conditions);
- more agricultural data are needed for compliance checking for the WFD.

3.3 Conclusions and recommendations

Conclusions

Monitoring data from national networks can be used and are used to underpin new or additional policy measures, but there are certain restrictions regarding the details of underpinning depending on the type of monitoring approach used.

Underpinning of new or additional measures should be done by using a combination of data from national monitoring networks, research derived data and modelling. The data from national monitoring networks can also be used to show that no new measures are needed. However the environmental target values are not well defined. And although the WFD gives clear threshold values, especially with respect to eutrophication compliance checking is ambiguous.

Recommendations

It might be helpful to make a comprehensive overview of the use of data from national monitoring networks in the underpinning of more or less specific Action Programme measures and the manner in which they are used, for example, in combination with research data and/or models. This topic could be a subject for a next MonNO_3 workshop.

4 The need for special networks for NVZ designation and/or underpinning of derogation

4.1 Introduction

The Netherlands was granted derogation by the European Commission for four years in 2006. One of the obligations stemming from the derogation decision was to monitor 300 derogation farms during this period annually. In 2006, this led to an increase in monitoring effort from about 200 farms to 500 farms annually (see Figure 10) and an increase in sampling frequency by 25% of waters on farms in the Low Netherlands with man-made drainage. Water sampling regards sampling of upper groundwater, tile drain water, and ditch water. Denmark was granted derogation for 2003-2004 for the first time and this derogation was renewed in 2004 and 2008 for four years each time. Unlike the Netherlands, the derogation did not lead to an increase in monitoring in Denmark.

Denmark and the Netherlands apply their Action Programme to the whole country. Countries like England, France and Belgium designated nitrate vulnerable zones (NVZs). The designated area increased in all countries since the first designation (see Table 3). The Flemish region of Belgium increased their monitoring effort significantly in 2003, so as to, amongst other reasons, underpin the NVZ designation. Recently, the Flemish region changed its policy and applies one Action Programme to the whole area of the region.

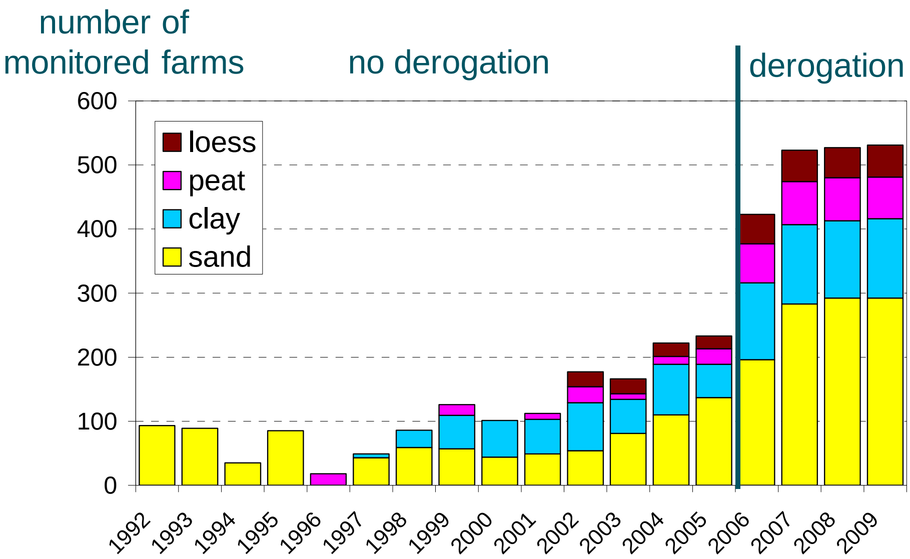


Figure 10 Increase of monitored farms as consequence of the Netherlands derogation.

In general, countries with designated NVZs and with derogation are assumed to have a larger need for monitoring than countries applying their Action Programme to the whole territory and without derogation. Countries with designated NVZs but without derogation and countries applying their Action Programme to the whole territory but with derogation are assumed to have an intermediate need for monitoring. For example, England, a country that designated NVZs and was granted derogation (see Table 2), is expected to invest more in monitoring than Austria, that applies the Action Programme to the whole country and has no derogation. However, the picture of countries performing additional monitoring for derogation and/or designation (Table 2) indicates that there are other factors that determine the extent of monitoring.

There are large differences between countries in the extent in area and level of the derogation (Table 4), which might explain differences in monitoring efforts. For example, Denmark and Germany, countries with no additional monitoring for derogation, have less than 5% of the agricultural area under derogation and a maximum manure application of 230 kg N per hectare, while Ireland, the Flemish region of Belgium and the Netherlands, countries with additional monitoring obligations, have at least 8% of the agricultural area under derogation and a maximum manure application of 250 kg N per hectare (see Table 4). Northern Ireland indicates to have additional monitoring, although only 0.5% of the agricultural area is under derogation. This might be due to additional monitoring for designation of NVZs, since Northern Ireland only recently changed from the designation approach to the whole territory approach.

Differences between countries in the area designated as NVZs are less striking (see Table 3), since most countries increased their designated area, since the first designation, to at least 40% of the agricultural area. This increase occurred in many EU countries (see Figure 11).

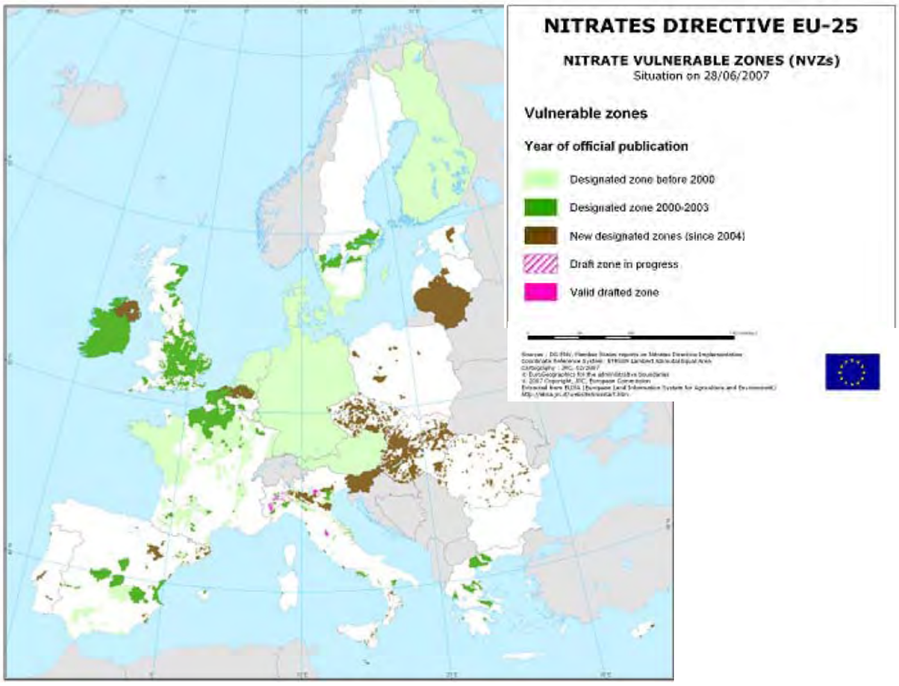


Figure 11 Change in area designated as NVZ in the European Union (Source: EC, 2010b).

All countries that designated NVZs and did not apply for derogation indicated to have increased their monitoring effort (Table 2). However Scotland and the Walloon region of Belgium designated NVZ and have a derogation, but nevertheless did not increase their monitoring effort. Again, other factors are of influence, such as, history of monitoring, the type, intensity and extent of agriculture, and the sensitivity of soils for nitrate leaching and surface water for eutrophication.

In most countries groundwater and surface water monitoring networks were designed for national purposes and were already operational before the Nitrates Directive was implemented in their national regulations. In Denmark and the Netherlands special networks for monitoring the effects of changes in the agricultural minerals policy on water quality were developed for national purposes before the Nitrates Directive was implemented in their national regulations, as well.

Nitrogen use in Dutch and Flemish agriculture is high compared to other areas in the European Union (Figure 7), at least partly due to the high livestock density (Figure 6). The effect of the N surplus on the environment depends on the vulnerability of the soils for nitrate leaching (Figure 12) (Velthof et al., 2007, 2009). A study on the European scale showed that not only N surpluses are high in the Netherlands (NL) and Belgium (BL), but also nitrate leaching is calculated to be high compared to, for example Denmark (DK) and Germany (DE) (Figure 13) (Oenema et al., 2008, 2009).

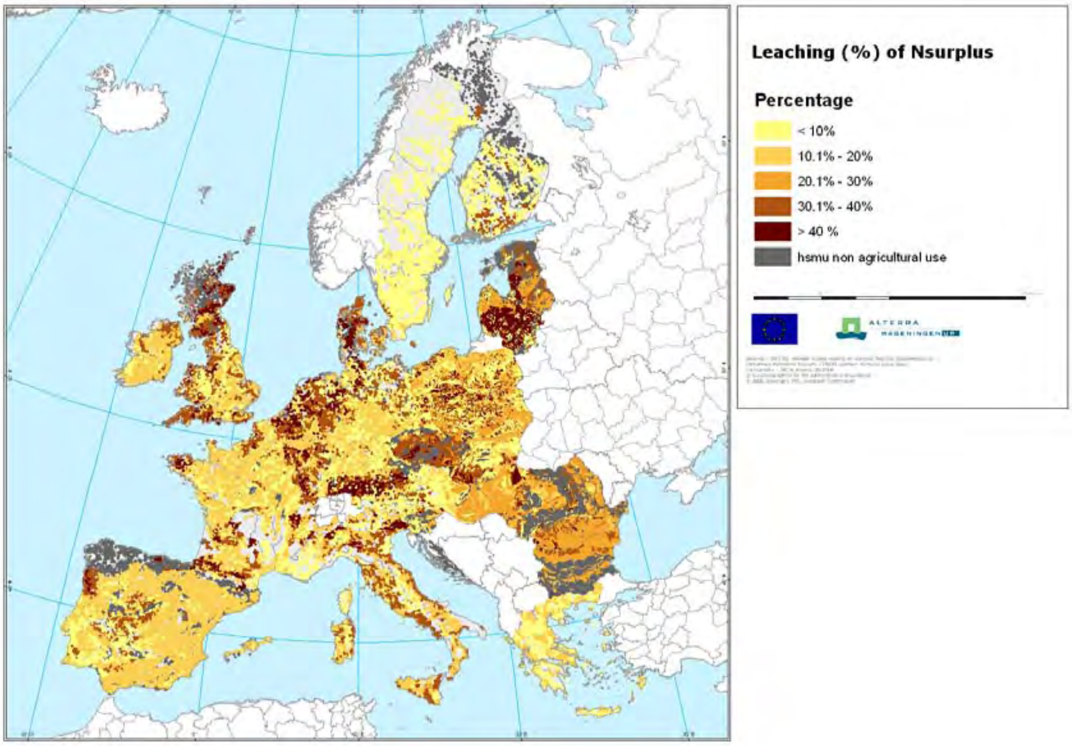


Figure 12 Leaching percentage of N surplus, based on data for 2000 (Velthof et al., 2007, 2009).

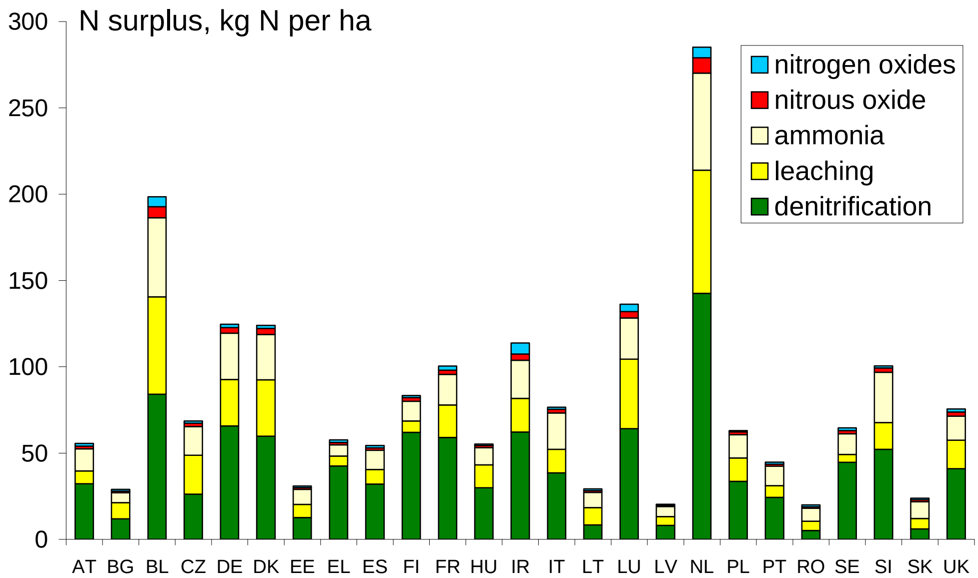


Figure 13 Fate of N surplus in soils in EU Member States, based on data for 2000 (Oenema et al., 2008).

The question discussed at the workshop was whether existing networks can be used or special networks are needed for monitoring for NVZ designation and/or for underpinning of derogation.

4.2 Discussion

Monitoring for NVZ designation

Countries that apply the whole country approach, and do not designate NVZs, may distinguish between vulnerable and less vulnerable areas in their Action Programmes. However, Action Programmes are not always regional but may consider combinations of crops and soils for which different rules apply. For example, in Denmark and the Netherlands different levels of nitrogen application limits exist for the same crop on different soil types.

Action Programmes are in some countries, that do designate NVZ, considered as a general regulation for agriculture, that means that Action Programme measures are compulsory for farmers both inside and outside NVZs (for example, Walloon region).

Drivers for current and future Action Programmes are:
- the attitude of farmers organisations towards general and specific measures;
- the balance, often difficult to find, between more justifiable specific measures – giving more difficulties for compliancy checking and requiring more accounting by farmers – and as less fair experienced general measures which, on the other hand, result in less ‘red tape’;
- WFD River Basin Management Plans, that require more local measures than Nitrates Directive Action Programmes.

These drivers partly determine the choice of a country for the whole territory approach or for NVZ designation.

It was noted that drivers behind the designation of NVZs are:
- the area effected by designation;
- the possibility for additional legislation in NVZs without effecting all farmers; and
- the restriction of intensive administration to farmers inside NVZs.

Considerations for monitoring in case of NVZ designation are:
- the need for a more intensive monitoring – higher density of sampling frequency – within NVZs, as well as monitoring directly related to agricultural practices, for example, monitoring of soil mineral nitrogen within NVZs;
- the need to report on whole country level to show also water quality outside NVZs and to be able to give a picture of the water quality at the national level;
- the discussion that takes place in some countries about using ‘the polluter pays’ principle for passing on the extra monitoring costs to farmers.

Some argued that in principle there is no need for additional monitoring and that the monitoring within NVZs is similar to monitoring outside NVZs. This might be due to the existing monitoring network and the intensity of farming, that means, level of nitrogen pollution. Occasionally, there may be need for additional monitoring:
- during revision of designation to support delineation;
- to link water quality monitoring data to pressures;
- to get a better coverage in space and time.

Whether one can use existing monitoring networks for NVZ designation depends on the existing monitoring network and the ‘risks’ involved in designation. A Member State may designate a large area or it may apply the Action Programme to its entire territory, in order, for example, to prevent the risks of 'not designating vulnerable areas' or in the interest of maintaining coherent, area-wide codes of 'good farming practices'. If a Member State has chosen this approach and the pressure from farmers against this approach is low, the need for monitoring will be relatively low. This is the case in, for example, Austria and Germany. However, if involved farmers protest against this approach, the need for monitoring might increase as well. This is actually the case in the Netherlands, where the Action Programme is applied to the whole territory. This whole territory approach is currently under discussion in the Dutch Parliament. In case only a small area is designated, for example, to minimize the number of farmers involved, this increases the risk of 'not designating vulnerable areas' and this approach will increase the need for monitoring to show compliance with the Nitrates Directive. England and France are examples of the latter.

Monitoring for derogation

All derogation decisions establish monitoring requirements. There are different requirements in the decisions taken by the European Commission for different countries. The logic behind the differences is not known. The European Commission seems to consider existing monitoring arrangements in place, intensity of agriculture – for example, the nitrogen surplus and livestock density – and area covered by derogation. The extent of the requirements for monitoring seems to be related to number of farms subjected to the derogation, which is more or less the same as the area of agricultural land under derogation (requirements of the EC). It is not directly evident how extra monitoring can prove that the derogation causes no detrimental effect to the environment.

Since most countries have derogation for the first time, it is not certain if requirements within Derogation decisions will become more stringent in course of time. Derogations of Denmark and the Netherlands are renewed without new requirement within the decisions. However new Action Programmes, providing the basis for a derogation decision, contain more and stricter measures for agriculture. In some countries the Derogation decision requires monitoring of phosphorus (P) in farm waters, as some countries have P measures in their (new) Action Programmes at farm level. It was suggested during the workshop to make monitoring of P in lakes part of the reporting obligations of the Nitrates Directive.

Whether current monitoring networks can be used depends on the need for special monitoring to underpin derogation. The common idea is that the derogation requires monitoring at farm scale, for example, agricultural record, technology, and water monitoring. An approach with mini-catchments is feasible but there may be an effect of non-derogation farms on water quality in these catchments. An additional problem, for both farm and mini-catchment approach, is that we do not know where derogation farms are in advance as farms apply for derogation annually. This problem is difficult to handle within a fixed monitoring network, while the use of a fixed monitoring network is often an obligation in the derogation decision.

The cost for monitoring was not considered by governments when they decided to apply for derogation. Therefore, countries try to make use of existing monitoring arrangements wherever possible and derogation monitoring is integrated in 'standard' monitoring networks. The European Commission seems to agree, as most monitoring obligations in derogation decisions make it possible to use the existing monitoring approach. However, the monitoring efforts need sometimes to be increased like in the Netherlands and the Flemish region of Belgium. Sometimes special requirements are added to the decision. The Flemish region, for example, has to demonstrate that level of nitrate loss from derogation farms is the same as from non-derogation farms (dairy, grass, et cetera). The extent of monitoring and research may also increase due to political pressure exerted by interest groups – for example, farmers unions – who claim a measure to be included in the Action Programme is not needed.

In some countries, the additional cost for derogation monitoring is paid by the farmers using derogation. For example, in the Walloon region of Belgium farmers pay for measuring of nitrate residue, the cost for reporting are covered by the Walloon government. In the Netherlands, monitoring for the second derogation (2010-2013) will be paid by farmers using derogation via a levy per hectare of land under derogation. The cost for monitoring is in addition to costs arising from obligations farmers have, such as:
- no import of manure over 170 kg N ha^{-1};
- to make a fertilisation plan;
- to determine soil fertility before fertilisation .

4.3 Conclusions and recommendations

Conclusions

The existing monitoring strategy and networks can be used for NVZ designation and/or underpinning derogation. However, the monitoring effort has sometimes to be increased.

The extent of the increase in monitoring effort needed to comply with the requirements of the European Commission depends on many factors, such as the extent of the agricultural area designated as NVZ (in case of designation), the extent of the area under derogation and the level of the derogation (in case of derogation), the intensity of agriculture (N surplus, livestock density), the monitoring approach used and the existing monitoring effort, the measures included in the Action Programme, and the pressure exerted on the government by stakeholders and interest groups (farmers unions, environmental pressure groups).

Monitoring requirements for obtaining derogation are formally regulated (derogation decision), while there are no formal requirements for monitoring for designation of NVZs.

Recommendations

No recommendations.

5 Acknowledgement

The authors want to acknowledge and thank all the participants of the second $MonNO_3$ workshop for their invaluable input and discussions during the workshop, as well as their comments and suggestions on the draft version of this chapter ‘Synthesis of workshop’.

6 References

Remark: websited were visited in March 2011

CSO (2010) Area Farmed in June by type of land use, year and region. Central Statistics Office Ireland. Website www.cso.ie.

EC (1991) Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Communities, L375, 31/12/1991, 1-8.

EC (1997) The Implementation of Council Directive 91/676/EEC concerning the Protection of Waters against Pollution caused by Nitrates from Agricultural Sources. Report of the Commission to the Council and European Parliament. Brussels, 01.10.1997, COM(97) 473 final (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:1997:0473:FIN:EN:PDF).

EC (1999) Draft guidelines for the monitoring required under the Nitrates Directive (91/676/EEC). Version 2, with annexes 1 through 6. European Commission, Directorate-General XI (Environment, Nuclear Safety and Civil Protection), Directorate D (Environment, Quality and Natural Resources).

EC (2002) Commission Decision of 18 November 2002 concerning a request for derogation under point 2(b) of Annex III to and Article 9 of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L319:24 (Danish derogation, till 1 August 2004).

EC (2003) Draft guidelines for the monitoring required under the Nitrates Directive (91/676/EEC). Version 3, with annexes 1 through 3. European Commission, Directorate-General XI (Environment, Nuclear Safety and Civil Protection), Directorate D (Environment, Quality and Natural Resources).

EC (2005a) Commission Decision of 5 April 2005 concerning a request for derogation under point 2(b) of Annex III to and Article 9 of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L94:34-36 (Danish derogation, till 31 July 2008).

EC (2005b) Commission Decision of 8 December 2005 granting a derogation requested by the Netherlands pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L324:89-99 (Dutch derogation, till 31 December 2009).

EC(2006) Commission Decision of 22 December 2006 granting a derogation requested by Germany pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L382:1-4 (German derogation, from 2006 to 2009).

EC (2007a) Commission Decision of 22 October 2007 granting a derogation requested by Ireland pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L284:27-30 (Irish derogation, till 17 July 2010).

EC (2007b) Commission Decision of 14 December 2007 granting a derogation requested by the United Kingdom with regard to Northern Ireland pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L337:122-126 (UK derogation, till 31 December 2010).

EC (2008a) Commission Decision of 21 December 2007 granting a derogation requested by Belgium with regard to the region of Flanders pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L16:28-33 (Belgium derogation, till 31 December 2010).

EC (2008b) Commission Decision of 20 December 2007 granting a derogation requested by Belgium referred to the region of Wallonia pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L32:21-24 (Belgium derogation, till 31 December 2010).

EC (2009a) Commission Decision of 12 October 2009 amending Decision 2006/1013/EC granting a derogation requested by Germany pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L268:35-36 (German derogation, till 31 December 2013).

EC (2009b) Commission Decision of 29 May 2009 granting a derogation requested by the United Kingdom of Great Britain and Northern Ireland with regard to England, Scotland and Wales pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L141:48-51 (UK derogation, till 31 December 2012).

EC (2009c) Guidance on groundwater status and trend assessment. Common implementation strategy for the Water Framework Directive (2000/60/EC). Guidance Document No. 18. Luxembourg: Office for Official Publications of the European Communities (http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/guidance_documents/guidance_n18pdf/_EN_1.0_&a=d).

EC (2010a) Commission Decision of 5 February 2010 amending Decision 2005/880/EC granting a derogation requested by the Netherlands pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Union, L35:18-20 (Netherlands derogation, till 31 December 2013).

EC (2010b) Commission staff working document. On implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources based on Member. State reports for the period 2004-2007. Accompanying document to the Report from the Commission to the Council and the European Parliament (COM(2010) 47) (http://ec.europa.eu/environment/water/water-nitrates/pdf/swd.pdf).

EEA (2010) The European environment – state and outlook 2010. Maps and Graph. Estimated nitrogen surplus across Europe, 2005 (http://www.eea.europa.eu/data-and-maps/figures/estimated-nitrogen-surplus-across-europe-2005).

Eurostat (2008) Agricultural statistics main results 2007-2008. Luxembourg: Office for Official Publications of the European Communities.

Eurostat (2010a) Land Use/Cover Area frame Survey. Results on EU land cover and use published for the first time. Eurostat Newsrelease 145/2010 (http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/5-04102010-BP/EN/5-04102010-BP-EN.PDF).

Eurostat (2010b) Livestock density. Eurostat Data Explorer (v2.5.7-20101117-4063 PROD_EUROBASE; Last update: 06-10-2010). (http://epp.eurostat.ec.europa.eu/tgm/graph.do?tab=graph&plugin=1&language=en&pcode=tsdpc450&toolbox=type; visited 18 January 2011).

Fraters, B., Kovar, K., Willems, W.J., Stockmarr, J. and Grant., R. (2005) Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Synthesis of workshop contributions. In: Monitoring effectiveness of the EU Nitrates Directive Action Programmes (ed. by B. Fraters, K. Kovar, W.J. Willems, J. Stockmarr and R. Grant) (Results of the international MonNO_3 workshop in the Netherlands, 11-12 June 2003), pp. 57-83, Bilthoven, National Institute of Public Health and the Environment, RIVM report 500003007.

Oenema, O., Z., Lesschen, J.P. and Velthof, G.L. (2008) MITERRA-EUROPE Assessment of nitrogen flows in agriculture of EU-27. Powerpoint presentation (http://eea.eionet.europa.eu/Public/irc/eionet-circle/water/library?l=/copenhagen_freshwater_2/presentations_day2/miterra-europe_2008ppt/_EN_1.0_&a=d).

Oenema, O., Witzke, H.P., Klimont, Z., Lesschen, J.P. and Velthof, G.L. (2009) Integrated assessment of promising measures to decrease nitrogen losses from agriculture in EU-27. Agriculture, Ecosystems and Environment, 133(3-4), 280-288.

Van Dijk, W. and Ten Berghe, H. (Eds.) (2009) Agricultural nitrogen use in selected EU countries. A comparison of N recommandations, and restrictions in response to the EU Nitrates Directive. Wageningen University and Research Centre, Applied Plant Research Unit AGV, PPO report nr. 382.

Velthof, G.L., Oudendag, D. and Oenema, O. (2007) Development and application of the integrated nitrogen model MITERRA-EUROPE. Service contract 'Integrated measures in agriculture to reduce ammonia emissions' Contract number 070501/2005/422822/MAR/C1; part 1. Alterra, Wageningen, the Netherlands

Velthof, G.L., Oudendag, D., Witzke, H.R., Asman, W.A.H., Klimont, Z. and Oenema, O. (2009) Integrated Assessment of Nitrogen Losses from Agriculture in EU-27 using MITERRA-EUROPE. Journal of Environmental Quality 38, 402-417.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by Austria

Ch. Schilling, H. Loishandl-Weisz, G. Hochedlinger and J. Grath

Umweltbundesamt (Environment Agency Austria), Spittelauer Lände 5, A-1090 Wien, Austria
e-mail: christian.schilling@umweltbundesamt.at; harald.loishandl-weisz@umweltbundesamt.at; johannes.grath@umweltbundesamt.at

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in Austria and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). Austria has established an integrated monitoring system for surface water and groundwater. According to the Nitrates Directive, Action Programmes are applied throughout the national territory, therefore the designation of vulnerable zones is not required. The Action Programmes, the good agricultural practices and additional voluntary preventive measures come along with effectiveness assessment, compliance checks and further supporting measures concerning training sessions and awareness raising for water protection and sustainable farming. Regarding the nitrogen balance based on the annual reported sales of mineral fertiliser and on the nutrient removal by harvest, the long-term trend shows a decrease of the nitrogen surplus. The monitoring stations in surface water and groundwater give a comprehensive and representative overview of the status in terms of nitrate pollution. In general, average nitrate concentrations in Austrian waters are at a rather low level. However, elevated nitrate concentrations occur in the eastern part of Austria due to intensive agriculture and low precipitation in this area.

1 Introduction

1.1 General

Austria's landscape and climatic heterogeneity is reflected in its water regime and aquatic ecology. The mean total annual precipitation is 1,170 mm, but values range from less than 500 mm in low-lying regions in north-eastern Austria with regions of intensive agriculture to more than 2,500 mm per year in high altitudes in the Northern Alps with predominantly extensive agriculture and forests. This leads to the situation that there are mostly no problems with nitrate concentrations, neither in groundwater nor in surface water. However, the problem areas with regard to elevated nitrate levels in groundwater concentrate in the east, north and partly in the south part of Austria particular in regions with intensive agriculture.

The high variation of conditions throughout Austria would favour the designation of nitrate vulnerable zones, but Austria decided on political level to apply the Action Programmes on the whole territory due to the following reasons:
- general objective is to achieve and maintain all groundwater resources for potential use as drinking water - section 30 Austrian Water Act;
- nation-wide Action Programme provides a basic protection of water resources;
- protection of inland waters as well as to contribute to protection of the receiving seas (reduction of nutrient loads);
- avoiding difficulties with the designation of 'Nitrates Vulnerable Zones' (NVZs) in detail;
- avoiding distortions of competition between farmers within the country through different environmental obligations.

In 1991, existing water quality monitoring was standardised, based on legal provisions. The monitoring programme covers rivers, groundwater in porous media and groundwater in karst and fractured rock. Responsibility lies with the Federal Ministry for Agriculture, Forestry, Environment and Water Management in co-operation with the provincial authorities and the Umweltbundesamt (Environment Agency Austria).

1.2 Overview of goals and measures

Background information on the implementation of the Nitrates Directive

According to Article 3 (5) of the Council Directive 91/676/EEC (Nitrates Directive), Austria has set up an Action Programme referring to Article 5 of the Directive which will be applied throughout the whole national territory. In line with provisions of Article 3 (5) it is not required to designate individual potentially endangered regions as nitrate vulnerable zones.

Although the Action Programme will be applied on the whole territory, it has to be clearly stated that this does not imply that the national territory can be seen as nitrate vulnerable zone (this is verifiably not the case), nor that the criteria for nitrate vulnerable zones are potentially met.

Since Austria decided to apply its Action Programme on the Whole Territory according to Article 3 (5), Article 6 of the Directive does not apply. This means that there is no obligation for a review of the eutrophic state of the surface waters. But according to Article 5 (6) Austria has to:
'.. monitor the nitrate content of waters (surface waters and groundwater) at selected measuring points which make it possible to establish the extent of nitrate pollution in the waters from agricultural sources'.

This is realised by using a multipurpose monitoring network which is able to cover the requirements in terms of monitoring the eutrophic state of the surface waters and the chemical quality of groundwater according to relevant European Water Directives such as the Water Framework Directive (WFD) and the Urban Wastewater Treatment Directive through chemical and biological quality elements.

Overview of the implementation of Nitrates Directive with environmental measures and goals

In Austria the effectiveness of Action Programmes is assessed particularly on the basis of developments of water quality, but additionally by:

- tracing the nitrate emissions into the waters at the sources (development of agriculture, livestock units and of areas under agricultural use; assessment of leakage water, modelling nitrate emissions, et cetera);
- compliance checks on the provisions of the Action Programmes.

Good agricultural practices

In Austria rules for good agricultural practices were announced by a regulation in 1995 at first. As it was decided to apply the Austrian Action Programme on the whole territory, the good agricultural practices were substituted by the regulations included in the Action Programme.

Measures of Action Programme

The first Action Programme was reported to the European Commission in 1996, followed by Action Programmes in 1999, 2003 and 2008. Elements of the Action Programme 2008 are:

- prohibition periods for the application of fertilisers (during the winter months);
- storage capacity for livestock manure;
- procedures for land application of fertilisers;
- application of nitrogenous fertiliser on sloped farmland;
- limitation of fertilisation ;
- buffer strips next to surface waters.

The assessment of effectiveness of measures is supported by model calculations (see chapter 3 of this paper – Forecast future developments).

Derogation rule

In the Nitrates Directive the specified amount of nitrogen of manure applied on farmland is limited by 170 kg per hectare. Austria made use of the possibility of a derogation concerning exceedances of this limit up to 210 kg per hectare from manure for cattle keeping farms under severe restrictions for the years 2006 and 2007. Currently there is no derogation in Austria.

Additional voluntary preventive measures

The Austrian Action Programme includes exclusively compulsory measures. Additional measures can be called on voluntarily within the scope of ‘Agri-Environmental Programme’; referred to as ÖPUL (Österreichisches Programm zur Förderung einer umweltgerechten, extensiven und den natürlichen Lebensraum schützenden Landwirtschaft). This programme supports predominantly small and medium sized farms and traditional ecologically sustainable farming. Overall participation is general high and in 2006 amounted to 126,600 farms with about 2.22 million ha and in 2007 to 121,700 farms with 2.20 million ha farmland.

The aim of the Austrian Agri-Environmental Programme is comprehensive ecologically sustainable farming. Since 2002 participation in some water-relevant measures has increased (Table 1).

Table 1 Participation (in hectares) in water-relevant measures in Agri-Environmental Programme (ÖPUL).

ÖPUL measure	2002	2007
Organic farming	295,000	340,000
Erosion protection in agriculture	113,000	155,000
Projects for prevention of water pollution	114,000	149,000

Control of the Action Programme regulations
In Austria the water inspection authority is supervising the condition of waters based on the Austrian Water act and related ordinances. This also includes the Action Programme for nitrate. Additional controls are executed on farm level by Agrarmarkt Austria (AMA) focused on the mandatory obligation of the farmers in the context of Cross Compliance in the Common Agricultural Policy (CAP). Furthermore, the inspection of compliance of voluntary measures in the Agri-Environmental Programme (ÖPUL) is an additional duty of AMA.

Supporting measures
For the implementation of the Action Programme, further supporting measures and activities are carried out:
- training sessions for farmers,
- measures concerning further education, and
- accompanying advice and awareness raising for water protection and sustainable farming.

Overview of trends of nitrogen surpluses
For an assessment of nitrogen emissions into groundwater it is important to know the nitrogen balance on farmland. Table 2 shows the results of the nitrogen balance according to the method published by Organisation for Economic Co-operation and Development (OECD; see, for example, BMLFUW, 2008).

Table 2 shows figures on the nitrogen balance from 2001 to 2006 as published in the national report in compliance with the EU Nitrates Directive. The annual surplus fluctuated between 44.8 kg ha^{-1} per year in 2001 and 24.2 kg ha^{-1} per year in 2005.

The national nitrogen balance fluctuated over the years depending on the annual reported sales of mineral fertiliser and on the nutrient removal by harvest, which depends on the weather conditions. However, it can be pointed out that the long-term trend shows a decrease of the nitrogen surplus as shown in Figure 1.

Table 2 Nitrogen balance for farmland in Austria for the 2001-2006 period (BMLFUW, 2008).

	2001	2002	2003	2004	2005	2006
Input (tonnes per year)	407,128	402,029	378,129	381,983	381,408	384,615
Mineral fertiliser	120,000	118,000	94,400	100,600	99,700	103,700
Farmyard manure	170,858	167,104	166,206	163,766	163,673	162,022
Balance in storage	-364	-295	-295	-295	-295	-295
Organic fertiliser	4,660	4,450	4,871	4,722	4,729	4,884
Deposition	48,343	48,329	48,329	46,506	46,296	45,748
N immobilisation	61,240	62,074	62,227	64,270	64,891	66,142
Seeds	2,391	2,367	2,391	2,414	2,414	2,414
Output (tonnes per year)	257,607	264,872	235,165	267,712	304,057	285,970
Crops harvest	102,441	100,188	94,515	117,262	105,160	99,005
Forage crops and grassland	155,166	164,683	140,650	150,450	198,897	186,965
Balance (tonnes per year)	149,521	137,157	142,963	114,270	77,351	98,645
Farmland (km^2)	33,340	33,330	33,330	32,073	31,928	31,550
SURPLUS (kg N ha^{-1} per year)	44.8	41.2	42.9	35.6	24.2	31.3

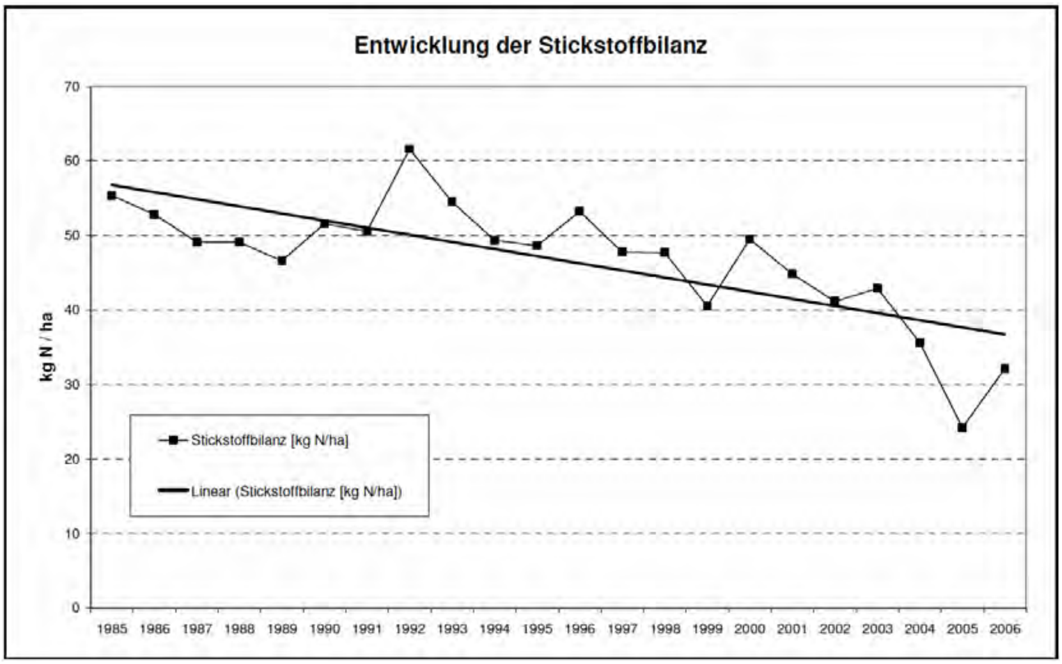


Figure 1 Changes in the nitrogen balance (kg N ha^{-1} per year) for farmland in Austria for the 1985-2006 period; N balance (■) and linear regression line (BMLFUW, 2008).

1.3 Overview of monitoring network

Surface water monitoring

As already mentioned, Austria applies the Action Programmes on the whole territory. Therefore the monitoring network should be designed in a way to be able to trace nitrate pollution back to agricultural sources and to give a representative overview of the water quality of all water bodies.

Since 1991 the water quality of Austrian waters has been assessed in framework of the national monitoring programme based on standardized, legally binding criteria throughout the whole territory. In 2006 the monitoring network was adapted according to the requirements of the Water Framework Directive (EC, 2000).

In the course of the adaptation, the previous monitoring network – covering polluted and non-polluted waters to the same extent – was revised by implementation of:
- surveillance monitoring stations to give a representative overview (basic network), to assess long-term changes in water quality and to cover (background) conditions in water bodies not impacted by human activities;
- operational monitoring stations to assess the status of water bodies which have been identified to be at risk, that means, which may potentially fail the environmental standards given by the Water Framework Directive and to evaluate changes in the status of water bodies following the implementation of programmes of measures.

This adaptation resulted in a reduction of monitoring sites which are under continuous observation, which means that in terms of a more problem-oriented approach, the monitoring network was thinned out in waters with low pollution levels but consolidated in water bodies which may risk failing the ‘good status’.

In fact the surveillance monitoring stations give a comprehensive and representative overview of the status of waters whereas the operational monitoring stations reflect the situation in higher polluted waters. This monitoring network is able to cover the different requirements for observations according to the European Water regulations and is therefore used as multipurpose monitoring network to assess the water status in line with the respective provisions of the relevant regulations.

For an assessment of the situation of surface water bodies in respect to nitrate levels and the eutrophication status according to the requirements of the Nitrates Directive predominantly the surveillance monitoring stations are used because of their representative location and the availability of long-term data records. Additionally, monitoring stations in operation within the monitoring programme before the revision were used since the last national report on the Nitrates Directive covered the period 2003-2007 (BMLFUW, 2008).

Groundwater monitoring

Groundwater is the major resource for drinking water abstraction in Austria (99%). Half of the drinking water is taken from groundwater in porous media (which is mainly in the flat areas along the rivers) and the other half from springs in karst and fractured rock (mainly in the alpine region). The abstraction is divided into about 90% for public (central) supply and about 10% for self-supply by private wells in remote areas.

Due to the Austrian integrated nationwide monitoring network it is possible to pursue the goal to preserve the drinking water quality in all groundwater bodies (section 30 Austrian Water Act) or to remediate single groundwater bodies at risk according to the threshold values for drinking water.

The total area of Austria was assigned to groundwater bodies and groups of groundwater bodies of shallow groundwater. Single groundwater bodies are bodies with more than 50 km^2 which are of special importance due to the quantity of groundwater resources. They are characterised by different pressures that are regarded as relevant for groundwater chemical or quantity status. Groups of groundwater bodies were delineated according to hydro(geo)logical characteristics.

The average area covered by representative monitoring sites is shown in Table 3. The sites in individual groundwater bodies represent much less area than the sites in groups of groundwater bodies. So the density of the monitoring network is higher in sensitive areas.

Table 3 Characteristics of groundwater monitoring in shallow groundwater bodies (GWB).
Number of sites and average area represented by monitoring sites for individual and groups of GWB.

Shallow GWBs	Total area (km^2)	Number of monitoring sites	Area represented per monitoring site (km^2)
Individual GWBs	9,681	1,192	8.1
Groups of GWBs	74,026	790	91.7
Total	83,708	1,982	41.4

2 Effect monitoring

2.1 Strategy for effect monitoring

Surface water monitoring

Since the designation and the observation of NVZs is not necessary in Austria, the monitoring network consisting of predominantly surveillance monitoring stations is used to give a representative overview of the water status of the surface water bodies in terms of nitrate pollution from agricultural sources. These surveillance monitoring stations are located on all important water bodies reflecting the different conditions of Austria. The selection of these stations was based on several criteria (which will be explained in more detail in the following chapter), one was the continuous documentation of the water quality status and the availability of existing data. Thus, these stations provide a comprehensive overview on both the present situation as well as on long-term changes in water quality.

In 2006 the monitoring network was adapted according to the requirements of the WFD. Three different types of surveillance monitoring stations were defined on the basis of the criteria described below.

Type 1 surveillance monitoring stations
- considerable discharge, catchment size > 2,500 km²;
- sites needed for information exchange;
- considerable transboundary water bodies;
- continuous documentation of water quality status;
- existing monitoring stations – use of existing data.

This resulted in the selection of 31 stations.

Type 2 surveillance monitoring stations
- very good ecological and chemical status;
- high sensitivity of biocenosis;
- long-term and complete records.

This resulted in the selection of five (reference) stations.

Type 3 surveillance monitoring stations
- considerable discharge, catchment size > 1,000 km²;
- typical utility areas (pressures) of respective provinces;
- existing monitoring station – use of existing data.

This resulted in the selection of 40 stations.

These surveillance monitoring stations form the ‘basic monitoring network’ for the continuous and representative documentation of the water quality status. For the evaluation of the water quality status for reporting requirements under the Nitrates Directive (last national report on Nitrates Directive) additional monitoring stations have been used which were observed until the end of 2006. All together 271 surface water stations have been used to assess the nitrate levels in surface waters (see Figure 2).

Groundwater monitoring

The quality of groundwater is measured nationwide as a rule four times per year at more than 2,000 monitoring sites.

Austria differentiates between:
- groundwater in porous media with about 1,640 monitoring stations,
- groundwater in karst and fractured rock with about 340 monitoring stations, and
- deep groundwater bodies with about 25 monitoring stations.

The karst groundwater in the northern and southern Limestone Alps, along with the groundwater in porous media in valley and basin landscapes, represents Austria’s most important groundwater resources.

Figure 3 comprises a map with annual mean values and maximum values for nitrate in individual groundwater bodies (and groups of groundwater bodies) and springs in karst and fractured rock. Individual groundwater bodies are fully coloured and groups of groundwater bodies are hatched.

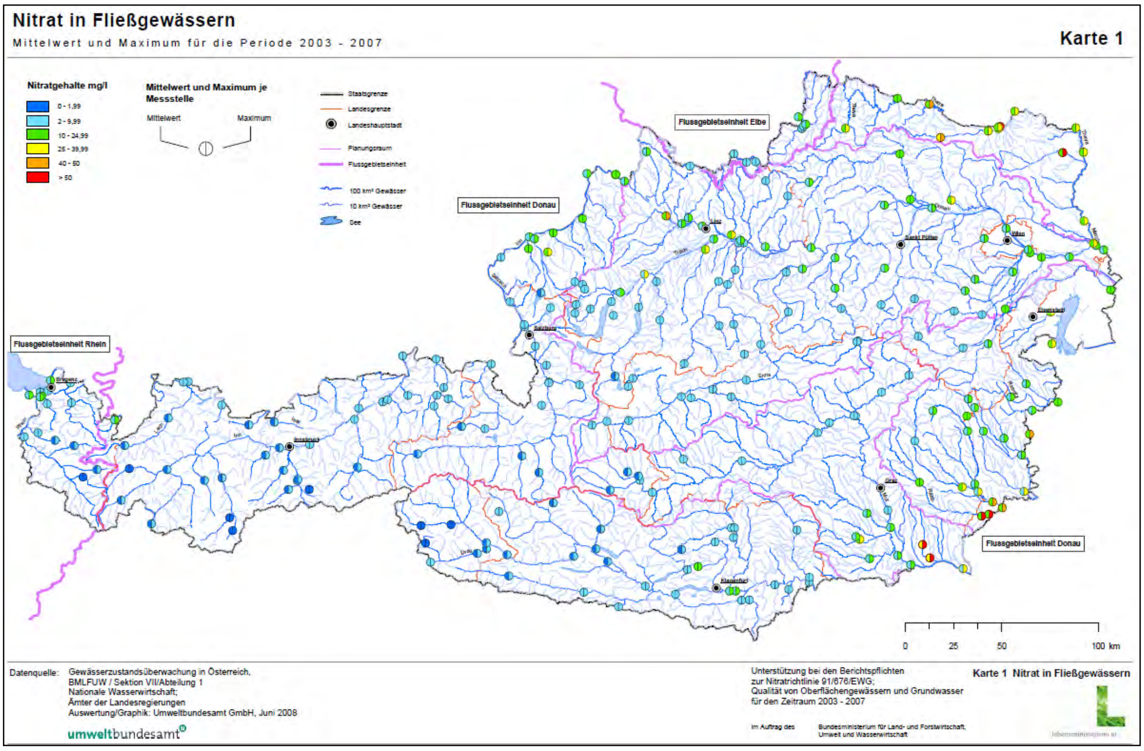


Figure 2 Average and maximum nitrate concentrations in Austrian rivers for the period 2003-2007 (BMLFUW, 2008).

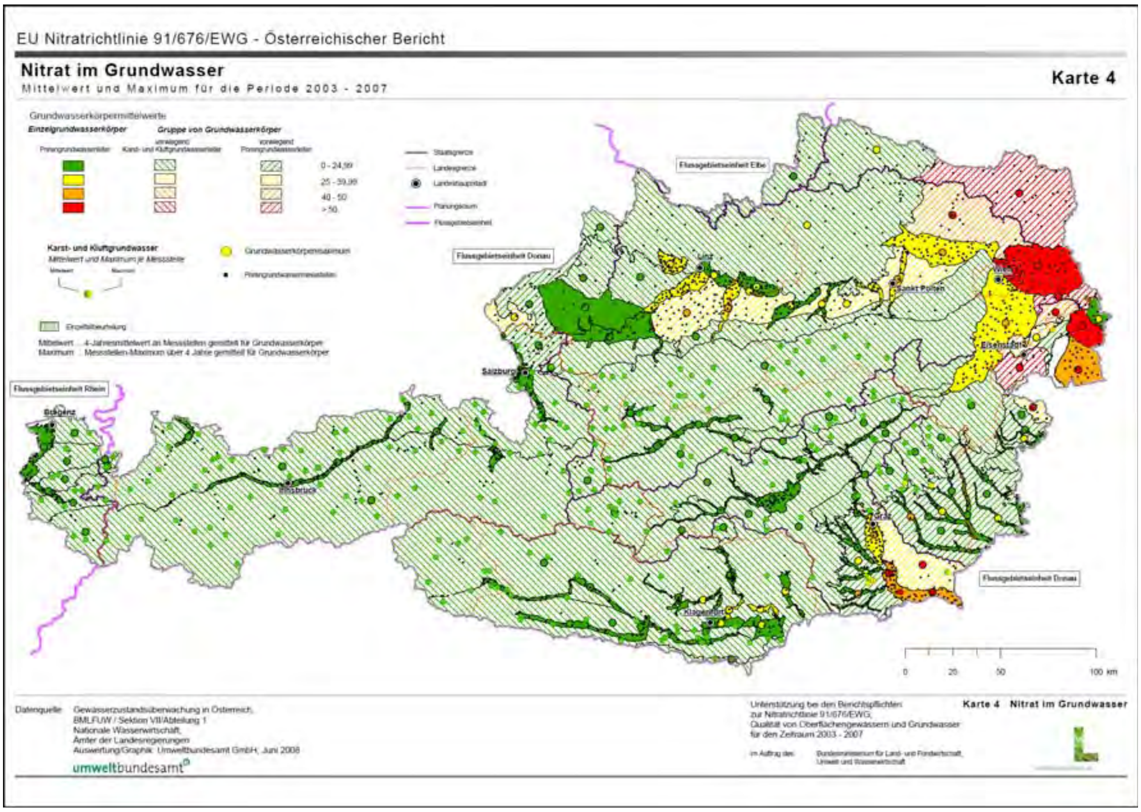


Figure 3 Average and maximum nitrate concentrations in groundwater in Austria for the period 2003-2007 (BMLFUW, 2008).

According to the fact that on the one hand there is high precipitation in the mountainous part of Austria with extensive agriculture and, on the other hand, lower precipitation in the east and north of Austria with intensive agriculture, the areas with regard to elevated nitrate concentrations in groundwater are concentrated in the east, north and partly south of Austria (see Figure 3).

2.2 Detailed technical description of the networks used for effect monitoring

Monitoring requirements under the Nitrates Directive:

- Member States shall draw up and implement suitable monitoring programmes to assess the effectiveness of Action Programmes established pursuant to Article 5.6.
- Member States which apply Article 5 throughout their national territory shall monitor the nitrate content of waters (surface waters and groundwater) at selected measuring points which make it possible to establish the extent of nitrate pollution in the waters from agricultural sources.

Guidance for monitoring
For both groundwater and rivers the duration of one monitoring cycle is six years (this is in line with WFD-provisions) and comprises the elements given in Figure 4 and explained below.

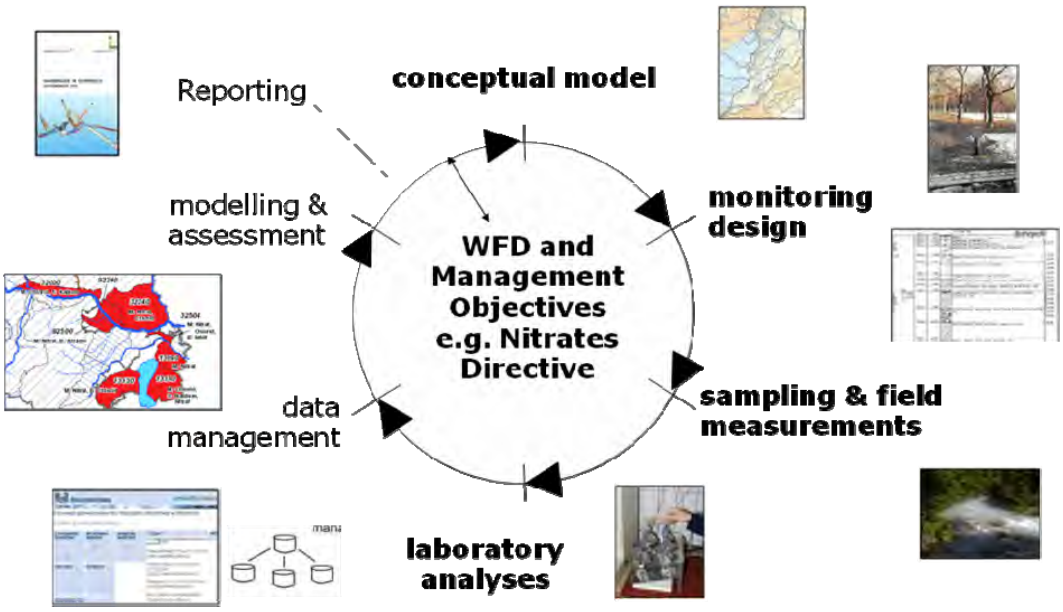


Figure 4 Outline of water quality monitoring in Austria.

Principles for the selection of sites are:

- conceptual model (hydro(geo)logical characteristics, pressures, receptors);
- assessment of risks and levels of confidence incl. distribution of key pressures;
- practical considerations concerning monitoring stations (for example, long-term access, existing sites, multipurpose monitoring).

Groundwater monitoring is focused on the most sensitive part of the groundwater body – as a rule, the upper zone of shallow groundwater bodies. The sampling and laboratory analyses are executed by accredited (private or public) laboratories.

Quality assurance (QA) includes both sampling and analysis. For sampling the following elements have to be considered:
- strategy;
- techniques;
- sample treatment;
- field measurements;
- compulsory training sessions.

Validated methods for the analysis, in accordance with national and international standard methods,
and in case of absence of suitable standard methods – ‘in house’ validated methods are used. The following methods are considered in addition:
- detailed requirements laid down in the public call for tender;
- laboratory control visits; and
- spiked samples.

2.3 Data interpretation

Surface water monitoring

For the evaluation of nitrate concentrations in the surface waters the average nitrate concentrations and the average winter nitrate concentrations for the reporting period 2003-2007 as well as the maximum nitrate concentrations have been used in line with the Development Guide for Member states reports (EC, 2008) for the Nitrates Directive. Table 4 shows the compilation of the evaluation.

For the period 2003-2007 more than 80% of the monitoring stations showed an average nitrate concentration which is lower than 10 mg NO_3 l^{-1}. In respect to maximum nitrate concentrations, about 60% of the stations were below this concentration level. Only 1.5% of the stations showed average nitrate concentrations between 25 and 40 mg NO_3 l^{-1}, and no station indicated average concentrations above 40 mg NO_3 l^{-1}. In general average nitrate concentrations in the Austrian surface waters are on a low level, which is also evident from Figure 2. Medium average and maximum nitrate concentrations with isolated high peaks in maximum concentrations have been observed only in northern and eastern parts of Austria, where agriculture is the dominant land use in conjunction with decreasing average annual precipitation.

To assess long-term changes in nitrate concentrations the calculated average nitrate concentrations for the reporting period 2003-2007 have been compared to calculated average nitrate concentrations for the previous period 1999-2003 for those stations, which have been used for the assessments in both periods. The compilation of the trend assessment is shown in Table 5.

The average nitrate concentration of all monitoring stations is with 5.91 mg NO_3 l^{-1} for the period 2003-2007 almost equal to 5.77 mg NO_3 l^{-1} for the period

1999-2003 and stable on a low level. A large percentage of the monitoring stations (77%) can be classified as stable. This situation is confirmed by the fact that an equal fraction of the monitoring stations shows weak upward as well as weak downward trends in average nitrate concentrations, and that no station shows strong upward as well as strong downward trends.

Table 4 Nitrate in rivers in Austria for the period 2003-2007.
Number and percentage of monitoring sites per nitrate concentration class.

	Quality classes (mg NO_3 l^{-1} and mg NO_3-N l^{-1})					
mg NO_3 l^{-1}	< 2	2 - < 10	10 - < 25	25 - < 40	40-50	> 50
mg NO_3-N l^{-1}	< 0.45	0.45-2.3	2.3-5.6	5.6-9.0	9.0-11.3	> 11.3
	Number of stations per quality class					
Average	46	179	42	4	0	0
Average in winter season	39	164	58	4	0	0
Maximum	8	154	74	23	6	6
	Percentage of stations related to total number of stations					
Average	17	66.1	15.5	1.5	0	0
Average in winter season	14.7	61.8	22	1.5	0	0
Maximum	3	56.8	27.3	8.5	2.2	2.2

Table 5 Trends in average nitrate concentrations in rivers in Austria between the period 2003-2007 and the period 1999-2003.
Average 2003-2007 minus average 1999-2003; number and percentage of stations per trend class.

	Classes for trend analyses (mg NO_3 l^{-1} and mg NO_3-N l^{-1})				
mg NO_3 l^{-1}	< -5	-5 to -1	-1 to +1	+1 to +5	> +5
mg NO_3-N l^{-1}	< -1.13	-1.13 to -0.23	-0.23 to +0.23	+0.23 to +1.13	> +1.13
	Number of stations per trend class				
Trend - average	0	14	95	14	0
Trend - average in winter season	1	10	99	13	0
Trend - maximum	14	19	43	25	22
	Percentage of stations related to total number of stations				
Trend - average	0	11.4	77.2	11.4	0
Trend - average in winter season	0.8	8.1	80.5	10.6	0
Trend - maximum	11.4	15.4	35	20.3	17.9

† Trend classes: strong increase (> +5), weak increase (+1 to +5), stable (-1 to +1), weak decrease (-5 to -1), strong decrease (< -5).

Groundwater quality

The majority of groundwater monitoring sites show average values for nitrate below 25 mg l^{-1} (Table 6). Almost all sites in karstic groundwater belong to this category except five springs in regions of intensive agriculture and less groundwater recharge. The ratio of monitoring sites in groundwater in porous media with average values below 25 mg l^{-1} varies between 65% and 80%. Elevated nitrate concentrations exceeding 50 mg l^{-1} occur in the north-eastern part of Austria (see Figure 3).

Table 7 shows the trends in groundwater for nitrate concentrations based on average values of the periods 1999-2003 and 2003-2007. It is obvious that the class of rather stable nitrate concentrations is dominant. Almost all promptly reacting monitoring points in karstic groundwater and in groundwater in fractured rock belong to this class. But also more than 50% of groundwater in porous media belongs to it. The next most relevant class is the one of weak decreasing concentrations. This applies to about 25% of the monitoring sites in groundwater in porous media. In porous media there are more monitoring sites with decreasing than with increasing trends in general, except for phreatic groundwater from 0-5 metres, with nearly equal shares.

Table 6 Nitrate concentrations in groundwater in Austria in 2003-2007-period; percentage of sampling points per nitrate class.

Groundwater type	Nitrate classes (mg NO_3 l^{-1})				Number of monitoring points
	< 25	25 - < 40	40 - 50	> 50	
Phreatic groundwater (0-5 m)	73.5	10.9	4.7	10.9	761
Phreatic groundwater (5-15 m)	65.3	15.2	6.7	12.8	594
Phreatic groundwater deep (15-30 m)	65.8	16.5	9.5	8.2	158
Phreatic groundwater (> 30 m)	80.0	16.0	2.7	1.3	75
Captive groundwater	71.7	13.9	6.1	8.3	180
Karstic groundwater	97.6	2.0	0.0	0.4	249

Table 7 Trends in average nitrate concentrations in groundwater in Austria between the period 2003-2007 and the period 1999-2003;
Average 2003-2007 minus average 1999-2003; percentage of sampling points per trend class†.

Groundwater type	Classes for trend analyses (mg NO_3 l^{-1})					Number of monitoring points
	< -5	-5 to -1	-1 to +1	+1 to +5	> +5	
Phreatic groundwater (0-5 m)	10.2	16.5	41.0	17.9	14.3	714
Phreatic groundwater (5-15 m)	10.1	26.5	36.3	16.8	10.3	554
Phreatic groundwater deep (15-30 m)	6.7	25.0	50.8	15.8	1.7	120
Phreatic groundwater (> 30 m)	1.6	23.8	57.1	15.9	1.6	63
Captive groundwater	13.1	22.2	43.1	11.8	9.8	153
Karstic groundwater	0.0	1.4	96.2	2.4	0.0	209

† Trend classes: strong increase (> +5), weak increase (+1 to +5), stable (-1 to +1), weak decrease (-5 to -1), strong decrease (< -5).

3 Use of additional methods

Forecast of future developments of water quality

The development of water quality depends on given pressures from point and diffuse sources, climatic and natural conditions. So there are several uncertainties with regard to a forecast for water quality. To get additional information besides trend calculations for nitrate, further investigations were initiated during the last reporting period:

- model calculation of the future development of agriculture to estimate possible trends and their effect on waters;
- pilot study to estimate the mean groundwater residence time of selected groundwater bodies and springs (UBA, 2008a; UBA, 2008b);
- pilot study to clarify the possibility of an assessment of source apportionment of nitrate (communal or diffuse sources).

The investigations carried out so far lead to the suggestion that we can expect a decrease in the concentrations of nitrate in groundwater bodies because of the measures taken. But this decrease will occur with a time delay due to the ascertained mean groundwater residence time especially in groundwater in porous media. In the main part of Austria – with relatively low concentrations of nitrate – it is assumed that the stable status will be maintained.

4 References

BMLFUW (2008) EU-Nitratrichtlinie 91/676/EWG; Österreichischer Bericht (Nitrates Directive 91/676/EEC; Austrian Report). Bundesministerium für Landwirtschaft, Forstwirtschaft, Umwelt und Wasserwirtschaft. Wien.

EC (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities, L 327, 22/12/2000, 1-72.

EC (2008) Nitrates Directive – Status and trends of aquatic environment and agricultural practice. Development guide for Member States' reports. Office for Official Publications of the European Communities, Luxembourg, pp. 1-42.

UBA (2008a) Pilotprojekt Grundwasseralter – Endbericht 2008 (Pilot project groundwater age – Final report 2008). Umweltbundesamt, Wien.

UBA (2008b) Pilotprojekt Grundwasseralter – 2. Herkunftsanalyse von Nitrat mittels Stickstoff-, Sauerstoff-, Schwefel- und Kohlenstoffisotopen (Pilot project groundwater age – 2. Source analysis of nitrate by means of nitrogen, sulphur and carbon isotopes). Umweltbundesamt, Wien.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by Belgium, the Flemish region

R. Eppinger[1], K. Van Hoof[2] and S. Ducheyne[3]

[1] *Flemish Environment Agency – Division for Operational Water Management – Groundwater Management, Koning Albert II-laan 20 bus 16, B-1000 Brussels, Belgium*
e-mail: r.eppinger@vmm.be

[2] *Flemish Environment Agency – Staff General Director – Integral Water Policy – Diffuse Pollution, A. Van de Maelestraat 96, B-9320 Erembodegem, Belgium*
e-mail: k.vanhoof@vmm.be

[3] *Flemish Land Agency – Manure Bank –Policy Support, Gulden Vlieslaan 72, B-1060 Brussels, Belgium*
e-mail: sofie.ducheyne@vlm.be

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the Flemish region of Belgium and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). In order to meet the requirements of the European Nitrates Directive several Flemish Action Programmes have been developed. The implementation orders of the Flemish Manure Decree (including its adaptations) are called Manure Action Plans (MAPs). Monitoring activities are executed in the scope of these MAPs, consisting of manure, soil, surface water and groundwater monitoring. Till 2006 water quality monitoring was relevant for the detection and designation of nitrate vulnerable zones. Since 2007 the Action Programme is applied on the entire territory of Flanders. Consequently, monitoring activities are focused on global effect monitoring of measures taken. Furthermore, monitoring is executed to meet the requirements of the European Water Framework Directive (WFD) in a combined approach. Since the starting point of the Action Programmes manure production as well as nitrogen and phosphorous surpluses on soils have decreased significantly. However, the quality of surface water and groundwater remains critical concerning nitrate concentrations. There might be a slight improvement that has to be confirmed by longer time series. Besides the nitrate problem, eutrophication effects in surface water occur due to the phosphorous concentrations.
Research programmes started in 2009 to determine process factors for nitrate transport with the aim of a better coupling of nitrate residues in soils with surface water and groundwater quality. These process factors will help to set up nitrate residue threshold values for a convenient determination of nitrogen application standards, which will not lead to the exceedance of the environmental target value (50 mg NO_3 l^{-1}) for water. Results are not available yet.
A derogation request of Flanders was granted on 21 December 2007 (EC, 2007), applying for the period 2007-2010. Additional monitoring obligations are set up due to this Commission Decision. Minimum 150 farms have to be screened in the scope of a derogation monitoring network. Fertilisation effects on parcels

under derogation and parcels without derogation need to be compared. Therefore nitrogen and phosphorous residues will be measured, nitrogen fluxes modelled and linked to surface water and groundwater quality data, supported by process factors.

1 Introduction

1.1 Environmental goals and measures

Goals

Soil – nitrate residues
In order to check the effectiveness of the Flemish Nitrates Directive Action Programme, the instrument of monitoring the nitrate residue in the soil profile at farm parcels in autumn (1 October - 15 November) is implemented in this Action Programme (Vlaamse regering, 2008, 2006).

The nitrate residue is the amount of nitrate-N (kg NO_3-N ha^{-1}) that remains in the soil profile (0-90 cm) from 1 October till 15 November. This amount of nitrogen can possibly leach out of the soil profile during winter time and can cause possible nitrate pollution of surface waters or groundwater. As the nitrate residue is measured on parcel level, it is a good indication of the fertilisation practice on the parcel.

Based on research the threshold value for nitrate residue in the soil in autumn was set at 90 kg NO_3-N ha^{-1} since the second Manure Action Plan (MAP2bis – Vlaamse regering, 2000). In the third Action Programme (Vlaamse regering, 2008, 2006) the threshold value of 90 kg NO_3-N ha^{-1} was maintained. In the current manure legislation it is foreseen that a differentiation of the nitrate residue threshold value in function of crop and soil type can be done from 2009.

Surface water
The most guiding environmental goal in manure policy and the follow-up of the effectiveness of the Action Programme for the Nitrates Directive remains the 50 mg NO_3 l^{-1}. Though, the assessment concepts of the Water Framework Directive (WFD) – where the goal is to reach the good ecological status with nutrients as supporting elements – are becoming more and more important in integral water policy in Flanders.

The Flemish Environmental Regulation (VLAREM II, Vlaamse regering, 1995a) specifies the quality objectives for surface water. Beside a common base-quality there are also quality objectives for surface water with a specific use in execution of the EU Directives for fishing water, shellfish water, swimming water, and fresh surface water for the production of drinking water.

The basic quality objectives concerning surface water were determined independent from the Nitrates Directive. The testing of the results against the standard is done on the base of a series of measurements over one year. With respect to nitrate there is no specific nitrate standard. The quality standard for nitrate was determined as the sum parameter ‘nitrate plus nitrite’ (10 mg N l^{-1}). In normal conditions there is just a minimal fraction of nitrite in surface water, it is therefore defensible to use the limiting value concerning nitrate as 10 mg N l^{-1} (or 44.3 mg NO_3 l^{-1}). The quality objectives is expressed as a 90-percentile, implying that exceedance of the threshold value is limited to maximum 10% of the measurements per location and must be nowhere higher than 150% of this value (15 mg N l^{-1}).

The ecological criterion 'eutrophication' that has been established in the Nitrates Directive (EC, 1991), cannot be tested against the standing legal environmental standard in Flanders. In the present basic quality objectives only the standard for orthophosphate aims at the prevention of eutrophication (the limiting value for still waters is 0.05 mg ortho-P l^{-1} as a 90-percentile. For running waters, the presented quality objective is a 90-percentile value of 0.3 mg ortho-P l^{-1}.

Under the Water Framework Directive (EC, 2000), a draft regulation has been prepared with quality objectives for the supporting physico-chemical parameters. The objective for the nitrate concentrations makes a distinction between water bodies with a small (< 300 km²) and a large catchment area (> 300 km²). For the smaller water bodies, the standing objective of 10 mg NO_3-N l^{-1} remains. For the larger water bodies, the draft objective is 5.65 mg NO_3-N l^{-1} (corresponding to 25 mg NO_3 l^{-1}) as a 90-percentile. With respect to orthophosphate, type-specific objectives have been prepared where the class boundary between the good and moderate status is ranging from a yearly average value of 0.07 mg ortho-P l^{-1} for the most vulnerable types to 0.14 mg ortho-P l^{-1}. For total P and total N, quality objectives for the summer average of 4 mg N l^{-1} and 0.14 mg P l^{-1} are proposed.

Groundwater
The main goal is to reach good qualitative status of groundwater as required by the European Directives – for example Nitrates Directive (EU, 1991), Water Framework Directive (EU, 2000), more specific the Daughter Directive Groundwater (EU, 2006) – and the Flemish Environment Law, regulated by VLAREM II (Vlaamse regering, 1995a) and the Decree Integral Water Policy (Vlaamse regering, 2003), including its related orders. The most relevant parameters of the Flemish Action Programmes (MAP) in the scope of the Manure Decree (Vlaamse regering, 2006, 1991a) are the dissolved nitrogen and phosphorous compounds:

- Concerning nitrogen: The quality standards of 50 mg NO_3 l^{-1} for nitrate shall not be exceeded anywhere. Due to realistic estimations it is impossible to reach this goal till 2015, as required by the Water Framework Directive (WFD). For this reason Flanders has applied for an extension of the target period (maximum 12 years additionally, according to WFD Article 4[4]) for all nitrate polluted groundwater bodies. However, a general decrease of nitrate concentrations in groundwater is necessary on short term, to fulfil the requirements of the Nitrates Directive and to show the efficiency of the measures taken (Article 10 on reporting, derogation reports).
- Concerning phosphate: The quality standard for ortho-phophate of 6.7 mg PO_4 l^{-1} as indicated in the VLAREM II-regulation, shall not be exceeded anywhere. This parameter is less mobile in groundwater, leading to a minor impact on the water quality in general. The standard of 6.7 mg PO_4 l^{-1} is only exceptionally reached. However, these relatively high concentrations might lead to eutrophication in case of groundwater flow systems with fast discharge to surface water (for example, impact on base flow). A new quality standard for ortho-phophate of 1.34 mg PO_4 l^{-1} has been proposed to the

Flemish government by the Flemish Environment Agency via the Minister of Environment for adjusting the VLAREM II-regulation.

Measures

Nitrate vulnerable zone designation
During the period 2000-2002 9% of the agricultural surface in Flanders was designated as vulnerable zone, mainly related to current and future drinking water supply areas (Vlaamse regering, 1995b). Under pressure of the European Commission the vulnerable zones were expanded to 46% of the agricultural area since 2003 (Vlaamse regering, 2002). In the third Action Programme (since 2007) the whole territory of Flanders is designated as vulnerable zone.

Action Programmes
The second Flemish Action Programme (2000-2006) is regulated by the second Manure Action Plan (MAP2bis; 2000). The strategy of this Manure Action Plan was based on three pillars:
1) tackling the source (new feed technology and low-nutrient feed; nutrient excretion balances; restructuring of livestock breeding);
2) judicious fertilisation (control of nitrate residue after crop harvest; adapt N/P ratio by manure processing in function of crop need);
3) manure processing and manure export.

Maintaining the stand-still principle had to prevent a further increase of manure surpluses above the level of 1992 in Flanders. Moreover a stringent license renewal or take-over policy was conducted. A nutrient level (maximum production level of a farm) was introduced for every farmer to induce a nutrient stop. It was compulsory for large manure producers to process and/or export their manure surpluses. A manure distribution policy remained important to tackle manure surpluses in high manure pressure regions of Flanders. For this reason manure transport between regions is intensively followed up by the responsible Flemish agency (Manure Bank).

Total application standards for non-vulnerable zones were for respectively grass; maize; crops with low N need; other crops 450; 275; 125; 275 kg N ha^{-1} $year^{-1}$. Manure application standards for non-vulnerable zones were for respectively grass; maize; crops with low N need; other crops 250; 250; 125; 200 kg N ha^{-1} $year^{-1}$. Total application standards for vulnerable zones were for respectively grass; maize; crops with low N need; other crops 350; 275; 125; 275 kg N ha^{-1} $year^{-1}$. Manure application standards for vulnerable zones were for respectively grass; maize; crops with low N need; other crops 170; 170; 125; 170 kg N ha^{-1} $year^{-1}$.

During the second Action Programme a storage capacity of six months was compulsory for liquid manure. In non-vulnerable zones it was forbidden to apply fertilisation between 15 September and 31 January (grassland)/15 February (other crops). In vulnerable zones it was forbidden to apply fertilisation between 1 September and 15 February.

The third Flemish Action Programme (since 2007) was agreed with the European Commission to comply with the Nitrates Directive after the European Court of Justice ruling of 22 September 2005. In this third Action Programme (Manure Decree of 22 December 2006, Vlaamse regering, 2006) Flanders is completely designated as vulnerable zone. The application standards have become more stringent (as the application standards of vulnerable zones must be applied). In addition more stringent standards must be applied on sandy soils and/or for some crops. The application of chemical phosphorus fertiliser is not allowed unless need is proven. The horticulture is more integrated in the third Action Programme.

Parcel based control of the nitrate residue after harvest has become more important in the third Action Programme. In case of exceedance of the nitrate residue threshold value, a distinction of measures is made in function of risk zones (zones with poor surface water quality). The role of the Manure Bank is extended towards a more advising and sensitising role, besides its other tasks of controlling and supervising administration.

The obligation of manure processing is still an important measure. The manure processing obligation for farmers depends on the community manure production level and the manure surplus of the farm with a maximum level of 60%. A system of tradable manure processing certificates is introduced to fulfil the duty. In order to control the manure production in Flanders, the previous nutrient level is replaced by a system of tradable nutrient emission rights. Expansion of individual farms is again possible within determined conditions by taking over nutrient emission rights with or without reduction of the emission rights or by processing 125% of the manure of the expansion.

Other changes in the third Action Programme are: transport of manure is followed by use of GPS-systems; during the third Action Programme a storage capacity of nine months is compulsory for liquid manure from 2012 on and it is generally forbidden to apply fertilisation between 1 September and 15 February with some exceptions.

Use of derogation
The derogation request of Flanders was granted on 21 December 2007 (EC, 2007), established in the context of the third Action Programme (2007-2010). Farmers can apply for derogation on parcel level on yearly base. In 2007 approximately 10,500 farmers (30% of the farmers) were granted the derogation, corresponding to an agricultural surface of approximately 186,300 ha (28% of the agricultural surface). In 2008 approximately 3,500 farmers (10% of the farmers) were granted the derogation, corresponding to an agricultural surface of approximately 83,000 ha (12% of the agricultural surface).

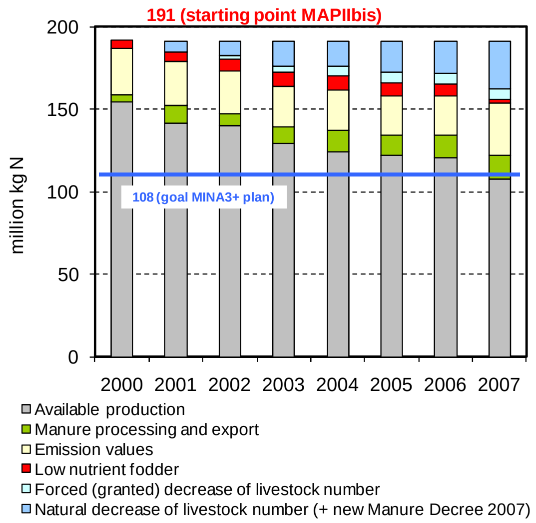
The height of derogation from grazing livestock manure and treated manure (clarified fraction after pig manure separation under certain conditions) is 250 kg N ha^{-1} $year^{-1}$ on parcels cultivated with grassland and maize undersown with grassland and 200 kg N ha^{-1} $year^{-1}$ on parcels cultivated with winter wheat followed by a catch crop and with beets. In case of derogation, fertilisation plans and fertilisation accounts must be made up for the farm. Nitrogen and phosphorus soil samples have to be taken by the derogation farmer.

1.2 Overview of trends in nitrogen and phosphorus surpluses

Since the first Action Programme N and P_2O_5-loads and surplus trend in Flanders has been followed intensively. In Figure 1 the evolution of animal manure (N and P_2O_5) production is given since 2000, including the reasons of the decrease of manure production and the goals for manure application in Flanders. When considering the manure production evolution, one must be conscious of the context of the legislation which may differentiate during the years. The manure production and the available manure production for application on Flemish soils in the period 2000-2007 have been influenced by:

- natural decrease of livestock number;
- forced (granted) decrease of livestock number;
- changes of excretion standards in the third Action Programme (Vlaamse regering, 2008, 2006);
- use and changes of nutrient balance system (low nutrient fodder, fodder techniques);
- use and changes of ammonia emission values of livestock housing and manure stock (NH_4 emission of 15% has been changed to both higher and lower values more in line with actual emissions, 10%, 15% or 20%, since 2007);
- manure processing and export.

The pressure from the agricultural sector with respect to phosphorus has decreased significantly during the last 15-20 years. This is illustrated by the evolution of the soil surface balance for nutrients N and P of agriculture in Flanders, as reported in the Flemish Environment Report (MIRA-T – Anonymous, 2006).



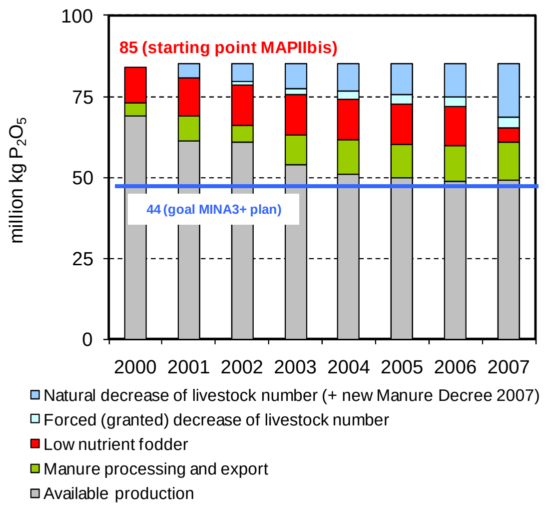


Figure 1 Evolution of the animal manure production (million kg N and P_2O_5) since 2000.
Including the reasons of the decrease of manure production and the goals for manure application in Flanders (Mestbank, 2009).

The surplus on the agricultural soil surface balance for nutrients is the difference between nutrients ending up on the agricultural soil (fertiliser, deposition) and crop extraction and ammonia emission. This surplus eventually ends up in the air and the water or remains in the soil. In 2007 the surplus of phosphorus decreased by 95% and that of nitrogen by 67% compared to 1990 (see Figure 2).

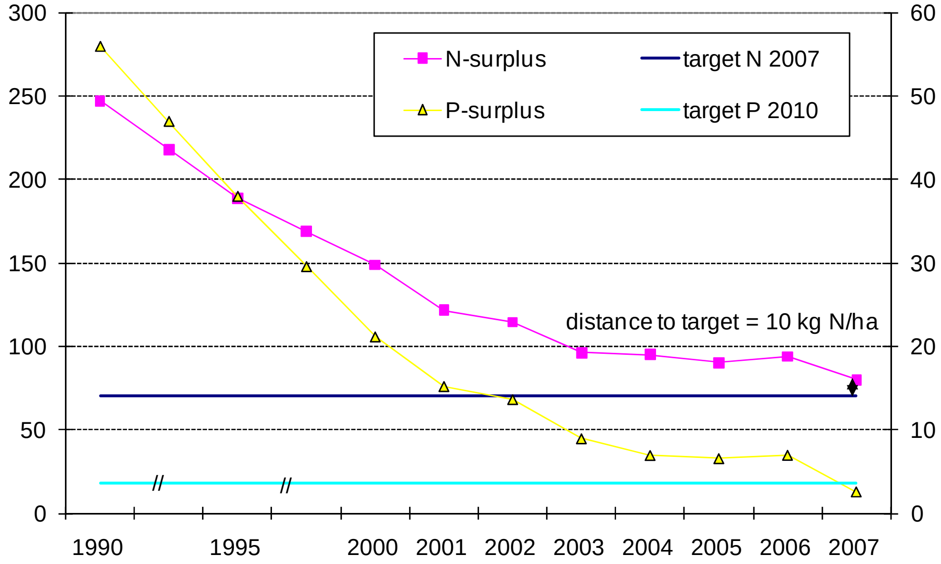


Figure 2 Evolution of the nitrogen (N) and phosphorus (P) surplus on the soil surface balance of agriculture in the Flemish region of Belgium.

This marked decline was mainly a consequence of a reduced use of chemical fertiliser, though it remains difficult to get reliable numbers on chemical fertiliser use. In addition, the production of animal manure decreased due to reduced livestock numbers and a lower nutrient content of the fodder.
More specifically in connection to surface water, the losses of nitrogen and phosphorus to surface water in Figure 3 are calculated using the SENTWA model. Both erosion and leaching are taken into account in this model. From the evolution of the N losses for average precipitation can be concluded that the N loads from agriculture in 2005 are almost 20% lower than those in 1990. This is fully attributable to efforts undertaken in the agriculture sector. The evolution of the time series at constant precipitation takes into account changes in agricultural area, crops, livestock, chemical fertiliser use (-44% since 1990), use of livestock manure (internal transport and increased treatment and export).

1.3 Overview of trends in nitrate, nitrogen and phosphorus concentrations

Surface water

Figure 4 shows the evolution of the nitrate and orthophosphate concentrations from 1991 until 2007. The distance to target for phosphates is still significant. The nitrate figure shows the nitrate enrichment in the MAP-network.

The surface water quality in Flanders with respect to nutrients is not good yet. Even if Figure 4 illustrates that there is a clear improvement since the beginning of the 1990s, Figure 5 shows that the status assessment in the water bodies for the WFD for nutrients and oxygen is one of the important reasons for not achieving the good ecological status yet.

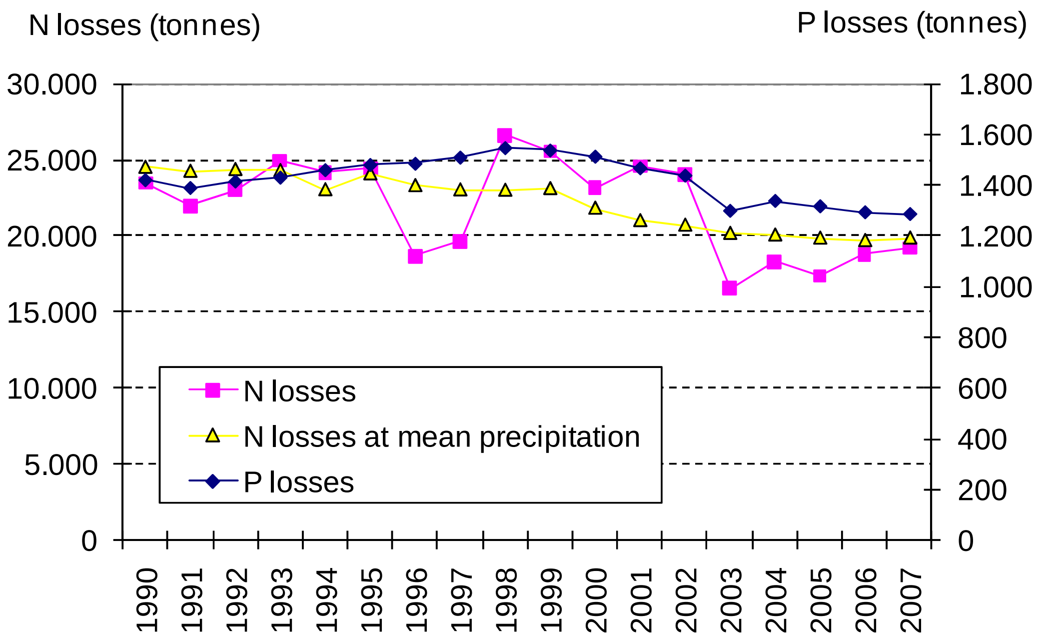


Figure 3 Evolution of N and P losses to surface water in the Flemish region of Belgium, calculated using SENTWA model.

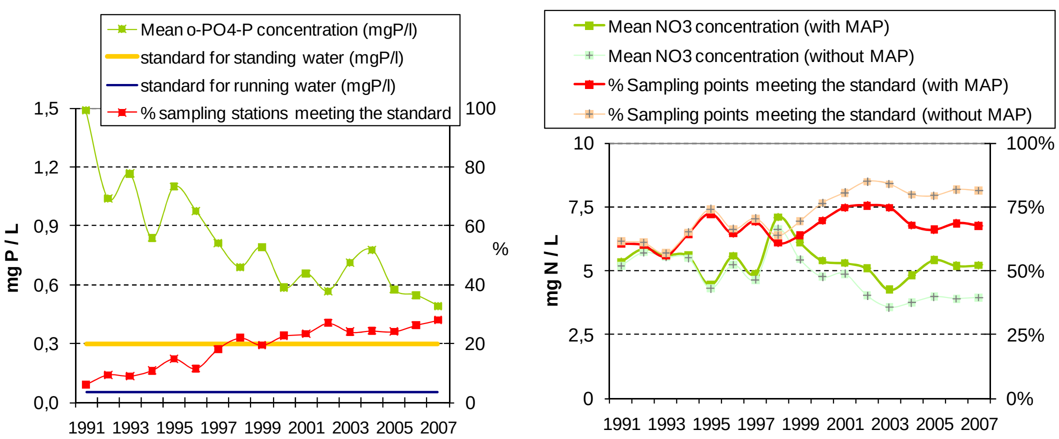


Figure 4 Evolution of mean concentrations ortho-P (left) and NO_3 (right) in Flemish surface waters in the 1991-2007 period.

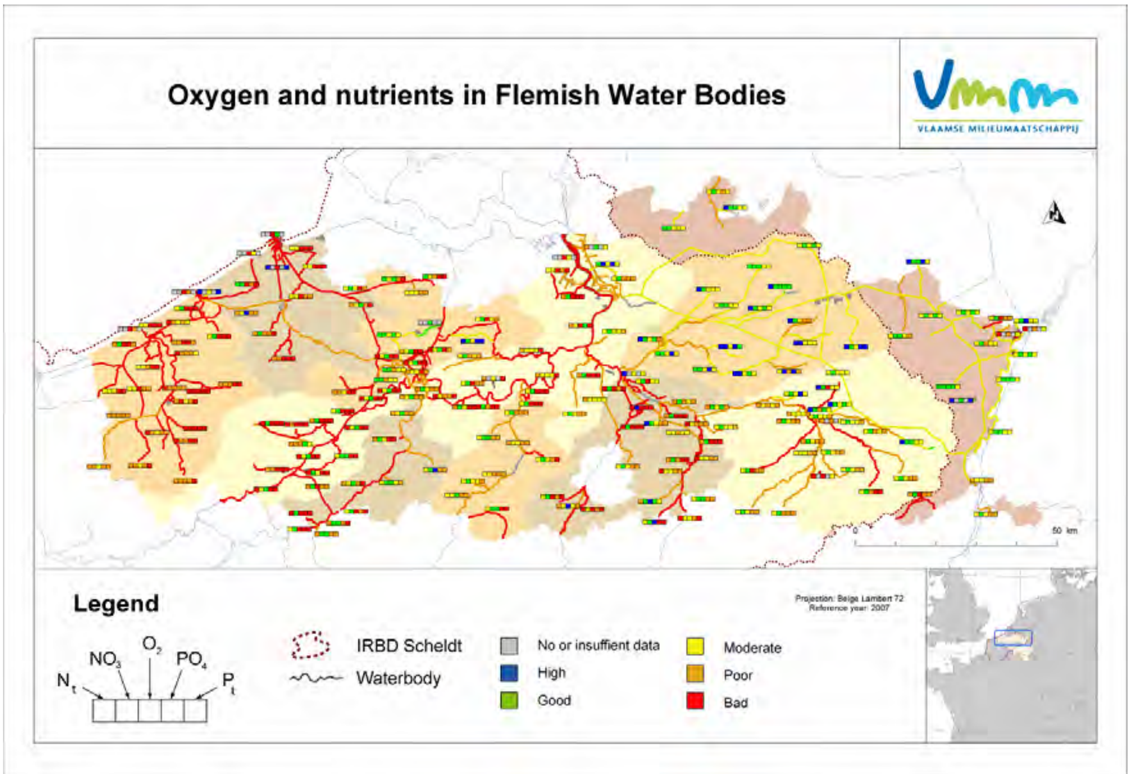


Figure 5 Nutrients and oxygen as biological supporting elements of the ecological status in Flanders.

Groundwater

The subdivisions can be made for groundwater with regard to:

1. the vulnerability of so-called hydrogeologically homogeneous zones;
2. the redox-dependent measuring depth.

Ad. 1 Vulnerability of hydrogeologically homogeneous zones
Flanders is subdivided in 33 hydrogeologically homogeneous zones (HHZs). These HHZs are delineated zones of similar nitrate transport and nitrate removal in the associated phreatic aquifers. The concept of the HHZs was explained in detail in the report on the previous MonNO_3 workshop (Eppinger et al., 2005). Around 2,100 multilevel wells with mainly three screens at different levels are distributed over the agricultural land of the entire Flemish region. More information about this specific network can be found in the chapter 'Effect Monitoring', further in this paper. This monitoring network is fully operational since 2004. Thus, comparable results are only available for the period 2004-2008.

Figure 6 shows by means of coloured triangular symbols the evolution of nitrate concentrations in groundwater on basis of changes between the maximal average concentrations per well of 2004 and 2007. The evolution on zone level is indicated apart by the given background colours. Zone specific trends are visible, showing certain dispersion. A significant decrease of nitrate concentrations can be observed for some HHZs, while others keep a status quo situation or an ongoing increase of nitrate input (see red zones on Figure 6). In comparison, classes of absolute nitrate concentrations are shown in Figure 11.

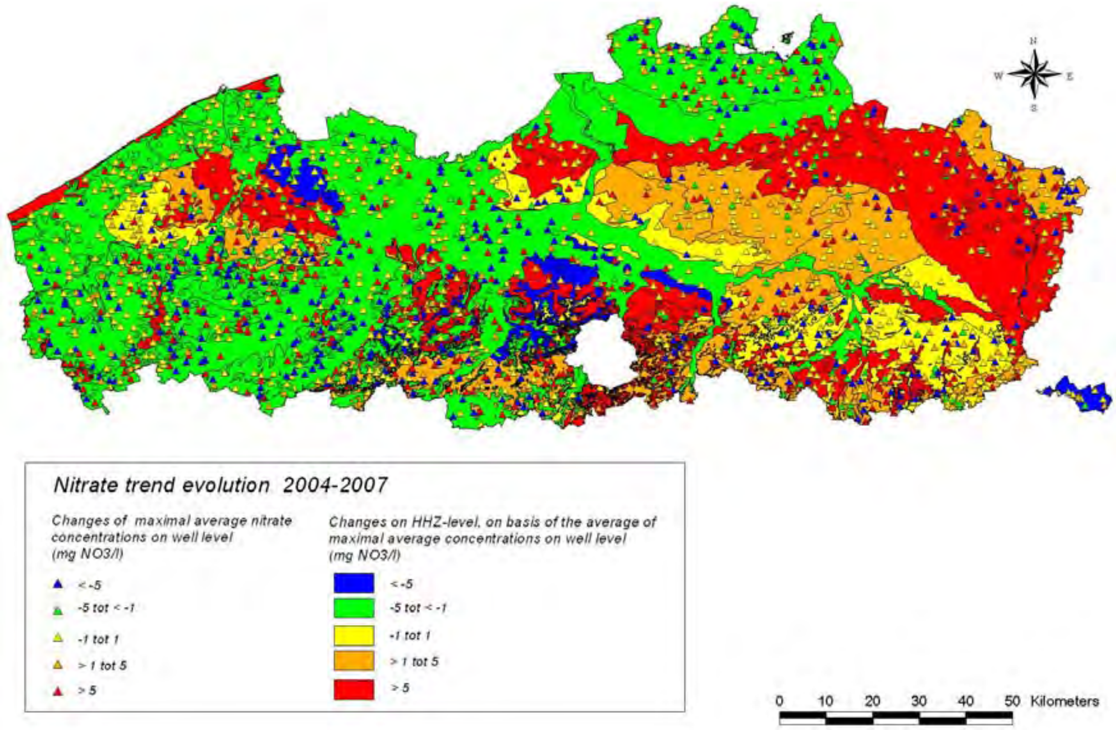


Figure 6 Nitrate trend for agriculture-influenced phreatic groundwater in Flanders for the period 2004-2007.

Ad. 2 Measuring depth (screen levels)
Nitrate evolution can be shown, globally, on the level of different redox-dependent measuring depth, due to the multilevel-well installations. Average nitrate concentrations per HHZ have been weighed in relation to the agricultural land inside each HHZ and summarised for whole Flanders.

Generally speaking, no clear trend is visible for the weighed nitrate load of the agriculture-influenced phreatic groundwater in Flanders (Figure 7). Due to nitrate transport and nitrate removal in groundwater as well as due to the installation principle of the monitoring network – that takes into account depth differentiation of groundwater quality (redox zones) – average nitrate concentrations differ on screen level.

Maximum concentrations are found in the shallowest groundwater (screen level 1) with most recent input. Screen level 2 is mainly situated in the basic part of the nitrate vulnerable oxic zone of the aquifers, so that nitrate concentrations are still relatively high. Normally screen level 3 is meant to be installed in the practically nitrate-free underlying reduction zone. Due to local boundary conditions some screens are still installed in the basic part of the oxidation zone leading to the detection of some nitrate load on this level. Nevertheless a strong decrease with depth of different screen levels is visible.

Concerning phosphorous compounds no general statistics are shown here. Besides naturally high phosphate concentrations in groundwater in the coastal area, no contamination problems are detected in relation to existing quality standards. Anyhow, a revision (lowering) of quality standards is proposed leading probably to a different approach in the scope of a better control of eutrophication aspects in relevant zones.

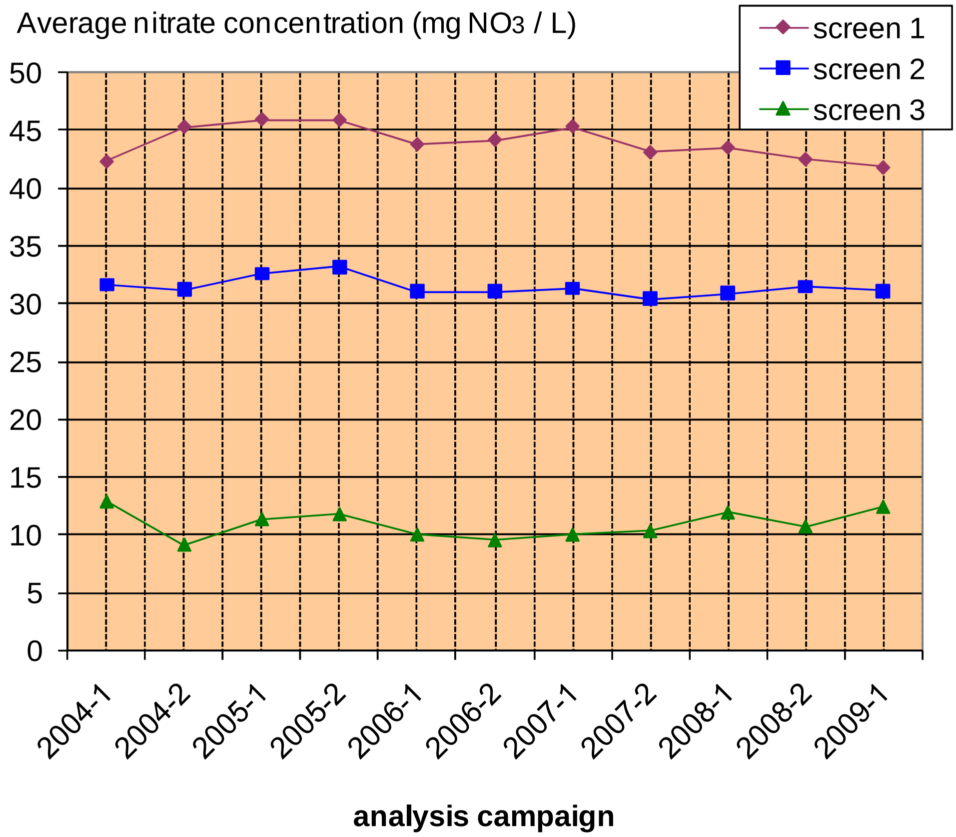


Figure 7 Weighed average nitrate concentrations in groundwater of Flanders per screen level for eleven analysis campaigns in the period 2004-2009.
Screen 1 is the shallowest screen and screen 3 the deepest.

1.4 Overview of monitoring networks

Surface water

Since 1991 the Flemish Environment Agency (VMM) manages a network with more than 1,000 monitoring locations on canals, brooks, rivers and lakes spread all over Flanders. Nitrate and phosphate are monitored every month. In addition, since 1999 there is a more specific nitrate monitoring network within rural areas. This monitoring network, called MAP network, is used for effect monitoring for the Nitrates Directive and is described in extensu further-on in this paper.
Since 2006, the monitoring of surface water quality has been changed in order to meet the obligations for the WFD. Two hundred-and-two Flemish surface water bodies have been derived to be reported to the European Commission. The water quality is evaluated separately in these water bodies using the monitoring results in the surveillance and operational monitoring network.

Groundwater

Some minor changes took place since the previous MonNO_3-workshop (Eppinger et al., 2005) concerning available monitoring networks. The networks of the former Flemish Environment administration (AMINAL) are run now by the Flemish Environment Agency (VMM) due to a reorganization. Mainly the function of networks has been adapted due to:

1. the designation of the whole entire territory of Flanders as Nitrate Vulnerable Zone (since 1 January 2007), and
2. the requirements of the Water Framework Directive and the related river basin management plans.

The following groundwater quality networks are discussed: phreatic groundwater network, primary monitoring network, and other networks.

Phreatic groundwater network (nitrate monitoring network)
The specific monitoring network with its 2,100 multilevel wells in shallow groundwater spread over the agricultural regions of Flanders was originally installed for:

a) identifying of groundwater (potentially) affected by agricultural nitrate pollution for the designation of nitrate vulnerable zones, using the HHZ model, and
b) control and evaluation of the effects of the Flemish Action Programmes (MAPs) in the scope of the Manure Decree on basis of the HHZ model – 'general effect monitoring'.

Point (a) above has become irrelevant since the designation of the entire territory as nitrate vulnerable area since 1 January 2007. Nevertheless the relevance of point (b) has been expanded since the application of derogation in some agricultural areas (on parcel level). This phreatic groundwater network has an additional function in the scope of derogation monitoring.

The term 'phreatic groundwater network' is used for this monitoring network because it also has a function for the identification of the general groundwater quality in the scope of surveillance monitoring (WFD). Qualitatively good status is not given or endangered for almost any of the designated phreatic groundwater bodies, due to some diffuse polluting parameters (for example nitrate and pesticides). Consequently, the entire phreatic groundwater network is also in function for the operational monitoring (WFD).
Furthermore the phreatic groundwater network has been enlarged with around 100 multilevel wells in nature areas for determining background levels. A further enlargement to industrial areas is being considered. More details on the phreatic groundwater network are given under the chapter 'Effect Monitoring', further in this paper.

Primary monitoring network
The old primary network with around 375 mainly deep observation wells has been enlarged since 2004 to 570 wells (around 800 well screens) to reach a better groundwater management concerning quantitative and qualitative aspects. The depth of the wells varies between 5 and 600 m below surface. Consequently, the monitoring network is used for the surveillance monitoring (WFD), mainly of confined groundwater bodies or deeper parts of phreatic aquifer systems. Background level of parameters and pollution, mainly due to secondary effects, are measured. In case of detected pollution of deeper (confined) groundwater bodies (for example Brabant Massif), the wells are also integrated in the operational monitoring. In contrast to the original nitrate

monitoring network, the wells are located all over Flanders, independent on the land use (next to settlements and industrial areas but also at rural sites).

Other networks
Other networks like networks of water supply companies, of nature organisations, of the Belgian Geological Survey, and private supply wells give rather indications of quality status development, but won't be integrated in the general monitoring concept due to different boundary conditions; see also previous MonNO_3 report (Eppinger et al., 2005).

Specific monitoring network for derogation

Further explanations are given in the next chapter 'Effect Monitoring'.

2 Effect monitoring

2.1 Strategy for effect monitoring

Nitrate residues in the soil

The nitrate residue value in the soil after harvest is a measurable feature on parcel level to predict possible nitrate leaching to surface and/or groundwater and is related to the fertilisation practice on the parcel. Therefore this value is used as a policy instrument and is used as a measure to monitor and adjust the fertilisation practice of farmers.

Surface water

In 1999 the Flemish Environment Agency expanded its surface water monitoring network with sampling points in exclusively agricultural areas. This extension will be further mentioned as 'MAP network'. This subset of the monitoring network gives the opportunity to give the agricultural organisations feedback of the consequences of the (changed) manuring (fertilizing) practices regarding the quality of surface water. The data will be used by the agricultural organisations to inform their members, to sensitise and to motivate them.
In 2001-2002 this MAP network was used to designate vulnerable surface waters and vulnerable zones. So it became highly policy-relevant and it was used to assess the effect of the Action Programme on the surface water quality. To allow a more targeted assessment of NVZs, the network was expanded to almost 800 sampling points (see Figure 8). The VMM presented a list of suitable locations that meet the monitoring criteria to the agricultural organisations for comment. These comments were taken into consideration, before the VMM began with the exploitation of this extensive MAP network. The first sampling took place in November 2002. Since the Action Programme is applied on the whole territory, the direct policy relevance of the network has decreased and it has become again an instrument to assess and communicate on the effect of agricultural practices on the water quality.

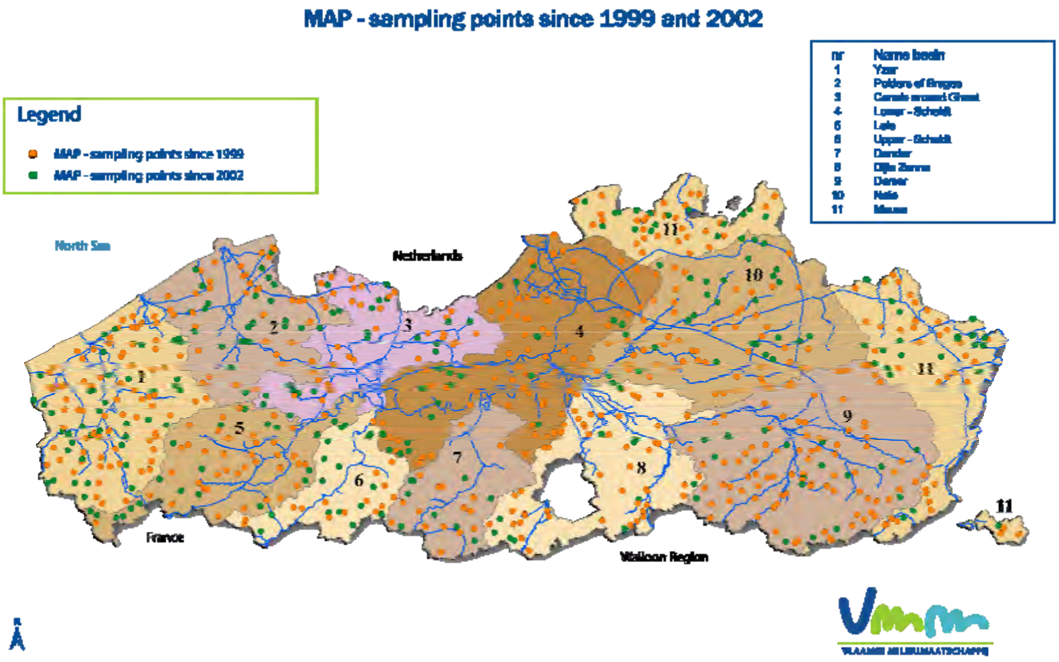


Figure 8 Surface water monitoring points in Flanders within the MAP network since 1999 and since 2002.

Groundwater

A new specific phreatic groundwater monitoring network was developed as already described in the report of the previous MonNO$_3$ workshop (Eppinger et al., 2005). This network is related to the vulnerability model of the hydrogeologically homogeneous zones (HHZs).These HHZs are units where nitrate spread and nitrate removal in the associated aquifers occur in a comparable way. The HHZ model, splitting Flanders in 33 different zones (39 with subdivisions in old NVZs), forms the base for the construction of the new phreatic groundwater monitoring network with its more than 2,100 multilevel wells (around 5000 well screens). This monitoring network is used for the Action Programmes of the Flemish Manure Decree, which has been developed for the purposes of the Nitrates Directive. The monitoring results must help in the decision-making process for the protection of vulnerable aquifer systems against nitrate pollution and eutrophication, if relevant. A further subdivision of HHZ evaluation units on catchment level (VHA zones), as mentioned in the previous MonNO$_3$ report, is no more relevant due to the designation of whole Flanders as NVZ.

Specific monitoring network for derogation

In the European Commission's decision granting Flanders a derogation (EC, 2007), the condition was laid down to establish and maintain a monitoring network for sampling of surface and shallow groundwater to assess the impact of derogation on water quality.

Monitoring sites corresponding to at least 150 farms have to be established in order to provide data on nitrogen and phosphorus concentration in soil water, on mineral nitrogen in the soil profile and corresponding nitrogen and phosphorus losses through the root zone into groundwater, as well as on nitrogen losses by surface and subsurface run-off, both under derogation and non-derogation conditions. The monitoring sites have to be representative of each soil type (clay, loamy, sandy and loess soils), fertilisation practices and crops. A reinforced monitoring has to be conducted in agricultural catchments on sandy soils. The composition of the monitoring network may not be modified during the period of applicability of the Commission Decision (2007-2010).

2.2 Detailed technical description of networks used for effect monitoring

Nitrate residues in the soil

The nitrate residue value is the nitrate-N (kg NO_3-N ha^{-1}) that remains in the soil profile (0-90 cm) in autumn. It is measured in the period 1 October – 15 November by use of soil samples for the depths 0-30; 30-60; 60-90 cm. A soil sample is taken on a parcel by taking at least 15 subsoil samples per 2 ha. The subsoil samples are taken as a cross or raster pattern or by subsequently traversing the parcel. Parcel extremities (for example livestock drinking locations) are not sampled. Soil samples are kept cool before being analysed. Standard operating procedures for sampling and chemical analysis must be used. Soil samples have to be taken and analysed by laboratories which are under supervision of the government. A detailed description of the procedure and methods can be found in BAM (2004) on: http://www.emis.vito.be/sites/default/files/pagina/referentielabo_VLM_BAM-deel1-1_Bemonstering_V3.1.pdf.

Parcels are selected for measuring the nitrate residue value based on risk analysis. A distinction is made on the basis of the location of a parcel in (or out of) risk zones (zones with poor surface water quality as defined in the third Flemish Action Programme). At least one parcel of each farmer in risk zones must be monitored every year by means of a nitrate residue value. At least 25% of the farms benefiting from derogation, at least 5% of the parcels with a derogation crop and at least 1% of the other parcels must be measured every year. Besides derogation other risk factors are taken into account in the selection of the parcels. Every year the nitrate residue is measured on approximately 9,000 parcels as an implementation of the Manure Decree.

In case of exceedance of the nitrate residue threshold value, measures can be taken. These measures are loss of derogation for the parcel the following year, an audit of the farm by the Manure Bank, the obligation of making up a fertilisation plan and register, nitrate residue measurements at the expense of the farmer the following year, and fines. A distinction in the kind of measures is made depending on the amount of the nitrate residue and on the location of the parcel in or out of risk zones. The Manure Bank is the competent authority for the execution of the manure policy.

Surface water

For each monitoring location the following criteria are applicable:
- the catchment area has an agricultural character;
- there is no influence of industrial waste water discharges;

- there is no influence of overflows (sewerage or collectors) or effluent discharge of a waste water treatment plant;
- the amount of nitrogen in a discharged domestic wastewater can be calculated and has a small impact (every inhabitant discharges an average of 10 g nitrogen a day).

The MAP network points are sampled on a monthly basis in principle, with three additional samples that are taken after or during rain periods, because it is expected that the wash out of nitrate is maximal at these moments, thus leading to maximum concentrations in surface water. Exceptions are made – also for reasons of resources – for the MAP points showing for a longer period (3 years) concentrations that are significantly lower than 50 mg NO_3 l^{-1} (maximum below 40 mg NO_3 l^{-1}). They are sampled 2-3 times a year and are called 'sleeping MAP points'.

Besides the analysis of the nitrate concentration there are also a few physico-chemical parameters measured during the sampling, particularly dissolved oxygen, the pH, the conductivity and the water temperature. All data is added to the Flemish surface water database, where they are publicly accessible after validation and confirmation (website www.vmm.be).

Groundwater

The division of Flanders in HHZs with different determined nitrate vulnerabilities has been utilised for the implementation of the new Flemish phreatic groundwater monitoring network with its 2,100 multilevel wells, which is directly in function of the application of the Nitrates Directive. The vulnerability is quantified as a weighting factor, based on six parameters: hydraulic conductivity, hydraulic gradient, thickness of unsaturated area, thickness of the water saturated oxidised zone, oxidation status of sediment during deposition and absence of (nitrate) reducing compounds. A weighting factor between 3 and 17 is given to the different zones. The wells have been installed in relation to the weighting factor of a zone. This leads to a final density of:
- one well per 200 ha agricultural area for the most vulnerable zones;
- one well per 1,133 ha agricultural area for the least vulnerable zone;
- averagely one well per 347 ha agricultural area.

The unequal distribution of wells serves for a better protection of zones that undergo a higher risk of nitrate contamination. More detailed information, for example over the choice of well locations, is available in the previous MonNO_3 report (Eppinger et al., 2005).

The standard implementation procedure of the wells with two screens in the oxidation zone and one in the shallow reduction zone of the phreatic aquifer has been derived from research projects; see, for example, Eppinger et al. (2002) and a doctorate study (Eppinger, 2008). Meaning is to follow up most recent nitrate-input (screen 1), the vertical and lateral distribution of nitrate in time (screen 2) and background concentrations as well as secondary effects (screen 3). A standard multilevel-well installation with three screens (screen length 0.5-1.0 m) is shown in Figure 9.

Anyhow, well installations and number of well screens (one to maximal four screens) are adapted to the natural boundary conditions in aquifers and can vary at some locations. For example due to very small or extraordinary thick

oxidation zones or underlying reduction zones in aquitards. Screen depth varies between 2 and 95 m below surface.
Since 2004 two analysis campaigns per year are executed on the phreatic groundwater monitoring network. The performance of one campaign in the spring period and one campaign in the autumn period accounts for possible seasonal effects of nitrate input. Due to the limited flow velocities in groundwater in general, two campaigns seem to be sufficient to follow the evolution of nitrate concentrations in mainly porous aquifer systems.

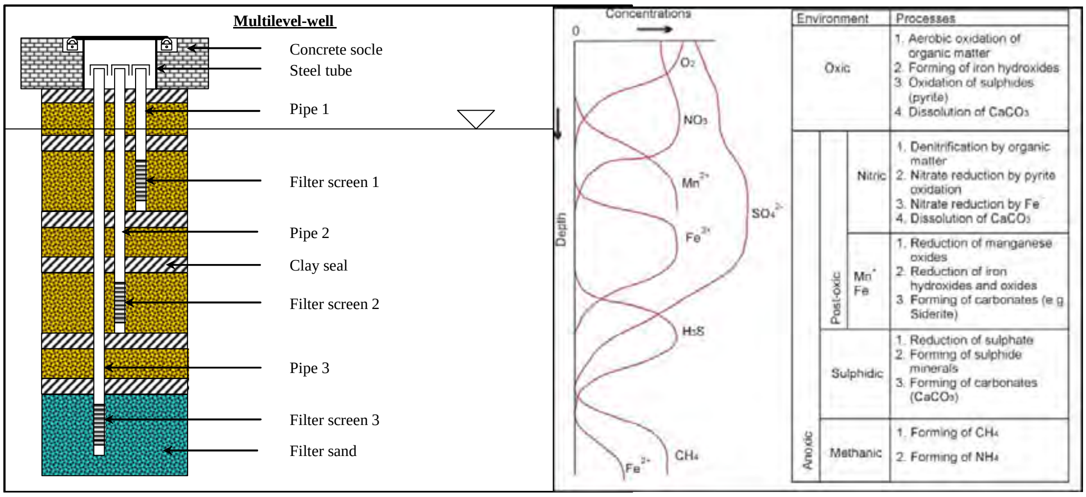


Figure 9 Standard multilevel-well installation of the phreatic groundwater monitoring network in relation to the redox zones after Berner (1981).
Colours: dark yellow = oxic, dark turquoise = anoxic (post oxic).

In addition to nitrogen en phosphorous compounds, the physico-chemical parameters, Total Organic Carbon (TOC), all relevant main ions and other potentially diffuse polluting parameters, for example pesticides and heavy metals, are analysed on the groundwater samples. Measuring all relevant main-ions is necessary for the data quality check in the scope of a quality assurance/quality control procedure (QA/QC) to set up ionic charge balances. Sampling and analyses are only executed by accredited institutions or labs following standardised analysis procedures according to NBN or ISO norms controlled by the Flemish reference lab (VITO). The necessary quantification limits and uncertainties are set parameter specific.

Specific monitoring network for derogation

The derogation monitoring network in Flanders was set up as a research project and is conducted by the Soil Service of Belgium in cooperation with the Catholic University of Leuven. The project started in the beginning of 2009. At the start of the project 180 farms and 225 parcels have to be selected. For this purpose the current 2,100 phreatic groundwater monitoring wells are screened for use in the derogation monitoring network. By taking into account application or non-application of derogation, soil type and crop, a selection of representative monitoring locations is performed. The agricultural organisations cooperate to convince farmers to participate in the monitoring network for derogation.

The agricultural information will be collected on one hand by the Manure Bank (on farm level and parcel level, for example cultivated crops). Other data, on the other hand, are to be supplied by the farmers that participate in the derogation monitoring network, for example fertilisation practise on parcel level, crop harvest data. And thirdly, soil and water quality data and nutrient content of manure have to be measured by the organisations responsible for the derogation monitoring network.

Soil data to be determined on the selected parcels are: standard soil analysis (including PAL: phosphorus measured in ammonia lactate extract); mineral N content of the soil in spring and nitrate residue value between 1 October and 15 November, phosphate saturation degree. The following parameters will be analysed:

– N and P in soil water for parcels with groundwater level deeper than 1,5 m. NO_3^-, NO_2^-, NH_4^+ is measured on soil samples between 90 and 150 cm. Ortho-P, total P, DOP (dissolved organic phosphorus) and DIP (dissolved inorganic phosphorus) is also measured on water from centrifugation of the soil samples.
– NO_3^-, NO_2^-, NH_4^+, ortho-P, total P, DIP, DOP of the water in the drainage system or the ditches is measured in case a representative sampling can be performed.
– NO_3^-, NO_2^-, NH_4^+, ortho-P, total P, DIP, DOP of the shallow groundwater (< 1.5 m).

Most of the methods for water sampling and analysis are described in the compendium for water analysis (WAC) and can be found on EMIS - Energie en Milieu Informatiesysteem voor het Vlaamse Gewest (http://www.emis.vito.be/lne-erkenningen-water). Additional data that are measured (method described in BAM, 2004) are the nutrient content of manure that is applied on the monitoring network parcels. Climatic data are collected for the use in monitoring data interpretation.

2.3 Data interpretation

Nitrate residues in the soil

The threshold value for the nitrate residue in the soil between 1 October – 15 November is based on the research project Herelixka et al. (2002). The threshold value was based on model simulations (WAVE-model; Vanclooster et al., 1994, 1996) for different climatic, soil, crop and hydrological situations. With the simulation model the nitrate residue value in the soil was calculated into a NO_3-N concentration in the water leaching out of the soil profile. A process factor, empirical derived, was used to make the link to the surface water concentration. The nitrate residue threshold value was derived by assuming that in 95% of the simulated years the mean nitrate concentration in the winter period may not be higher than 11.3 mg NO_3-N l^{-1} and in the remaining 5% of the simulated years the mean nitrate concentration in the winter period may not be higher than 150% of the quality standard for nitrate (< 16.9 mg NO_3-N l^{-1}). On the basis of the model simulations for different climatic, soil, crop and hydrological situations, nitrate residue threshold values were derived in order not to exceed the Nitrates Directive objectives. These threshold values were recalculated into mean values in function of the soil texture ‘sandy’ and ‘non sandy’ and in function of the crop (Table 1).

The process factor for surface water links the nitrate concentration in soil water leaching out of the soil profile and the actual concentration of nitrate in surface water in agricultural regions (N-eco² et al., 2002). This process factor accounts for transformation and dilution processes that take place during the horizontal transport of nitrate coming out of the soil profile towards the surface water. This process factor was calibrated and validated for four different catchments on the basis of several years data and making use of two different calculation models, namely DRAINMOD (Brevé et al., 1997) and Burns model (Burns, 1974). A process factor was unfortunately not calculated for the groundwater as the groundwater monitoring network was still in development at that moment. A research project was started in 2009 to link nitrate residue measurements with nitrate concentrations in groundwater and surface water on a catchment scale and to determine process factors for groundwater and surface water.

Table 1 Nitrate residue threshold values (kg NO_3-N ha^{-1}) as function of crop and soil type (Herelixka et al., 2002).

Crop	Soil type	
	Sandy	Non sandy
Maize	60	90
Beets	50	70
Vegetables without removal of crop residues	40	50
Grassland	70	100
Cereals followed by a catch crop	70	100
Other crops	50	80

Surface water

In areas characterized by manure surpluses, exceedance of the nitrate quality standard for surface water of 50 mg NO_3 l^{-1} occurs, see Table 2, especially during winter months with peak concentrations around New Year. Therefore it makes more sense to evaluate years including the whole winter season – ranging from July to June in year x+1, defined as winter years – instead of choosing classical calendar years.

The testing criterion in Table 2 is the 50 mg NO_3 l^{-1} standard of the Nitrates Directive and the manure action plan (MAP). The percentage of the MAP locations where the nitrate concentration in surface water exceeded at least one time the 50 mg l^{-1} limit in the considered period is shown. A trend of a significant improvement is being set.

The comparison of the percentages is indicative, because the compared periods are related to a different MAP network: (a) on one hand, over the years a few monitoring points were deleted and others added, (b) on the other hand, the network was enlarged by end 2002. The data illustrate the global evolution of the situation.

In spite of this positive evolution, the nitrate pollution stays problematic, especially in the western part of Flanders (basin of the rivers Yzer and Leie); see Figure 10. The monitoring results show that:

- the extent of the nitrate pollution of Flemish surface water caused by the agricultural sector remains important and problematic;
- even in catchment areas of some drinking water production centres, several monitoring locations are characterized by the presence of very high nitrate concentrations;
- the situation differs significantly from region to region, and the link with intensive cattle breeding and horticulture is very obviously.

*Table 2 Exceedance (*in %*) of the nitrate quality standard in surface water in the Flemish region per basin per winter year.*

Winter year Basins	1999 - 2000	2000 - 2001	2001 - 2002	2002 - 2003	2003 - 2004	2004 - 2005	2005 - 2006	2006 - 2007	2007 - 2008	2008 - 2009
Lower-Scheldt	65	35	30	24	36	30	35	37	24	22
Upper-Scheldt	67	60	56	45	67	59	38	45	31	41
Polders of										
Bruges	58	54	48	29	49	41	35	37	34	23
Demer	35	40	29	18	30	30	36	39	37	21
Dender	11	0	13	0	7	0	4	0	0	0
Dijle Zenne	35	33	30	16	24	22	17	32	22	15
Canals around										
Ghent	70	52	22	20	51	42	42	38	26	26
Yzer	74	74	69	60	74	68	74	68	68	43
Leie	91	86	71	72	80	80	80	83	68	63
Meuse	74	56	48	38	44	49	47	50	44	29
Nete	29	18	6	6	14	13	14	13	10	8
Flanders	59	50	41	31	42	40	41	43	37	27

Groundwater

On average, groundwater in around 38% of the wells exceeds the environmental quality standard for nitrate in groundwater of 50 mg NO_3 l^{-1} (see Table 3). In general, the assessment by means of the vulnerability model of the HHZs was confirmed by the results of the phreatic groundwater monitoring network. Exceedance of the quality standard for nitrate has been frequently encountered for some of the most vulnerable zones (for example 'Hoogterras'-sediments, Sands of Brussels in the hilly region; see Figure 11). Also the number of registered nitrate contamination problems for the least vulnerable zones (Polders – Area of saline water) is rather small. Nevertheless, the vulnerability score is a function of the total depth and the related mass of groundwater that can be contaminated. This means that also in less vulnerable zones, nitrate standard exceedance can be in the (very) shallow part of the associated phreatic aquifers (for example Thin Quaternary on top of the Paniselian clay). Furthermore the vulnerability score has to be interpreted as the potential of an HHZ and the associated aquifers to be contaminated by nitrate. The occurrence of exceedance of the nitrate quality standard in groundwater depends also on the input situation (pressure and impact). Important aspects are also the soil conditions and (locally) different meteorological conditions affecting the infiltration of nitrate-bearing water (for example concentration or dilution).

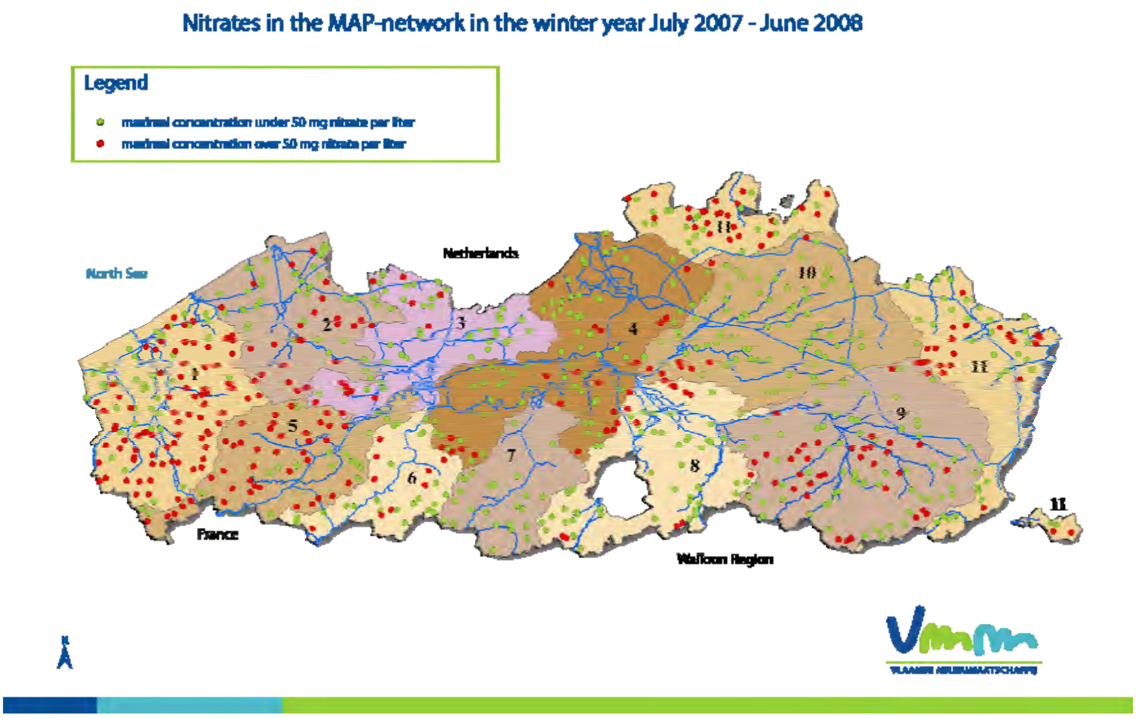


Figure 10 Nitrate concentrations in surface waters in Flanders for the winter year July 2007 - June 2008 (data MAP network).

Up to now, no significant changes can be detected in general, neither on campaign level (Table 3) nor in relation to the overall nitrate input (see Figure 11). The limited measurement period (2004-2009), as well as the long term effects in the groundwater compartment, especially in areas with thick unsaturated layers, do not allow yet deriving an underpinned trend evolution (see also Figures 6 and 7) in relation to the actions taken in the scope of the Manure Decree and its adaptations (last one in 2007).

Table 3 Exceedance of quality standards and target values in groundwater in Flanders, based on wells base per analysis campaign.

	Number of wells			Percentage	
Campaigns	sampled	≥ 50 mg l^{-1}	≥ 25 mg l^{-1}	≥ 50 mg l^{-1}	≥ 25 mg l^{-1}
2004 - spring	1,925	688	915	35.7	47.5
2004 - autumn	1,728	616	785	35.7	45.4
2005 - spring	2,026	801	1,029	39.5	51.0
2005 - autumn	2,004	756	961	37.7	48.0
2006 - spring	2,045	775	998	37.9	48.8
2006 - autumn	2,035	762	972	37.4	47.8
2007 - spring	2,047	790	1,024	38.6	50.0
2007 - autumn	2,031	776	977	38.2	48.1
2008 - spring	2,033	794	1,005	39.1	49.4
2008 - autumn	2,031	762	985	37.5	48.5
2009 - spring	2,041	769	1,022	37.7	50.1

However, changes can be seen on HHZ-level. Zones with a good water quality in the first analysis campaign show an increase in nitrate concentrations in groundwater, while in some stronger affected areas the nitrate load decreases. There is an indication that the Manure Action Plan in the scope of the Manure

Decree (for example manure transport to less problematic regions) leads to a redistribution of nitrate in Flanders (see also Figure 6). This does not necessarily lead to more exceedance of the nitrate standard in groundwater in less affected zones but to the deterioration in the range of nitrate values smaller than the nitrate standard of 50 mg l^{-l}. These observations have to be confirmed by ongoing monitoring.

Due to the density of the network, it is advised to work with interpolation methods on smaller units (HHZs or sub-units). It has to be taken into account that especially phreatic aquifers are characterized by a variation in groundwater quality along flow paths due to changing redox conditions in vertical and lateral direction (Berner, 1981). In other words different conditions occur in infiltration, transition and discharge areas.

A better coupling of nitrate surpluses in soils with nitrate concentrations in groundwater will be obtained by the already mentioned research project that started in 2009. Depending on land use (for example crop type and grassland), soil type and structure, sediment type (hydrodynamic and hydrogeochemical conditions), nitrogen application and meteorological aspects (precipitation, evapotranspiration), a significant nitrate flux occurs from the root zone below 90 cm below surface to be compared with nitrate input in groundwater by a process factor on (sub-)zone level. This process factor is meant to determine sufficiently application standards for nitrogen to fulfil the environmental target values. Results are not yet available.

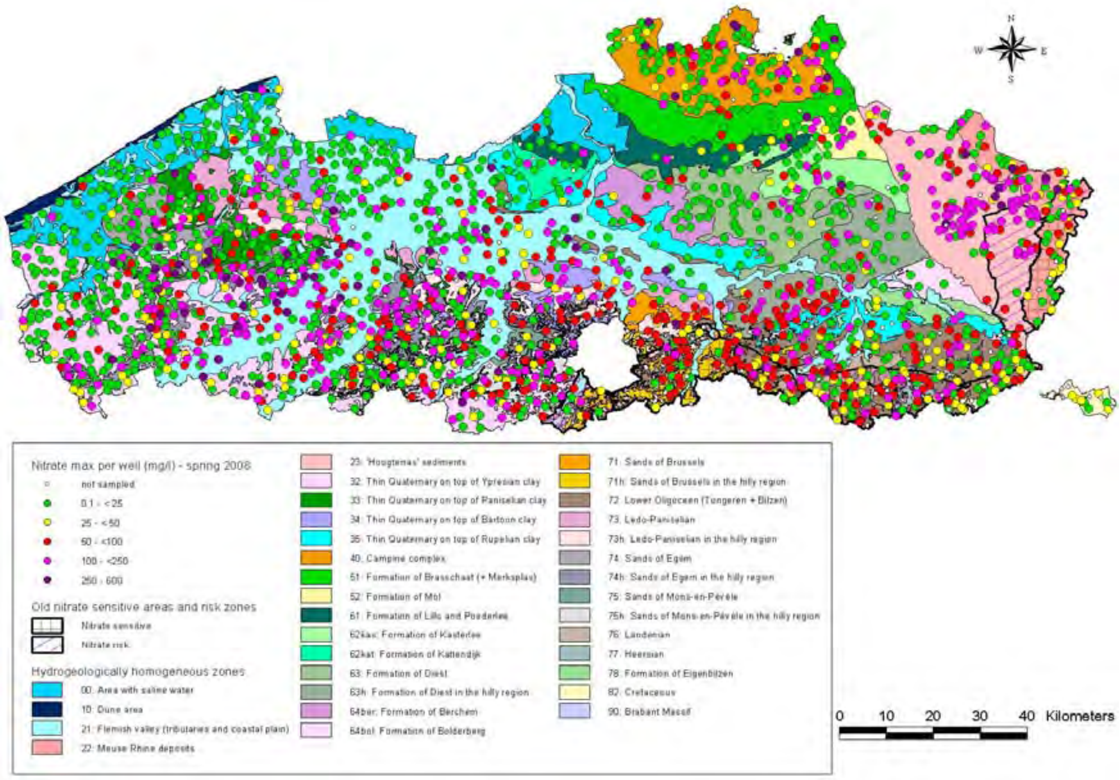


Figure 11 Nitrate concentrations in groundwater in Flanders in spring 2008 (maximum concentration per multilevel well).

Derogation

The interpretation of the data from the derogation monitoring network will be done by two different approaches:

- The first approach aims at an evaluation of the impact of the derogation on parcel level. In this approach a statistical analysis of the measurements will be done in order to evaluate the impact of the derogation. Also the evolution of the measured data in time in relation to the climatic data will be analysed. Nutrient balances on parcel level will be used to evaluate the impact of the derogation. Nitrate leaching will be modelled by use of the Burns model and compared with the measured data.
- The second approach aims an evaluation of the impact of derogation on the global water quality in case the first approach results in a significant difference (in case of derogation) of the nitrate concentration leaching out of the soil profile based on the measured nitrate residue values in the soil profile in autumn. In order to calculate the impact on the groundwater quality the process factors for groundwater will be used. In order to calculate the impact on the surface water quality, contrasting catchments of MAP-surface water measurement points in which derogation is either frequently or not frequently used, will be compared. These catchments are selected to be similar in soil types and crop rotations.

3 Discussion

Nitrate residue value in the soil

- The sampling method for nitrate residue values in the soil must take into account the nitrate residue variability in the field. For highly variable fields (for example vegetables) the sampling method must be adapted in order to take field variability into account.
- Standard operating procedures for determination of nitrate residue values in the soil (sampling; sample storage; analysis) are defined.
- The laboratories that measure nitrate residue values in the field are supervised by the government in order to check that standard procedures are being followed as required.
- As (1) the nitrate residue threshold value is derived as a mean value for a mean situation and (2) the nitrate residue value for a parcel is influenced by variability due to sampling in the field and analysis of the sample, the variation in the nitrate residue value should be taken into account when evaluating the measured value for a parcel against the threshold value to be sure that the threshold value is indeed exceeded.

Surface water

- The interpretation and comparison of nitrate concentrations over years is influenced by climatic factors (warm winters versus very cold winters, high precipitation). It is difficult to take this into account while making interpretations of the effectiveness of Action Programmes.
- The first goal of the Nitrates Directive remains the reduction of nitrate pollution. In the case of the WFD, this remains important but is not the

guiding objective anymore. Many other factors are decisive to achieve a good ecological status or potential.

- The density of the MAP network implies that the observation points are located in very small water bodies (smaller than 10 km²). So, the results are not used for the operational monitoring network for the WFD. Probably they will be of use for the investigative monitoring.
- The attitude of the agricultural sector has changed over the last ten years. In the first years, the monitoring network served as a way of proving that a part of the nitrate pollution was caused by the agricultural sector. Later on, it became decisive in the discussion on the enlargement of the NVZs. It also became clear that subsectors that are using almost no animal manure (horticulture for instance) are the source of (very) high nitrate concentrations. After discussions, also within the agricultural sector, finally this has lead to a specific legislation for horticulture and forestry.
- The MAP monitoring network is used to make generic observations. The question is whether it can also be used to assess local effects of local agricultural practices.
- Discussion remains on the sources of nitrate: manure, chemical fertiliser or sewerage from dispersed houses. Using isotope methods (for N, O and B), scientific research is going on to resolve this. Is the same approach used in other countries?
- The relations between nitrate in soil, nitrate in surface water, and nitrate in phreatic groundwater are clear at the qualitative level. Impressive efforts are ongoing to quantify these relationships. Are similar efforts taking place elsewhere?
- The derogation decision for Flanders requires to follow up both N and P. How is the effect monitoring for P carried out, taking into account the specific behaviour of P?

Groundwater

- Main criticism of the farming organisations in the past was not about the quality of the data but about the lack of knowledge about the real nitrogen and phosphorous application standards that are necessary to fulfil environmental target values concerning groundwater. The development of the zone specific process factors, taking into account relevant boundary conditions (natural + agriculture induced), is set up to give sufficient answers, also in the scope of derogation requests. For a clear linkage it is necessary to measure nitrate residues in soils in recharge areas of existing multilevel-wells on long term base.
- Effects of measures are strongly related to the time delay in aquifer transport systems. The groundwater travel time – the time it takes water to travel between the soil surface and depth of sampling within the aquifer – varies, depending on sediment properties (for example hydrodynamics), thickness of unsaturated zones and climatic conditions (seasonal effects). Travel times through unsaturated zones are estimated to range between one and several months in flat areas and valley zones with a near-surface groundwater table, and up to several years in hilly regions with a deep groundwater table. Which kind of groundwater age determination (for example tracer tests) gives best fit and does not lead to unacceptable high costs? The linkage between meteorological data (for example precipitation

and evaporation) and piezometric measurements can provide travel time indications, but is less precise. A combined approach of measurements and modelling on zone scale is a possible solution, for example, local groundwater recharge values modelled by WETSPASS (Meyus et al., 2004) can be used as important input parameters.
– How to deal with climatic changes? Is there any need for correction factors in trend analyses and how to specify these factors?
– Basic requirements for the quality of groundwater data are already discussed in the chapter 'Effect Monitoring', showing the necessity of a QA/QC approach in the scope of analyses projects with policy sensitive data.
– The phreatic groundwater monitoring network is a multifunctional network and covers also the necessary operational monitoring (WFD) in the scope of a combined approach. However an open discussion could be held on the target value concerning phosphate and eutrophication effects by base flow.

Monitoring network for derogation

In the scope of ongoing derogation research programmes the following discussion items can be pointed:
– Discussion on the method for sampling of soil water in non saturated soils.
– How should the results of the monitoring network be related to the results of the MAP monitoring network?

4 References

Anonymous (2006) MIRA-T: Milieurapport Vlaanderen – Focusrapport (Environment report – Focus report), published by Vlaamse Milieumaatschappij and Lannoo nv, Lannoo Campus, Leuven.
BAM (2004) Bemonsterings- en analysemethodes voor mest, bodem en veevoeder in het kader van het Mestdecreet. VITO (Vlaamse Instelling voor Technologisch Onderzoek) in opdracht van Vlaamse Landmaatschappij (http://www.emis.vito.be/referentielabo-vlm)
Berner, R.A. (1981) A new geochemical classification of sedimentary environments, J, Sediment, Petrol, 51, 359-365.
Brevé, M.A., Skaggs, R.W., Parsons, J.E., and Gilliam, J.W. (1997). DRAINMOD-N, a nitrogen model for artificially drained soils. Trans. ASAE, 40 (4): 1067-1075.
Burns, I.G. (1974) A model for predicting the redistribution of salts applied to fallow soils after excess rainfall or evaporation. Journal of Soil Science, 25: 165-178.
EC (1991) Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Communities, L375, 31/12/1991, 1-8.
EC (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities, L 327, 22/12/2000, 1-72.
EC (2006) Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration. Official Journal of the European Communities, L 372, 27/12/2006, 19-31.

EC (2007) Commission Decision of 21 December 2007 granting a derogation requested by Belgium with regard to the region of Flanders pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources (notified under document number C(2007) 6654).

Eppinger, R., Van Camp, M., De Smet, D. and Walraevens, K. (2002) Onderzoek naar de verspreiding van nitraat in het grondwater in Vlaanderen (in Dutch), Project executed by the Laboratory of Applied Geology and Hydrogeology, of the Ghent University for the Flemish water division, Ghent, Belgium

Eppinger, R., Vandevelde, D., Dobbelaere, A. and Maeckelberghe, H. (2005) Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Flemish region (Belgium). In: Monitoring effectiveness of the EU Nitrates Directive Action Programmes (ed. by B. Fraters, K. Kovar, W.J. Willems, J. Stockmarr and R. Grant) (Results of the international MonNO3 workshop in the Netherlands, 11-12 June 2003), pp. 57-83, RIVM report 500003007.

Eppinger, R. (2008) Mobiliteit en afbraak van nitraat in cenozoïsche watervoerende lagen in Vlaanderen en hun toepassing voor de bepaling van de kwetsbaarheid van ondiepe watervoerende systemen (Mobility and removal of nitrate in cenozoic aquifers in Flanders and their application for the determination of the vulnerability of shallow aquifer systems) (in Dutch with English summary). Doctorate Thesis. Faculty of Sciences – Division of Geology and Soil Sciences, Ghent University.

Herelixka, E., Vogels, N., Vanongeval, L., Oorts, K., Rombauts, S., Sammels, L., Verstraeten, W., El-Sadek, A. Coppens, F., D'Haene, K., Moreels, E., De Neve, S., Salomez, J., Boeckx, P., Librecht, I., Wellens, J., Geypens, M., Feyen, J., Merckx, R., Hofman, G., Van Cleemput, O., Van Orshoven, J., (2002): N-eco^2 - Determination of the amount of mineral nitrogen in the soil as a policy tool. Research project by K.U. Leuven, U. Gent and the Soil Service of Belgium under the authority of the Flemish Land Agency - Vlaamse Landmaatschappij (in Dutch) (http://www.vlm.be/intermediairs/studies/N-(eco)%C2%B2-studie/Pages/default.aspx).

Mestbank (2009) Voortgangsrapport 2008 betreffende het mestbeleid in Vlaanderen (Progress report 2008 with regard to the minerals policy in Flanders) (in Dutch). Vlaamse Landmaatschappij, afdeling Mestbank, Brussel Afdeling Mestbank, Gulden-Vlieslaan 72, B-1060 Brussel.

Meyus, I., Adyns, D., Woldeamlak, S.T., Batelaan, O. and De Smedt, F. (2004) Vlaams Grondwatermodel: Opbouw van een Vlaams Grondwatervoedingsmodel – eindrapport (Flemish groundwater model: development of a Flemish groundwater recharge model – final report) (in Dutch). Vakgroep Hydrologie en Waterbouwkunde, VUB. In opdracht van AMINAL-afdeling Water , 81 p. + annexes.

Vanclooster, M., Viaene, P., Diels, J. and Christiaens, K. (1994) WAVE, a mathematical model for simulating water and agrochemicals in the soil and the vadose environment. Reference and user's manual, release 2.0. Institute for Land and Water management, K.U.Leuven, Belgium.

Vanclooster, M., Viaene, P., Christiaens, K. and Ducheyne, S. (1996) WAVE, a mathematical model for simulating water and agrochemicals in the soil and the vadose environment. Reference and user's manual, release 2.1. Institute for Land and Water management, K.U.Leuven, Belgium.

Vlaamse regering (1991a). Decreet inzake de bescherming van het leefmilieu tegen de verontreiniging door meststoffen (Belgisch Staatsblad, 28 februari 1991) and all related adaptations (In Dutch).
Vlaamse regering (1995a) Besluit van de Vlaamse regering van 1 juni 1995 houdende algemene en sectorale bepalingen inzake milieuhygiëne (VLAREM II) (Decision of the Flemish government of 1 June 1995 regarding the common and sectoral provisions concerning the environment) (in Dutch). Belgisch Staatsblad, 31 juli 1995.
Vlaamse regering (1995b) Besluit van de Vlaamse regering van 20 december houdende aanvullende bepalingen inzake artikel 15, section 4, van het decreet van 23 januari 1991 inzake de bescherming van het leefmilieu tegen de verontreiniging door meststoffen (in Dutch). Belgisch Staatsblad 30 december 1995.
Vlaamse regering (2000) Decreet houdende wijziging van het decreet van 23 januari 1991 inzake de bescherming van het leefmilieu tegen de verontreiniging door meststoffen. Belgisch Staatsblad, 30 maart 2000.
Vlaamse regering (2002) Besluit van de Vlaamse regering van 14 juni 2002 tot het bezien, herzien en aanvullen van de kwetsbare zones water bedoeld in artikel 15, sections 3, 4 en 5 van het decreet van 23 januari 1991 inzake de bescherming van het leefmilieu tegen de verontreiniging door meststoffen (in Dutch). Belgisch Staatsblad 17/06/2002, Editie 2.
Vlaamse regering (2003) Decreet betreffende het Integraal Waterbeleid van 18 juli 2003 (Decree concerning integral water management policy of 18 July 2003) (in Dutch). Belgisch Staatsblad, 14 november 2003, 55038-55077.
Vlaamse regering (2006) Decreet van 22 december 2006 houdende de bescherming van water tegen de verontreiniging door nitraten uit agrarische bronnen (nieuw Mestdecreet) (Decree of 22 December 2006 concerning the protection of water against pollution by nitrates from Agricultural sources (new manure decree) (in Dutch).
Vlaamse regering (2006) - Decreet houdende de bescherming van water tegen de verontreiniging door nitraten uit agrarische bronnen (BS 29 december 2006).
Vlaamse regering (2008) - Decreet houdende wijziging van het Mestdecreet van 22 december 2006 en houdende wijziging van het decreet van 23 januari 1991 inzake de bescherming van het leefmilieu tegen de verontreiniging door meststoffen (BS 12 maart 2009).

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by Belgium, the Walloon region

C. Vandenberghe[1], J.M. Marcoen[1], C. Sohier[2], A. Degre[2], C. Hendrickx[3] and P. Paulus[3]

[1] *Gembloux Agricultural University (FUSAGx), Laboratoire de Géopédologie, GRENeRA, B-5030 Gembloux, Belgium*
e-mail: grenera@fsagx.ac.be

[2] *Gembloux Agricultural University (FUSAGx), Hydrology and Hydraulic Engineering, B-5030 Gembloux, Belgium*
e-mail: degre.a@fsagx.ac.be

[3] *Service Public de Wallonie (SPW) – Directorate General for Agriculture, Natural Resources and the Environment, 15 avenue Prince de Liège, B-5100 Namur, Belgium*
e-mail: francois.paulus@spw.wallonie.be

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the Walloon region of Belgium and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). Wallonia (southern region of Belgium) has implemented the Nitrates Directive by designating four vulnerable zones (now 42% of the territory) and introducing a first Action Programme at the start of November 2002 and a second one in 2007. The Action Programmes entail various means of reducing the risks of the pollution of water by nitrate: (a) struggle against nitrate losses in fields using a range of good agricultural practices, including certain restrictions on the use of fertilisers (quantities, spreading periods, soil conditions, et cetera), (b) keeping a balance on each farm between the organic nitrogen produced and spreading capacities on agricultural land, (c) adapting storehouses for animal manure to a capacity of 6 months and (d) promoting transfers of animal manure between farms in excess balance and farms which still have a way of using it on their land. The paper presents the principle of 'soil nitrate residue' measurements (APL or 'azote potentiellement lessivable' in French) that permits a yearly monitoring of the farming practices and constitutes a self-evaluation tool for the farmers. The paper also introduces the reference model EPICgrid dedicated to nitrogen transfer modelling in the context of the Walloon region. Following the first comparison exercise, these tools are consistent and complementary approaches to help farmers and authorities in nitrogen management. In the context of the Walloon region, dealing with deep groundwater bodies, fast indicators of potentially leachable nitrogen and nutrient fate modelling are the most practical way of assessing effectiveness of the EU Nitrates Directive Action Programmes.

1 Introduction

1.1 General

The geology and land use of the Walloon territory (17,000 km²) are surprisingly varied for such a small area. All agriculture is intensive but significant differences exist between the regions and between farms within the same region.

Overall (955 control wells), the nitrate concentration in groundwater is far below 50 mg l^{-1}. In vulnerable aquifers, concentrations above 50 mg NO_3 l^{-1} appear in 19% of the monitored sites (Cellule Etat de l'Environnement Wallon, 2007). Moreover, the trend is preoccupying. Surface water eutrophication is also present in vulnerable zones.

The programme to deal with nitrate of agricultural origin is therefore mainly focused on prevention, with a view to the sustainable management of nitrogen in agriculture. There are vulnerable zones (designated in 1994, 2002 and 2007), a code of good agricultural practices and one single Action Programme for these zones. The measures provided for in this programme are designed to meet the need to limit isolated and/or temporary cases of waste discharge, while limiting spreading to under 170 kg of organic nitrogen per hectare on average on the territory as a whole.

Up to now, scientific studies have not proven that it was necessary to take account of the characteristics of each vulnerable zone in this first Action Programme. A pilot catchment and 33 reference farms spread over each zone are monitored in order to check the effects of the Action Programme and to adapt it to each zone if necessary. The Action Programme started off in November 2002 and was reviewed in 2007; it is developed on three complementary levels: the field, the farm and the Walloon region.

In the field, the objectives are to limit nitrate leaching in winter and to prevent losses by leaching. The farmer must observe a number of good agricultural practices, particularly time periods for spreading manure and slurry, maximum doses of organic and mineral nitrogen per crop and per year, distances in relation to waterways, storage conditions for field manure, et cetera.

At farm level, the objective is to limit the pressure of organic nitrogen on agricultural land and to fight against point source pollution. The farmer must make sure to always take a soil-based approach, that means, to respect the balance between the organic nitrogen to be spread (coming from the herd or from the import of animal manure) and the total spreading capacity on crops and pastures (calculated by multiplying the surface areas by maximum permissible levels according to the zones).

Finally, on the scale of Wallonia, the objective is to optimise the utilisation of organic fertilisers between farms. The Action Programme promotes transfers of animal manure between farms in surplus and those with low organic amounts. These transfers must be declared to the Administration to allow checks at farm level.

1.2 Factor influencing nitrate occurrence

Description of natural factors influencing nitrate occurrence

The Walloon region has an Atlantic temperate climate. Annual rainfall amounts to 1,014 mm $year^{-1}$, of which 119 mm $year^{-1}$ refill the subsoil water, 321 mm $year^{-1}$ sustain the surface waters, and 582 mm $year^{-1}$ are reabsorbed into the atmosphere by evapotranspiration.

The geology and the soil types are rather varied: more than 60 associations of different soils are listed over the 17,000 km² of Wallonia, from deep sandy silt soils to very superficial clay-like, stony soils. When crossing the region from north to south, one first sees wide agricultural plains with many crops and little grassland, followed by a landscape of small valleys in which crops, pastures and forests alternate, ending finally in the elevated Ardennes Plateau that is mainly covered by forest and grassland, with deeper valleys.

The most intensively used groundwater bodies are situated in the unconsolidated strata and the coherent rocks of the north and the centre of Wallonia. Overall, these reservoirs are situated deep in the ground and are covered by loams or sands. The nitrogen transfer times measured and modelled between the surface and the aquifer amount to 5 to 15 years, depending on the location. In the more superficial aquifers, which are less used for drinking water production, the transfer times scarcely exceeds 3 years.

Description of human factors influencing nitrate occurrence

Global information on land use
The ten agricultural regions of Wallonia are characterized by pedological and climatic parameters (Figure 1); two categories of regions can be distinguished:
– regions used for grassland and fodder crops: the Ardennes, Famenne, the grassland region of Liège, the Jurassic region, the Haute Ardenne and the grassland region of Fagnes (pastureland represents between 70% and 90% of the agricultural area);
– regions used for cereals and industrial crops (sugar beet and potatoes): the silt region, the Condroz and the sandy silt region.
In the regions used for grassland, forests take up an average of over 50% of the total area.

Main crops
The utilised agricultural area (UAA) in the Walloon region is 755,545 ha in 2005, that means 45% of the territory. Forests cover 32% of the territory. The rest is occupied by settlement areas, economic activity zones and road infrastructure. The UAA comprises 50% pastureland and 50% arable land, see Table 1 (Recensement agricole, 2005). Between 2000 and 2005, the UAA decreased by 0.2%.

Maize cultivated for silage represents more than 90% of the area used for fodder crops other than grassland (52,000 ha). In the Walloon region, irrigable land areas are very limited: 5,513 ha in 1997, that is 0.7% of the UAA.

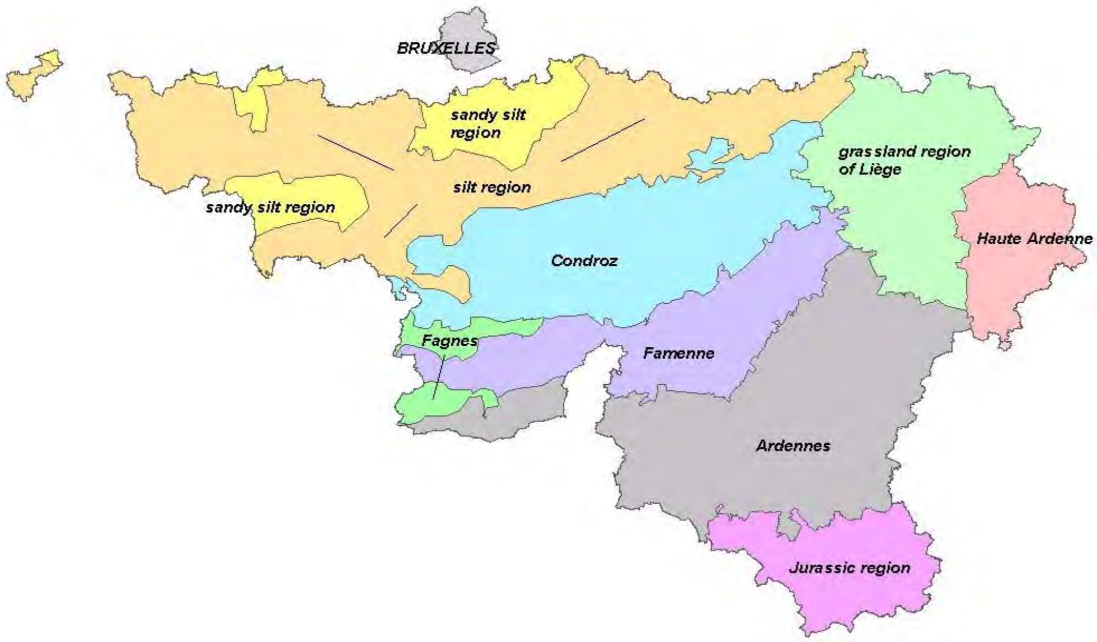


Figure 1 Map of the agricultural areas in the Walloon region.

Table 1 Surface area (ha), percentage of utilised *agricultural area (UAA), and development of the area between 2000 and 2005 (%) for the main commodities in the Walloon region.*

		Surface area (ha)	UAA (%)	Development 2000-2005 (%)
Grassland		374,054	49.5	- 0.6
	Permanent grassland	345,610	45.7	+ 2.6
	Temporary grassland	28,444	3.8	- 3.2
Fodder crops				
	Silage maize	52,817	7.0	+ 0.3
Main crops				
	Cereals	179,163	23.7	- 0.8
	Sugar beet	52,765	7.0	- 0.5
	Inulin chicory	12,879	1.7	+ 0.2
	Textile flax	12,553	1.7	+ 0.6
	Rapeseed	5,495	0.7	+ 0.1
	Potatoes	24,712	3.3	+ 0.5
Horticulture				
	Vegetable crops	12,047	1.6	+ 0.3
	Fruit crops	1,533	0.2	unchanged
Fallow		19,817	2.6	+ 0.3

Characteristics of agriculture (agricultural practices)
In 2005, the Walloon region had 17,000 farms. Between 2000 and 2005, the number of farms decreased by 4,000 farms. Consequently, between 2000 and

2005 the average farm size increased by 22%. In 2005, the average agricultural area of farms in the Walloon region was 44 ha (Recensement agricole, 2005).

Arable crop farms are mainly situated in the silt and sandy silt regions and in the Condroz region. Dairy specialisation predominates in the Haute Ardenne and the grassland region of Liège. The farming of livestock for meat is very common in the Ardennes, in the Jurassic region, Fagne and Famenne. 73% of the farms in the Walloon region have cattle. The number of heads of cattle continues to decrease since 1996, following the BSE crisis while the number of pigs and poultry increases (Table 2).

Table 2 Livestock in the Walloon region: animal numbers, production of nitrogen, and development between 2000 and 2005.

		Number of heads (×1000) and development (% between 2000 and 2005)		Number of heads ha^{-1}
		number	%	
Cattle	All	1,348	- 8.9	1.78
	Dairy cows	230	- 15.7	
Pigs		366	+15.5	0.48
Poultry				
	Laying hens	1,609	+79	2.12
	Broilers	3,440	+14.7	4.55

Total organic nitrogen production on farms in the Walloon region totals 78.930 tonnes. The cattle stock produces 94% of this quantity of organic nitrogen, pigs 3% and poultry 2%. This annual production corresponds to 107 kg of organic nitrogen per ha of UAA. This average value disguises the disparities specific to agricultural regions dominated by certain commodities.

Production of animal manure and use of fertilisers
In terms of volume and apart from direct pastureland recovery, two-third of organic fertilisation in Wallonia is in solid form (farmyard manure, compost) and one-third is in liquid form (liquid manure and slurry). In 2005, the average annual mineral nitrogenous fertilisation is 109 kg N ha^{-1} for the main arable crops in different agricultural regions. This represents a decrease of about 10 kg N ha^{-1} in five years (Figure 2). In 2005, the uptake of phosphate mineral fertiliser was about 30 kg P_2O_5 ha^{-1} applied per hectare. There again, the downward trend in the consumption of phosphate mineral fertilisers is clear to see.

1.3 Main points of the Action Programme

The Walloon Action Programme is a plan for the sustainable management of all forms of nitrogen in agriculture. The Action Programme currently applies to entire extent of Wallonia with certain stricter conditions in vulnerable zones. This makes the programme more demanding than the Nitrates Directive. The Walloon Action Programme has a number of main lines: the storage and handling of manure from livestock rearing, the application of fertilisers (conditions and quantities) and the principle of land-based agriculture, the Nitrawal supervisory structure.

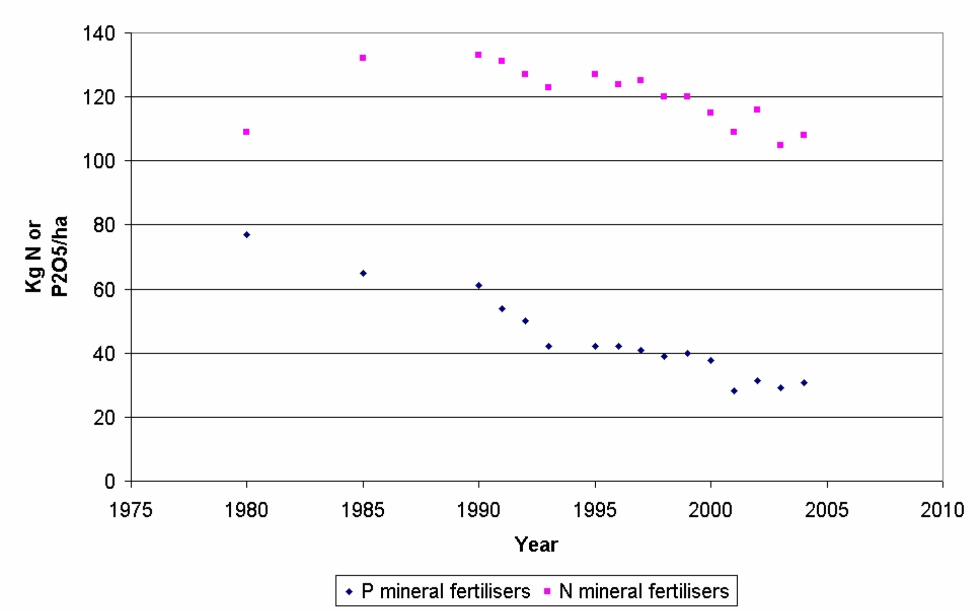


Figure 2 Change in the consumption in kg per hectare of phosphate (♦; P_2O_5) and nitrogen (■; N) mineral fertilisers in the Walloon region since 1980.

Maximum quantity of organic nitrogen

Legislation in Wallonia makes a distinction between arable land and grassland, which is less susceptible to the leaching of nitrate. It also makes an additional distinction between vulnerable zones and the rest of the Region.

For the whole of the Walloon region, the maximum admissible dose of organic nitrogen – whether or not it originates from manure – is 115 kg/ha on average per year on the arable land of a farm. For grassland, the maximum dose authorised is 230 kg/ha on average per year on the grazing land of a farm.

In vulnerable zones, this restriction remains valid, but is strengthened by an additional condition: no farm may apply more than 170 kg of organic nitrogen per hectare over the whole of its utilised agricultural area.

These restrictions are significantly stricter than the Nitrates Directive, because in view of the proportion of arable land (73.6%) and grassland (24.4%) in the vulnerable zones, this is equivalent to an overall restriction on organic fertilisation to 145.3 kg of N on average per hectare.

Good farming practices

Application of fertilisers
For the whole of the Walloon region, the application periods are regulated as shown below in Table 3 for the forthcoming Action Programme having started in 2007.

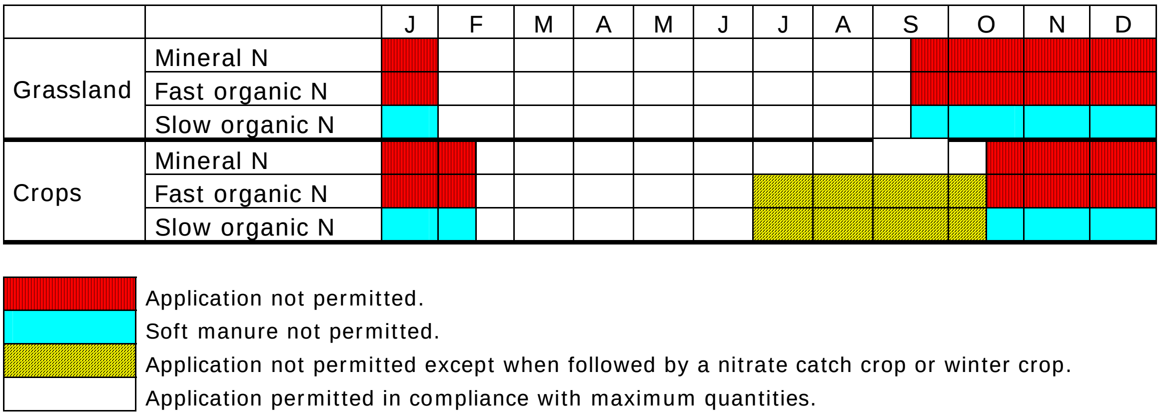
Organic fertilisers are subdivided into two types, according to their speed of mineralisation:

– fast-acting fertilisers, of the slurry or liquid manure type, poultry manure, et cetera;

– slow-acting organic fertilisers, such as manure.

Soft manure behaves somewhere between slow-acting fertilisers and fast-acting fertilisers, and are assimilated with these with regard to application periods. All forms of organic nitrogen are forbidden from 1 July, except when application is followed by a cover crop that can absorb the available nitrogen (winter crop or 'nitrate catch' cover). The application of all types of fertilisers is also forbidden less than six metres away from any surface water. Other conditions are also restricting application on water saturated, snow-covered, frozen or bare soils.

Table 3 Periods of application of mineral and organic fertilisers *in the Walloon region.*



The total quantity (organic and mineral) of nitrogen applicable is also regulated, regardless of whether the area is vulnerable or not. The maximum annual dose is set at 250 kg of nitrogen per hectare on all arable land within the farm, and 350 kg of nitrogen per hectare for all grassland.

Coverage of soil
In vulnerable zones and for every farm, a proportion of 75% of the land intended for spring crops must be covered in the autumn (winter crops being covered by definition). In extreme pedological and/or climatic situations, this level may be adjusted by the relevant authorities. Remaining areas may not be ploughed up in the autumn, because working the soil promotes the mineralisation of nitrogen.

Ploughing up grassland
Ploughing up permanent grassland causes the rapid and abundant mineralisation of the nitrogen stored. This is why special precautions are required in terms of nitrogen management. Ploughing grassland will only be authorised in vulnerable zones from 1 February to 31 May. It must then be followed for two years by one or two covers without leguminous crops.

The ploughed field may not be given any fertilisation during the first year after ploughing takes place, and no organic fertilisation for the two years following the soil being turned over.

Measurements of soil nitrate residue (SNR)
For discussion of the measurements of the soil nitrate residue, we refer to section 4.3.2.

Nitrawal supervisory structure

Nitrawal is a non-profit organisation that has been operating since 2001 to both assist and supervise farmers in managing their nitrogen levels on a day-to-day basis, as well as to assist the relevant authorities. The organisation is funded totally by the region and is managed by representatives from the water producers, the farming unions and by the two regional universities that are active on this topic: the Gembloux Agricultural University (Research group on the Environment and Nitrogen Resources, GRENeRA), and the Catholic University of Louvain.

Nitrawal is a body oriented strictly towards providing advice and personalized supervision for farmers, mainly in the area of nitrogen fertilisation, ensuring storage infrastructures comply with standards and crop-growing practices. For this purpose, Nitrawal produces clearly explained documents designed for farmers, meetings, conferences or individual visits to farms. The organisation is made up of some 15 engineers and technicians who specialize in implementing the legislation in a practical and concrete manner in the field.

1.4 Overview of trends in nutrient concentrations

Groundwater

Since the first Action Programme came into effect in 2002, there has been a trend towards a stabilisation in changes in the level of nitrate pollution in groundwater bearing layers. In fact in some area the pollution level is even decreasing. The less deep layers have shown the most favourable changes, because they have responded more quickly to the measures put into effect since 2002.

For each vulnerable zone or sub-area displaying nitrate problems, an indicator is calculated on a selection of representative sites spread across the whole of the area in question (Figure 3). These indicators are aggregated into an overall ‘vulnerable zone’ indicator, the developments of which are shown below. It confirms what has been noted above.

Surface water

The map below (Figure 4) shows the trends between 2001 and 2005 for the stations that cover both years. So there is no symbol representing the trend for all stations. On the whole, there is almost no variation in either one direction or the other. The nitrate levels in watercourses have been relatively stable over the years. The biggest improvements (reductions in nitrate) are located to the north of the Sambre-Meuse river.

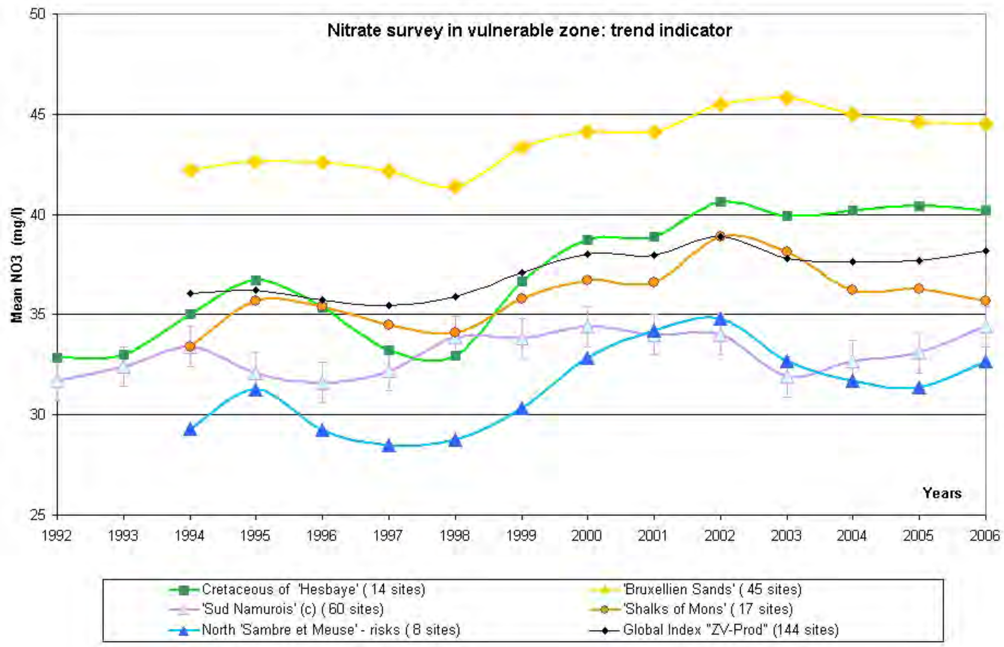


Figure 3 Trend in nitrate concentrations in groundwater of Nitrate Vulnerable Zones (NVZ) in the Walloon region since 1992.
Aggregated results from the nitrate survey for the NVZ.

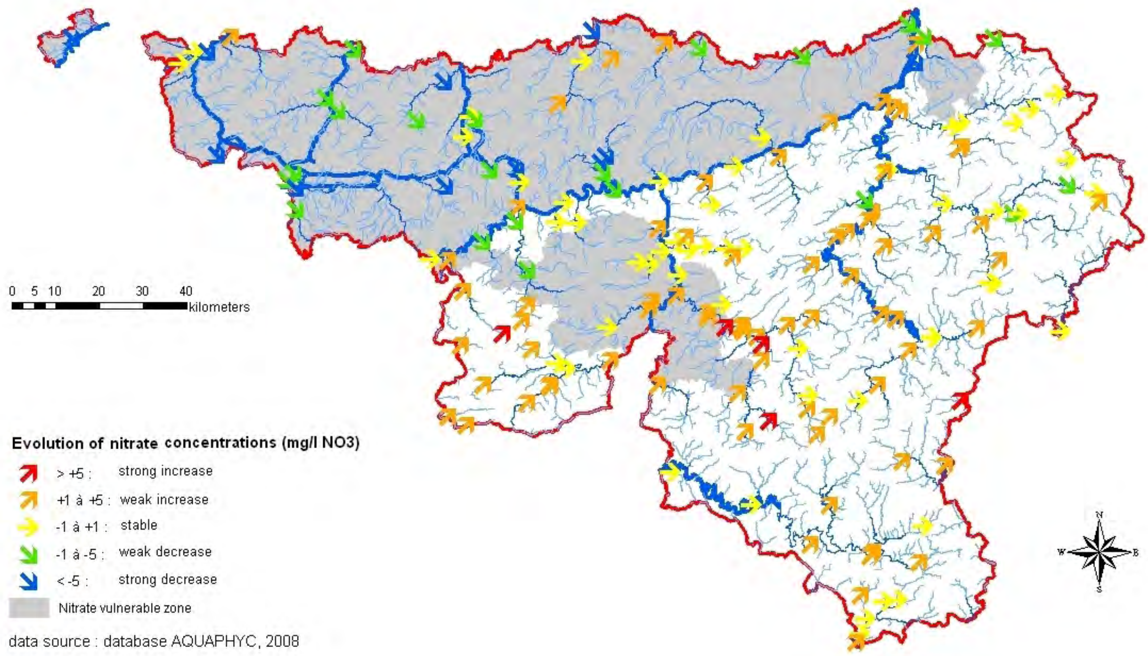


Figure 4 Changes in nitrate concentrations surface waters in the Walloon region between 2001 and 2005.

Phosphorus

Groundwater in Wallonia does not contain phosphorus, with the exception of a particular thermal spring. With regard to surface water, Figure 5 shows a steady decline in phosphorus in surface waters due partly to abandoning detergents containing phosphates in the 1980s and partly to the installation of stations equipped with denitrification and dephosphatation treatment processes.

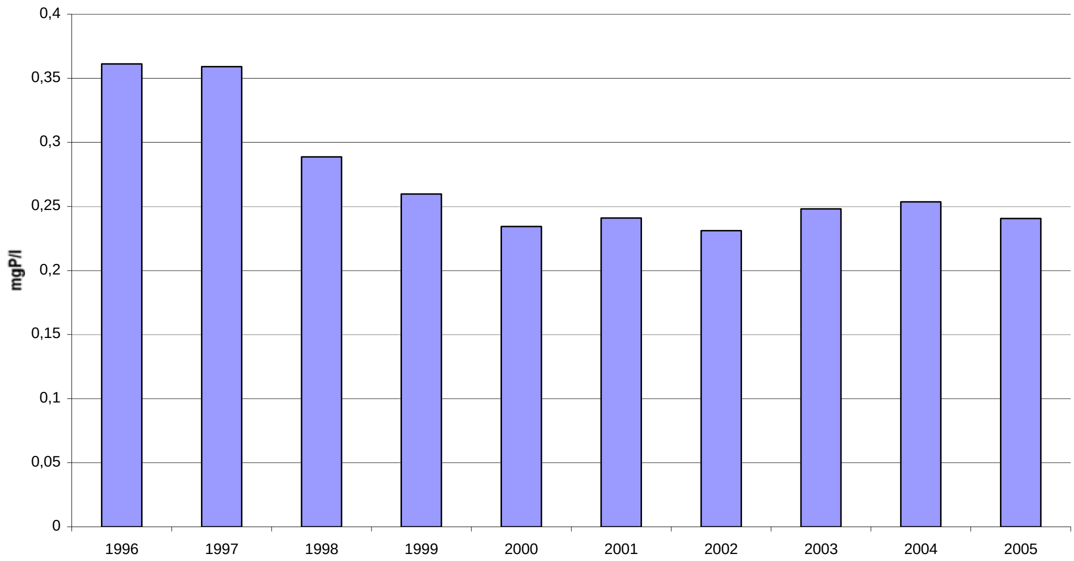


Figure 5 Changes in phosphorus concentrations in surface water in the Walloon region.
Changes in total average phosphorus concentrations for 146 monitoring sites for which the data covers the period 1996-2005.

1.5 Overview of monitoring networks

Monitoring in groundwater

The network implemented by the Walloon region for monitoring groundwater in order to meet the requirements of the Nitrates Directive and the Water Framework Directive is composed of some 950 measurement points spread across the whole of the region (Figure 6). This represents one measurement point each 18 km^2. These monitoring points are of different types:

- 300 boreholes (abstraction wells and surveillance wells called piezometers), and
- 650 superficial points (traditional wells and springs).

Piezometers are sampled at half depth (the pump is located in the middle of the screen, typically 3 m under the water table). In traditional wells however, the small water column just allows to install the widely used submersible pumps.

Monitoring in surface water

Since 2005, the network for measuring the quality of surface water has consisted of 357 stations at which nitrate is analysed (Figure 7).

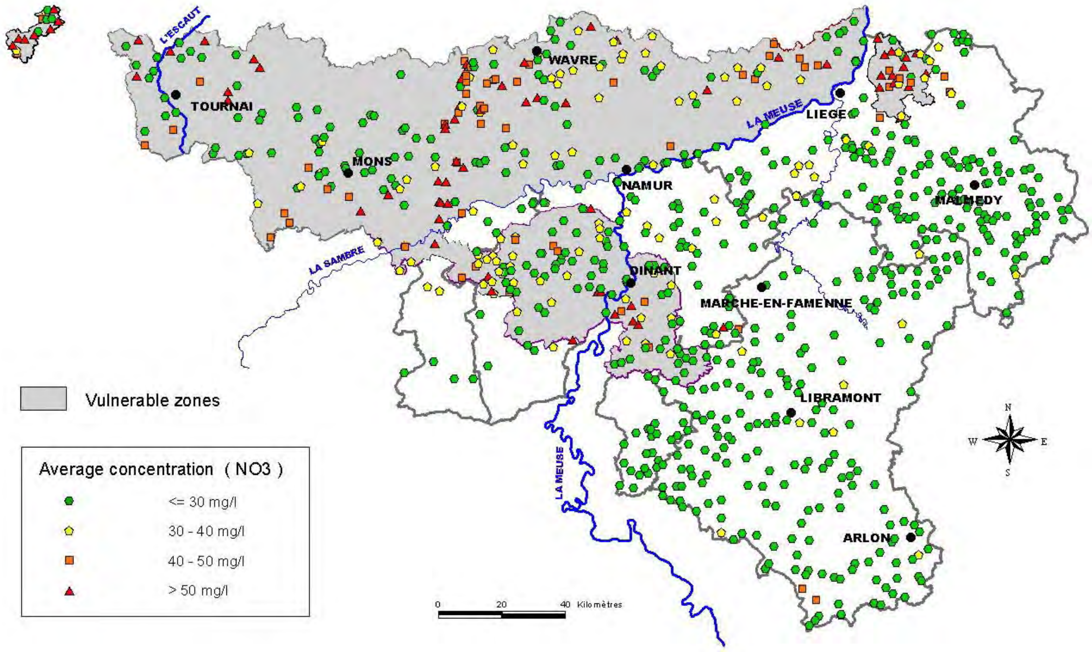


Figure 6 Groundwater quality monitoring network in the Walloon region (2005).

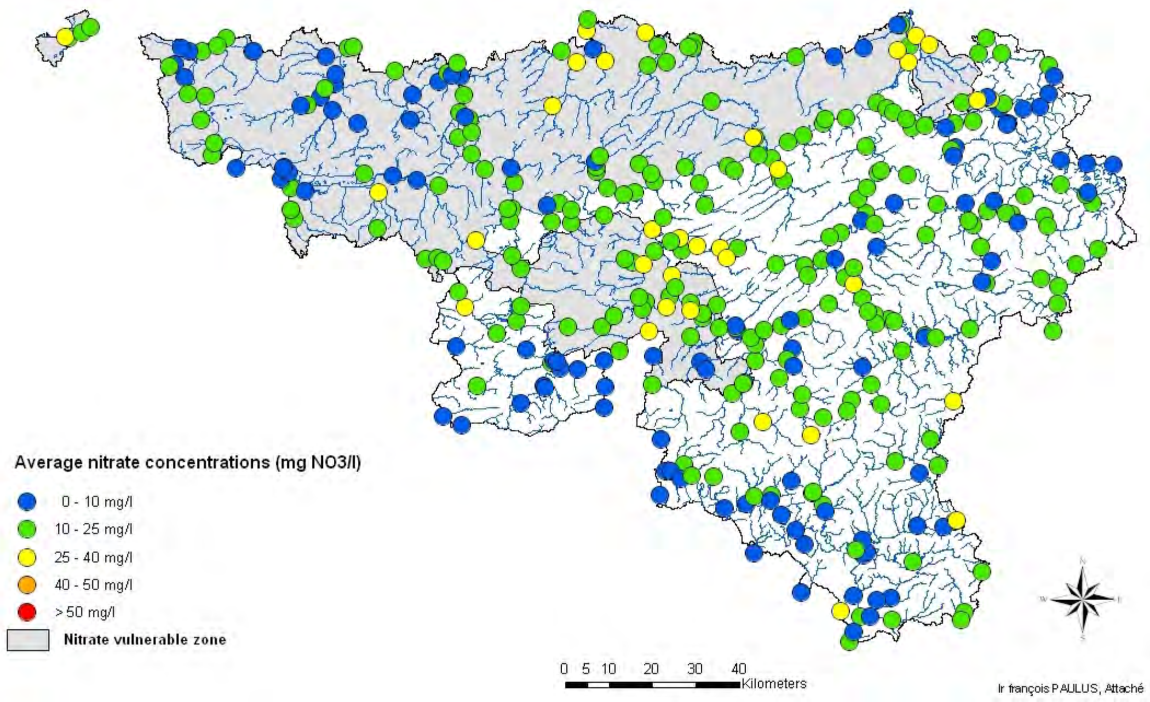


Figure 7 Surface water quality monitoring network in the Walloon region (2005).

Monitoring agricultural practices

Towards land-based agriculture

Each farm in Wallonia has to be land-based, which means that the quantity of organic fertiliser present in the farm over a one-year period must be lower than the maximum quantity that may be applied on the land of the farm. The result of the ratio between the quantity of organic nitrogen present and the land area of the farm is called the ‘soil linkage rate’ (SL) (Delloye et al., 2005). Depending on his own individual situation, the farmer has to maintain his soil linkage rate below the unit one (1), where necessary by entering into contracts with other farmers or by reducing his livestock. The Department has computerized data that each farmer sends in as part of the farm’s CAP[2] return, as well as the composition of his livestock. This data is used by a software programme called ‘TALISOL’, which makes it possible to calculate the situation for each farmer. As a result, each farm in the Walloon region is systematically checked every year, with accuracy, with regard to its production and use of manure from livestock and other organic fertilisers. If these levels should be breached, this check may lead to sanctions in relation to cross-compliance. This system represents a genuine tool for managing organic fertiliser application and is a major strong point in implementing the region’s Action Programme. It also takes account of forms of organic nitrogen other than manure from livestock.

Measurements of soil nitrate residue (SNR)

In vulnerable zones, a special monitoring programme has been launched in 2007, so that the practices of farmers can be monitored and guided better, as well as the application of total maximum doses of nitrogen. The programme also makes it possible to adjust those farming practices that do not contribute to better water quality. Consequently, each year, measurements of SNR will be carried out on arable land for a sample of 3% of the farms in NVZs, targeting in particular delicate crops in regard to nitrogen management (maize, potatoes, et cetera).

Parallel to this, these same dosages will be applied each year in a network of some 30 reference farms where good farming practices are implemented (Vandenberghe et al., 2004). Those farms were selected on the basis of, among other things, pedological criteria, in order to be representative of the regions to which they belong. They constitute the reference base for the ‘Agricultural Area Survey’. Around 220 parcels of land were selected on these 33 farms based on crop and soil type. These farms benefit from supervision consisting in appropriate fertilisation advices, for both organic and mineral nitrogen; the aim of which is to minimise nitrogen residue as much as possible at the beginning of the nitrate leaching period.

The SNR reference values are established for eight categories of land use (sugar beet, maize, pasture, et cetera) on the basis of the measurements of SNR developed two times each autumn (last week of October and first week of December) on the 220 parcels of land in the Agricultural Area Survey; see for an example Figure 8.

[2] Common Agricultural Policy of the European Union

Studies were carried out to establish the soil sampling method as well in arable and grassland (Hennart et al., 2006). More information (in French) can be found at www.grenera.be.

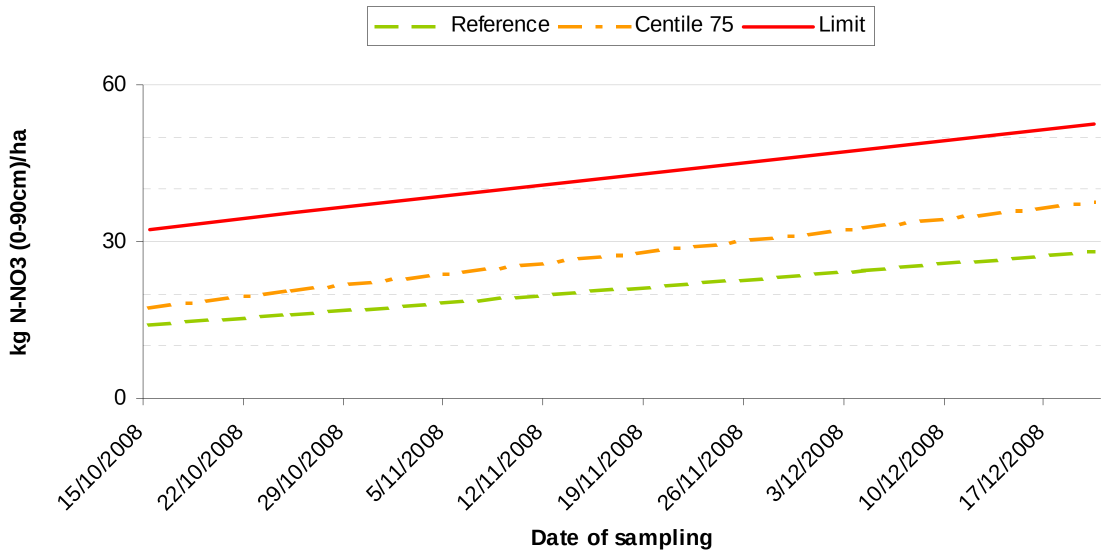


Figure 8 Soil Nitrate Residue (SNR) reference value for sugar beet for 2008, the 75-percentile value and the limit value.

This network, which is already in place since 2001, enables reference curves to be established each year for SNR for each category of crops, throughout the autumn. The results of each set of samples taken at a monitored farm will be compared with these reference curves. In case the limit value is exceeded in at least two of the three parcels of farm monitored, the farmer will be required to adjust his practices (with help of the Nitrawal supervisory structure) and other measurements will be carried out on his arable land, at his expense, in subsequent years. After three years of measurements, in case of unsatisfactory results, the farmer would have to pay a significant penalty.

This programme is aimed at: (a) making farmers aware of the danger of certain farm practices for groundwater (such as applying excessive amounts of organic fertiliser on a crop) and (b) conducting indirect checks on the overall level of fertilisation (organic and mineral) at these farms.

2 Effect monitoring

2.1 Strategy for effect monitoring

The effect monitoring strategy of the Walloon region is bases on three levels: the field scale, the catchment scale and the regional scale. Two indicators are used to monitor the agricultural practices and to assess the effectiveness of the Action Programme (Figure 9):

- the soil nitrate residue (SNR) measured at the beginning of the lixiviation period, and
- the nitrate concentration in the water (NCW).

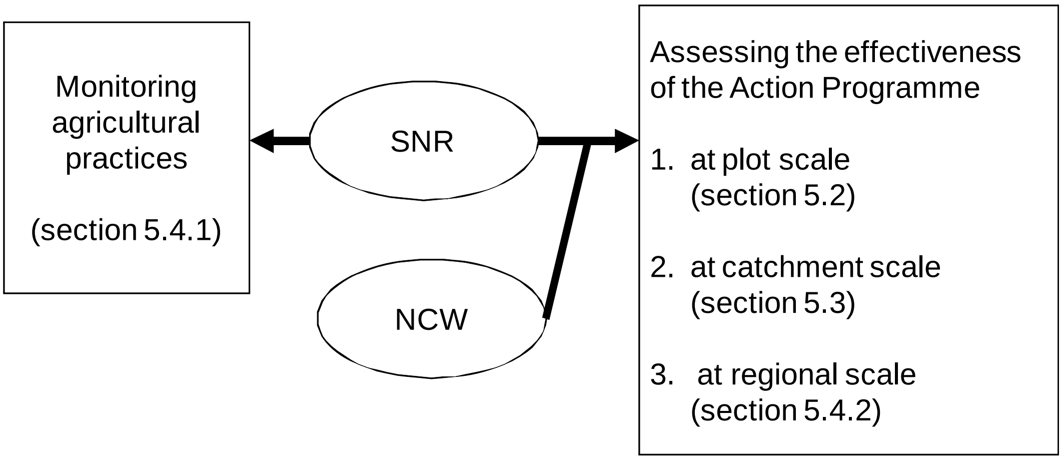


Figure 9 Effect monitoring of the Action Programme.
SNR is soil nitrate residue; *NCW is nitrate concentration in water.*

2.2 Effect monitoring at the plot scale

In 2003, six lysimeters have been installed in two of the 33 reference farms. These lysimeters are 1.5 m height, have a 1 m² section, and are placed 2 m deep in the (loamy) soil so that agricultural practices, such as tillage, are not disturbed.

The soil nitrate residue (SNR) and nitrate concentration in the water (NCW) collected are regularly measured to evaluate the impact of agricultural practices (crop, manure use, fertilisation rate). The aim is also to show the link between SNR and nitrate concentration in the leaching water. After five years of monitoring, it appears that:
- the level of SNR (in kg NO_3-N ha^{-1}) at the beginning of the leaching period is quite similar to NCW (in mg NO_3 l^{-1}) collected in the lysimeter during the leaching period (Figure 10);
- wheat followed by a catch crop and sugar beet are characterized by small SNR and NCW collected while potatoes and some vegetables (like leeks and spinach) are characterized by a high SNR and nitrate concentration in the water collected.

2.3 Effect monitoring at a catchment scale

Since 2004, a small catchment (100 ha) is monitored. In this area, the land use is only crops (mainly wheat, sugar beet, maize and potatoes). The eight farmers concerned are educated by Nitrawal to apply good agricultural practices. The mean ‘soil linkages rate’ (see section 4.3.1 of this paper) of these farmers is around 0.65. In each parcel, SNR is measured each spring to give mineral fertilisation advices and each autumn to be compared to the SNR reference values (see section 4.3.2). In 2007, only 11% of the parcels showed unsatisfactory SNR, that means, the SNR value of parcel higher than reference limit value.

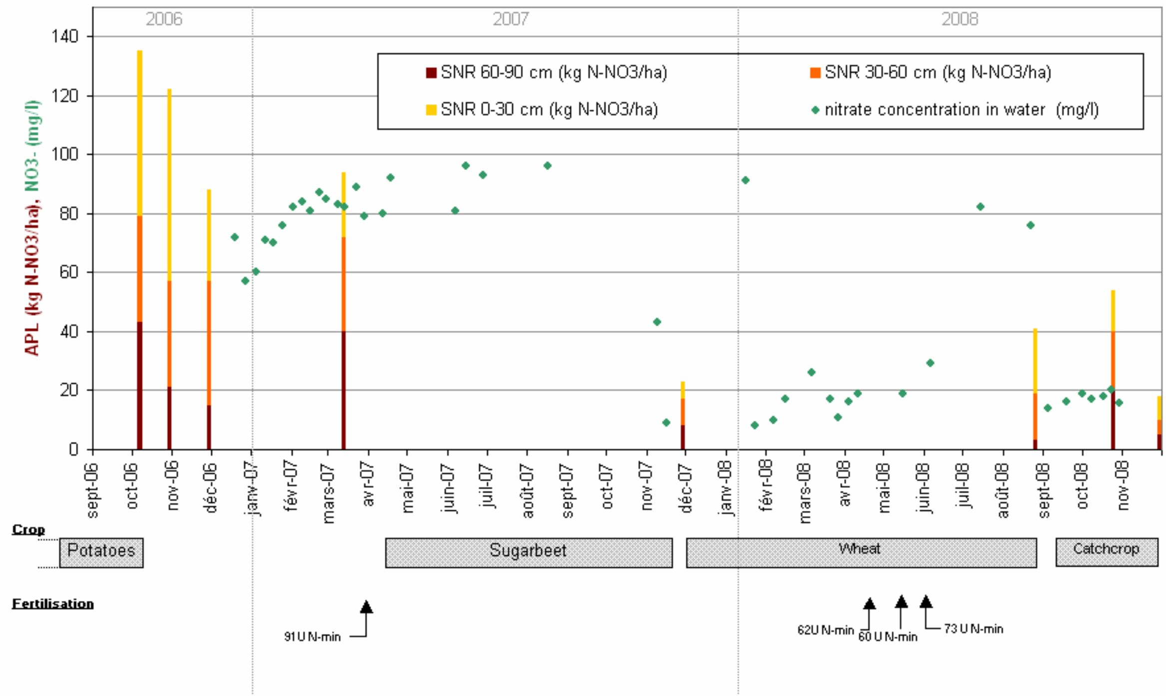


Figure 10 Soil nitrate residue (SNR, coloured lines) and nitrate concentration in the water (NCW, green diamonds) in the lysimeter of Bovenistier.

Groundwater level is on average 10 m deep and NCW is around 60 mg NO_3 l^{-1} (mean value of 11 measuring points sampled monthly by GRENeRA of the Gembloux Agricultural University). Due to the relation between SNR and nitrate concentration in the leaching water (see section 2.2), a positive trend in nitrate concentration of the groundwater is expected within a few years.

Modelling with the software SWAT is used to predict the effect of possible modifications of the Action Programme for trend detection in nitrate concentration. The choice of the software SWAT was made following the evaluation of the most common similar models by Schoumans and Silgram (2003).

2.4 Effect monitoring at the regional scale

Soil nitrate residue as a tool for monitoring agricultural practices

Since 2007, about 800 different parcels are sampled in the vulnerable zone each year to evaluate the compliance with the nitrogen fertilisation advices and good manure management, including post-harvesting spreading (Figure 11). So, SNR is measured between 15 October and 10 December in those parcels. The results are compared to the SNR reference value (see section 1.5) to allow their evaluation. In 2007, 30% of the sampled parcels show an unsatisfactory result. Within a few years, due to the penalties included in the Action Programme, it is expected that this percentage will decrease, thus demonstrating that farmers better observe the code of Good Agricultural Practice.

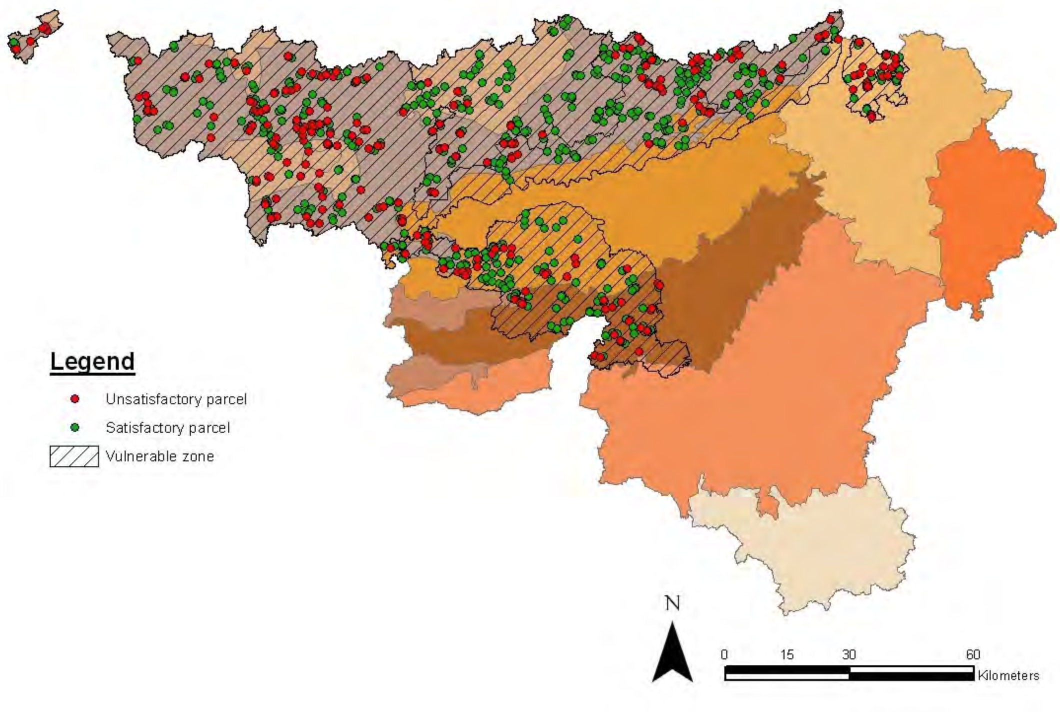


Figure 11 Soil nitrogen residue values (SNR) in the vulnerable zones of the Walloon region in 2007.
SNR below (satisfactory) or above (unsatisfactory) the limit value. Limit value depends on crop and time of sampling.

Modelling

Mathematical models simulating the complex processes in a watershed are useful tools to understand the problems and to find solutions through land-use changes and best management practices (Borah and Bera, 2003). In their review of 62 nitrogen dynamic models, Cannavo et al. (2008) pointed EPIC (Williams, 1995) as one of the few mechanistic models that represent all the N processes (mineralisation, leaching, volatilisation, nitrification, denitrification, uptake, and N_2 fixation). They also noted that EPIC supports a large number of crop species and uses parameters that do not require heavy laboratory measurements.

In the Walloon region, the EPIC code has been modified (Sohier et al., 2009). The local pedology description was introduced using the Belgian soil map (Tavernier and Marechal, 1972). The reservoirs depths between the top soil layer and the 1.5 m depth layer (root zone) were adapted to fit the pedological horizons. We also introduced the pedotransfer function proposed by Rawls and Brakensiek (1989), as it was shown by Masereel and Dautrebande (1995) to be the most practical choice in the Walloon region.

Under the root zone, we introduced new reservoirs, taking into account the geological description down to the groundwater table. Original equations from the EPIC model (Sharpley and Williams, 1990) that are also included in the SWAT model (Gassman et al., 2007) were adapted to these new reservoirs for water flows and nitrogen transfer. EPIC (and SWAT) model incorporate a mobile and an immobile fraction of nitrate in each soil layer (Neitsch et al., 2002). The mobile nitrate can leave the topsoil layer because of surface run-off, percolation, and lateral flow. The mobile nitrate in the underlying soil layers can move by lateral flow and percolation only. The algorithms for calculating organic nitrogen losses from the topsoil due to surface run-off were given by Neitsch et al. (2002).

The crop growth module of the EPIC model includes main Belgian crop productions. Nevertheless some light modifications were included into the code concerning wheat, potato and sugar beet (Masereel and Dautrebande, 1995; Cocu et al., 1999). Observed data relative to some fields were used to perform the calibration of the model (Cocu et al., 1999).

Then, the extended EPIC model was linked with a GIS (geographical information system) and the Belgian territorial databases. A regular squared grid composed of 1 km² cells each was used to represent the region (16,902 km²). Inside each 1 km² cell we identified the main hydrological response units (HRU) considering four inputs: soil description, slope, land use (including crop and technical operations), and meteorological data (Sohier et al., 2009).

Model results are water and nutrient flows in an ASCII matrix. It is very flexible so that different indicators can be built for different time periods with a GIS. To carry out the simulations since 1961, we have reconstituted the crop rotation history, the animal husbandry, the mineral fertilisation at the scale of the agricultural sub-regions (ten sub-regions in the Walloon region of Belgium) using a five-year time step until 2000 and exploiting data from the Belgian institute of statistics. We referred to Borgers et al. (2007) for the current situation. The simulations were carried on a daily time step until 12 December 2005. Only the results from 1 January 1971 to 12 December 2005 are taken into account.

Some validations, concerning water balances at watershed scale and deep nitrate transfer are presented in Sohier et al. (2009). This new model is called EPICgrid (Hydrology and Hydraulic Engineering, Gembloux Agricultural University).

Comparison of soil nitrate residue measurement and modelling results

Following the systematic campaign of measurements put into practice in the Walloon region, Sohier et al. (2008a) modelled water and nitrogen flows for the main three-year crop rotations identified by Borgers et al. (2007) in the different agro-hydrological sub-regions. They modelled the soil nitrate nitrogen content in the same soil layer. Figure 12 shows a comparison between modelling results and measurements of nitrate residue after wheat crop harvest (Sohier et al., 2008b).

The RMSE is equal to 12.8 kg NO_3-N ha^{-1} during the 2002-2005 period and 8.4 kg NO_3-N ha^{-1} in the 2003-2005 period. It can be noted that, except in 2002, the model is quite representative of the amount of nitrate residue after harvest and its evolution during autumn.

Modelling results

The model has enabled us to produce different maps about the distribution in depth and fate of nitrate in soil water. These maps present:

- the spatial distribution of nitrate concentration in the water leaving the root zone (Figure 13);
- the spatial distribution of nitrate concentration in recharge water just above the groundwater table (Figure 14);
- the time for the nitrate transfer in unsaturated zone from 1.5 m depth to the upper groundwater table (depth between 1.5 m and a maximum of 104 m) (Figure 15).

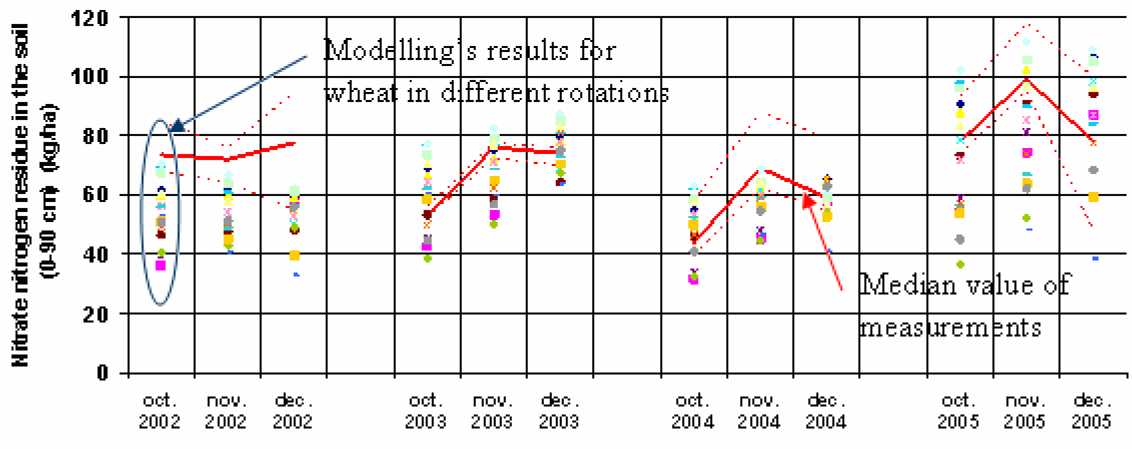


Figure 12 Potentially leachable nitrate nitrogen after wheat crop harvest: comparison of measured and simulated values with modified EPICgrid model.
(RMSE: 12.8 kg NO_3-N ha^{-1}; mean standard deviation of measured values: 22.8 kg NO_3-N ha^{-1}; mean standard deviation of modelled values: 11.2 kg NO_3-N ha^{-1}).

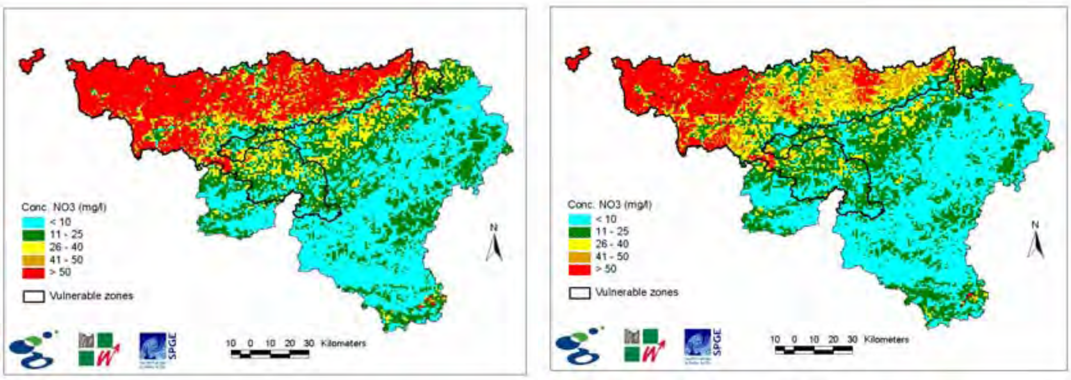


Figure 13 Spatial distribution of nitrate concentration in the water leaving the root zone.
Left: mean value for 1994-1999 period, right: mean value for 2000-2005 period.

On the one hand nitrate concentration under the root zone (Figure 13) is a fast indicator of the effect of cropping and grazing systems on nitrate concentration. On the other hand the nitrate concentration in recharge water (Figure 14) shows the direct pressure on the groundwater body, as a consequence of the cropping history and the characteristics of the upper vadose zone.

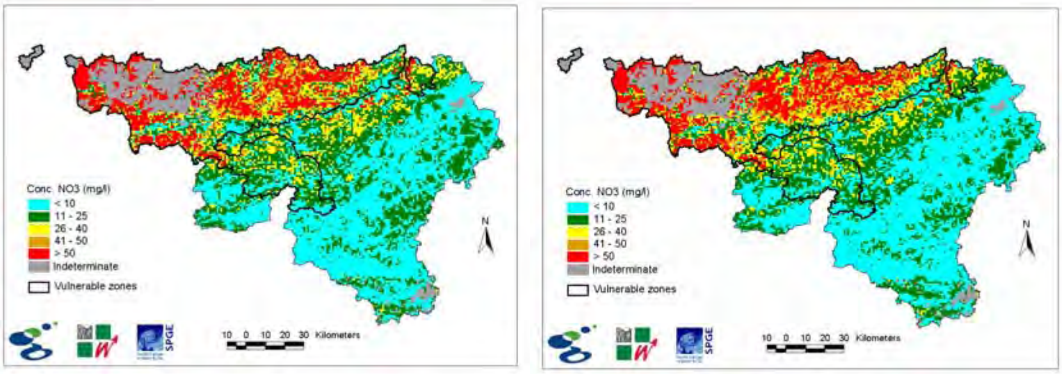


Figure 14 Spatial distribution of nitrate concentration in recharge water just above the groundwater table.
Left: mean value for 1994-1999 period, right: mean value for 2000-2005 period.

Figure 15 illustrates the mean transfer delay from the root zone to the groundwater table in the Walloon region. One can see that in a few zones the delay exceeds 15 years. This means that 15 years are needed for a new cropping practice to influence the groundwater recharge quality.

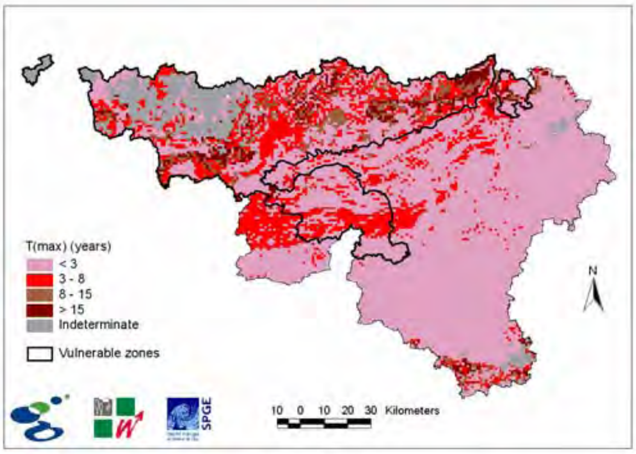


Figure 15 Time for nitrate transfer in unsaturated zone from 1.5 m depth to the upper groundwater table
Depth between 1.5 m and the maximum of 104 m.

3 Discussion

Soil nitrate residue

The Walloon region launched recently a vast monitoring and control programme based upon the measurement of soil nitrate residue (SNR) at the beginning of the leaching period. Comparison studies involving lysimeters showed a good correlation between SNR and nitrate concentration just under the root zone.

The current monitoring of a small river catchment should also confirm soon a good correlation between SNR and nitrate concentration measured in groundwater at the water table. Besides this, the control programme will enable:

- an individual monitoring of the agricultural practices of each ‘non satisfactory’ farm until the moment when satisfactory results are obtained;
- an evaluation – at the vulnerable zone level – of the improvement of the agricultural practices, by a yearly comparison between farms controlled for the first time.

Modelling

As the Nitrates Directive was implemented in the Walloon region in 2002 (Vandenberghe et al., 2004), modelling shows that some areas will not be impacted by the expected effects of new practices within a decade. It highlights the importance of fast indicators of cropping practice performances to help policymaking and the importance of transfer modelling through the vadose zone to take into account the cropping history of the field. The fast indicators can be field measurements of potentially leachable nitrogen (Vandenberghe et al., 2004) but also modelling results of nitrate concentration in soil water under the root zone (Figure 13). The first results from the field monitoring of ‘potentially leachable nitrate’ after wheat harvest confirm the accuracy of the model even if more samples are needed to validate the calculation for the main crops; see Sohier et al. (2008b) for more details. The monitoring of the upper groundwater quality also shows a good relevance of the modelling results (Sohier et al., 2009). Therefore the main maps produced by EPICgrid model constitutes major tools for nitrogen management at a regional level

Conclusion

The networks implemented to monitor water quality and agricultural practices and the modelling systems developed enable the Walloon region to evaluate with a good accuracy the efficiency of its Action Programme. These tools contribute also to improving this efficiency.

4 References

Borah, D.K. and Bera, M. (2003) Watershed-scale hydrologic and nonpoint-source pollution models: review of mathematical bases, Trans. ASAE 46 (2003), pp. 1553-1566.

Borgers, N., Vandenberghe, C. and Marcoen, J.M. (2007) Des pratiques agricoles aux reliquats en azote nitrique des sols en région wallonne. Collaboration scientifique entre l'Unité d'Hydrologie et d'Hydraulique agricole et le Groupe de Recherche en Environnement et Ressources Azotées dans le cadre de l'Evaluation des mesures prises pour réduire les incidences de la pollution diffuse d'origine agricole et domestique sur la qualité des masses d'eau de surface et souterraines de la région wallonne à l'aide du modèle EPICgrid-PIRENE (Convention RW-SPGE) (From agricultural practices to nitrate nitrogen residues in soils of the Walloon region. A scientific co-operation between the Research group for Hydrology and Agricultural Hydraulics and the Research group for the Environment and Nitrogen Research in the framework of the evaluation of the measures taken to decrease diffuse pollution incidents from urban and agricultural origin and their effects on the quality of surface and groundwater bodies in the Walloon region with the aid of the EPICgrid-PIRENE model). Gembloux: Faculté Universitaire des Sciences Agronomiques, 76 pp. http://www.fsagx.ac.be/gp/grenera/grenera_publications.htm.

Cannavo, P., Recous, S., Parnaudeau, V. and Reau, R. (2008) Modeling N dynamics to assess environmental impacts of cropped soils. Advances in Agronomy, 78, 131-174.

Cocu, X., Frankinet, M., Moeremans, B. and Dautrebande, S. (1999) Radar interferometry and water-soil-crop simulation model on field in Belgium. In: proceedings of the International conference of CNES, Meribel, France, 18th-22nd January. 5 pp.

Delloye, F., Dewez, A., Guillaume, Ph., Lambert, R., Peeters, A., Vandenberghe, C. and Marcoen, J.M. (2005) Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Walloon region (Belgium). In: Monitoring effectiveness of the EU Nitrates Directive Action Programmes (ed. by B. Fraters, K. Kovar, W.J. Willems, J. Stockmarr and R. Grant) (Results of the international MonNO3 workshop in the Netherlands, 11-12 June 2003), pp. 85-105, Bilthoven, RIVM report 500003007.

Cellule Etat de l'Environnement Wallon (2007) Rapport analytique sur l'état de l'environnement wallon 2006-2007. MRW - DGRNE, Namur, 736 pp.

Gassman, P.W., Reyes, R., Green, C.H., Arnold, J.G. (2007) The soil and water assessment tool : Historical development, Applications and Future Research Directions. Working paper 07-WP443. Center for agricultural and rural development. Iowa State University, 102 pp.

Hennart, S., Stilmant, D., Lambert, R. and Vandenberghe, C. (2006) Accuracy of the nitrate sampling scheme, proposed in the Walloon area, for grazed grassland. In: N management in agro-systems in relation to the Water Framework Directive (Ed. by J.J. Schröder and J.J. Neeteson) (14th N workshop October 2005, Maastricht, the Netherlands), pp. 300-302, Plant Research International, Wageningen, report 116.

Masereel, P. and Dautrebande, S. (1995) A simulation model of the evolution of soil moisture under wheat crops in the Belgian silty region. Bull. Rech. Agron. Gembloux, 30 (4), 353-372.

Neitsch, S.L., Arnold, J.G., Kinry, J.R. and Williams, J.R. (2002) Soil and Water Assessment Tool. Version 2000. Theoretical Documentation. USDA-ARS, Temple, TX.

Rawls, W.J. and Brakensiek, D.L. (1989) Estimation of soil water retention and hydraulic properties. In: Unsaturated flow in hydrologic modelling: Therory and practice. (Ed. by H.J. Morel-Seytou), pp. 275-300, Kluwer Academic Publishers.

Recensement agricole (2005) L'agriculture en Belgiqueen chiffres. Chiffres clés de l'agriculture 2005. Direction générale Statistique et Information économique (Statistics Belgium).

Schoumans, O.F. and Silgram, M. (eds.) (2003) Review and literature evaluation of quantification tools for the assessment of nutrient losses at catchment scale. EUROHARP report 1-2003, NIVA report SNO 4739-2003, ISBN 82-557-4411-5, Oslo, Norway, 120 pp.

Sharpley, A.N. and Williams, J.R. (1990) EPIC – Erosion Productivity Impact Calculator: 1. Model documentation. ARS-31. USDA.

Sohier, C., Degré, A. and Dautrebande, S. (2008a) Evaluation des mesures prises pour réduire les incidences de la pollution diffuse d'origine agricole et domestique sur la qualité des masses d'eau de surface et souterraines de la Région wallonne à l'aide du modèle EPICgrid (Evaluation of mandatory measures to limit the effects of non-point source agricultural and domestic pollution on groundwater bodies using EPICgrid model). Report of the Gembloux agricultural university, Belgium, 146 pp.

Sohier, C., Vandenberghe, C., Dautrebande, S., Marcoen, J.M. and Degré, A. (2008b) Nitrogen leaching forecasting: modelling and measurements. In: Predictions for Hydrology, Ecology and water Resources Management Using Data And Models To Benefit Society (Ed. by J. Bruthans, K. Kovar and Z. Hrkal) (Proc. of the international interdisciplinary conference, 15-18 September 2008, Prague, Czech Republic), pp. 123-126.

Sohier, C., Degré, A. and Dautrebande, S. (2009) From Root Zone Modelling To Regional Forecasting Of Nitrate Concentration In Recharge Flows – The Case Of The Walloon region (Belgium). Journal of Hydrology, Journal of Hydrology (2009), 369 (3-4), 350-359.

Tavernier, R. and Maréchal, R. (1972) Carte des Associations des Sols 1:500,000. Atlas de la Belgique, feuilles IIA et IIB (Map of soil associations 1:500,000. Atlas of Belgium, maps IIA and IIB) (in French), Bruxelles, Belgique.

Vandenberghe, C., Mohimont, A.C., Garot, T. and Marcoen, J.M. (2004) The agricultural area survey as a tool for implementing the European Nitrates Directive in the Walloon region of Belgium. In: Controlling nitrogen flows and losses (Ed. by D.J. Hatch, D.R. Chadwick, S.C. Jarvis, J.A. Roker) (Proceedings 12th Nitrogen Workshop, University of Exeter 21-24 September 2003), pp. 93-95, Wageningen Academic Publishers.

Williams, J.R. (1995) The EPIC model. In: Computer models of watershed hydrology (Ed. by V.P. Singh), pp. 909-1000, Water Res. Publ., Littleton, CO.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Czech Republic

P. Rosendorf[1], J. Klír[2], A. Hrabánková[1], H. Prchalová[1] and J. Wollnerová[2]

[1] *T.G. Masaryk Water Research Institute, Podbabská 2582/30, CZ-160 00, Praha 6, Czech Republic*
e-mail: rosendorf@vuv.cz; hana_prchalova@vuv.cz; anna_hrabankova@vuv.cz

[2] *Crop Research Institute, Drnovská 507, CZ-161 06, Praha 6, Czech Republic*
e-mail: klir@vurv.cz; wollnerova@vurv.cz

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the Czech Republic and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). The Czech Republic has dense monitoring network for measuring nitrate concentrations in surface and groundwater. Especially the surface monitoring network of Agricultural Water Management Authority and the T.G. Masaryk Water Research Institute is suitable for designation and revision of nitrate vulnerable zones (NVZs) and some part of monitoring station – investigative – are appropriate for further effect monitoring. At present, the special monitoring focuses on data collection and assessment of agricultural practices. Approximately 300 farms in vulnerable zones are an object of field studies and 30-40 pilot farms are used for verification survey of compliance with the requirements of the Action Programme. Main objective of the prepared strategy for effect monitoring in the Czech Republic is to interconnect all existing data and information about water quality and agricultural practice, with the aim to detect critical activities which have crucial effect on water quality in different regions of the Czech Republic. Other important aims of the strategy should be to consider other influences on nitrate concentration than agricultural practice (for example, inter-annual nitrate fluctuation which depends on dry and wet season, differentiation between sources of pollution in the catchment). Finally, the aim of the strategy should also be the development of a new methodology for the assessment of eutrophication of surface waters caused by agricultural sources.

1 Introduction

1.1 General

The Nitrates Directive implementation in the Czech Republic started in 1997, even before joining the European Union in 2004. A broad study mapping diffuse water pollution was prepared in the framework of a research and development project of the Ministry of the Environment, which was elaborated in 1998-2002 (Rosendorf, 2003). The project focused on collection of the available data on nitrate pollution of surface and groundwater and also on the evaluations and trends in pollution in the period prior to and after the transformation of the social system in the Czech Republic in 1989. Detailed maps were prepared for the vulnerability of the soil and subsoil to infiltration of nitrates into waters and, simultaneously, the evaluation of agricultural management and its impact on pollution of waters in various areas of the Czech Republic was evaluated. Technical designation of nitrate vulnerable zones (NVZs) and preparation of legislative documents for definition of the NVZs took place in a follow-up project in 2000-2002 (Hrabánková et al., 2002). Transposition of the Nitrates Directive was performed through section 33 of Act No. 254/2001 Coll., on waters, as amended. The First designation of the NVZs and adoption of the first Action Programme was finished in 2003 through Government Regulation No. 103/2003 Coll., on designation of NVZs and on the use and storage of fertilisers and livestock manure, rotation of crops and implementation of anti-erosion measures in these zones. The first Action Programme came into force in January 2004. The second Action Programme came into force in April 2008.

Description of factors influencing nitrate concentration in waters

The Czech Republic has temperate climate of continental character with most rainfall in summer and spring month. Mean annual precipitation is ranging from 400 to 1,400 mm with high precipitation in mountains on the north, south-west and east of the Czech Republic. The driest regions are on the lowland areas on the south-east and in the north-west of the Czech Republic. Much of the Czech Republic is covered by light soils with low clay content (Figure 1).

The nitrate concentration in surface and groundwater is strongly dependent on the typical land use of the watershed (Figure 2) and on the degree of dilution by infiltrated water. The nitrate concentration in waters is affected negatively by a high percentage of subsurface drainage, which occurs all over the agricultural regions too. Another important factor which affects negatively nitrate leaching is the big extent of fields without balks (grass or shrubby strips between two fields) and buffer strips (strips between field and adjoining surface water). Very sensitive regions to nitrate leaching are the dry south-eastern parts of the Czech Republic and the central highlands with light acid soils and a very dense subsurface drainage system.

1.2 Environmental goals and measures

National environmental goals with respect to nitrate leaching and designation of NVZs are similar as the requirements of the Nitrates Directive, namely 50 mg NO_3 l^{-1}. The exceedance of the standard for the concentration of nitrate is monitored in small agricultural streams and in shallow groundwater and evaluated as a 95-percentile value or as a maximum of a 4-year data set. A general standard of nitrate nitrogen concentration of 7 mg N l^{-1} (31 mg NO_3 l^{-1}) is applied for all surface waters as a 90-percentile value of one year data set according Government Regulation No. 61/2003 Coll., as amended.

In respect to Water Framework Directive (WFD), in 2007 a guideline was elaborated for the assessment of the ecological status of surface water bodies, valid for first River Basin Management Plans. The nitrate concentration standards in this guideline were defined for groups of water body types. Highest value of good status for group of the large river water bodies was laid down as a median value 20 mg NO_3 l^{-1}.

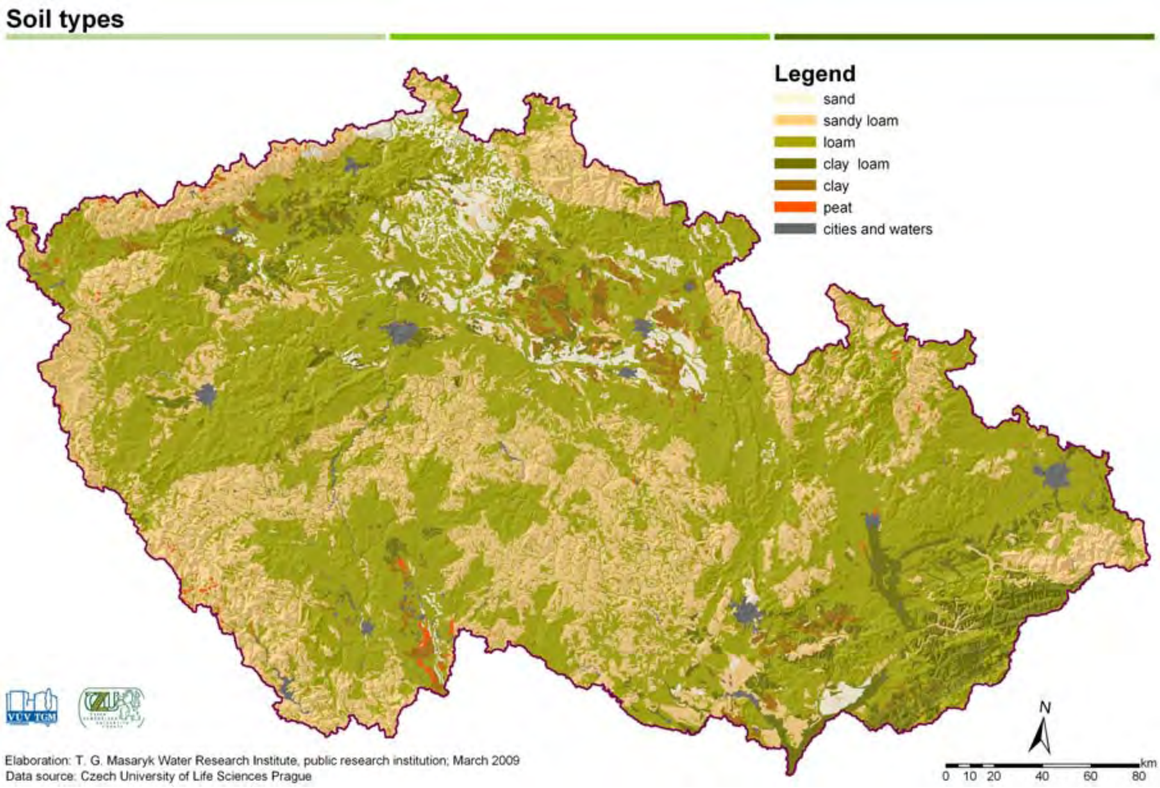


Figure 1 Map of soil types in the Czech Republic (Data: Czech University of Life Science, Prague).

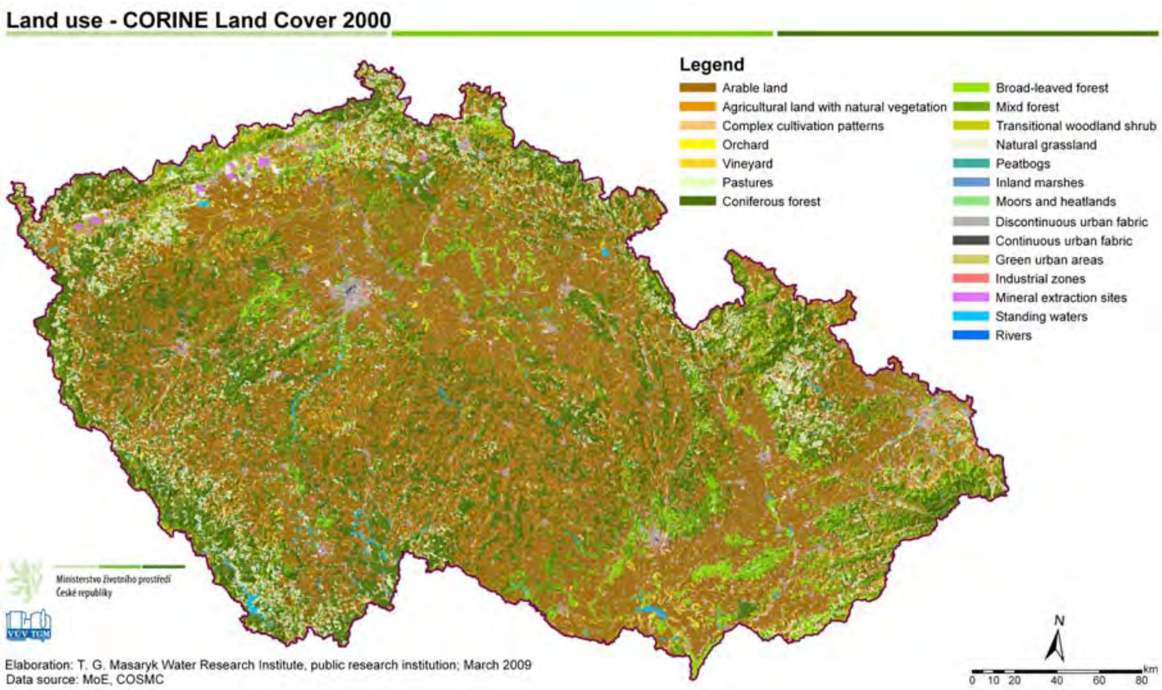


Figure 2 Map of land use in the Czech Republic (Data: CORINE Land Cover 2000).

Based on the above mentioned, it is desirable that – in the near future – the nitrate standards should be unified in terms of WFD and the more strict standards might be proposed for naturally sensitive areas (that means, sensitive species and habitats in Natura 2000 localities).

National environmental goals with respect to eutrophication are not determined exactly. At present, there is no mandatory guidance document in the Czech Republic that would deal comprehensively with the assessment of eutrophication of flowing and stagnant surface waters. The level of eutrophication is most frequently evaluated in various studies on the basis of the phosphorus concentration (especially in water reservoirs) or according to the ratio of phosphorus and nitrogen. The manifestation of eutrophication is most frequently measured in terms of the concentrations of chlorophyll-ɑ, the massive occurrence of blue-green algae or water bloom caused by algae. In water reservoirs, it is also possible to measure the transparency or oxygen deficit at the bottom of the reservoir. Thus, eutrophication is mostly evaluated only on the basis of one or a few indicators and there is practically no connection between the level of eutrophication of a monitoring point, water course or reservoir and the pollution source that contributes in a decisive manner to the high phosphorus and nitrogen concentration in the waters. It is this connection that is of key importance in decision-making on effective measures that would be used to reduce the level of eutrophication of the waters. The procedure of the assessment of eutrophication of surface waters in relation to the Nitrates Directive, whose working version was used for revision of NVZs in 2007, combines both assessment of the causes and consequences of eutrophication for surface water ecosystems and also the manner of differentiation of the predominant type of pollution source that affects the condition of the evaluated monitoring point or the entire water body. The assessment method is being developed by the T.G. Masaryk Water Research Institute, in the framework of the research plan (Rosendorf et al., 2008) ordered by the Ministry of the Environment. Only individual procedures of the prepared methodology were used for revision of vulnerable zones in 2007; these methods are related to assessment of the concentration of total phosphorus and chlorophyll-ɑ in flowing waters and to the basic differentiation of diffuse and point pollution sources (see Table 1 and Table 2).

Table 1 Proposed classification of total phosphorus and chlorophyll-ɑ concentrations used in the assessment of river eutrophication.

Indicator	Unit	Ultra-oligotrophic	Oligo-trophic	Mesotrophic	Eutrophic	Hyper-trophic
Total phosphorus (arithmetic mean)	mg l^{-1}	< 0.01	0.01-0.05	0.05-0.1	0.1-0.2	> 0.2
Chlorophyll-ɑ (value C_{95}†)	µg l^{-1}	< 2.5	2.5-8	8-25	25-75	> 75

† Characteristic concentration value with a 95% likelihood of not being exceeded.

The Czech Republic has taken the approach of designation NVZs instead of application the Action Programme throughout their national territory.

Table 2 Proposed classification of the ratio of nitrate nitrogen to total inorganic nitrogen for various types of pollution.

Indicator	unit	predominance of diffuse sources†	diffuse and point sources	predominance of point sources†
$N\text{-}NO_3/N_{anorg}$ (median)	%	> 95	95-90	< 90

† Without differentiation of the fraction from agricultural sources and atmospheric deposition.

In the first designation in 2003, NVZs were designated where water pollution by nitrates connected with agricultural management could be demonstrated and also where there was a danger that water pollution would increase unless effective measures were introduced. In some cases NVZs were also designated where there was not enough data and the areas were considered to be generally vulnerable to pollution (especially some groundwater areas). Thus, the Czech Republic adopted the principle according to which it designated specific vulnerable zones and also adopted stricter measures for these areas in the form of an Action Programme. The same approach was also used for preparation of the revision of NVZs in 2007 (Figure 3) with the difference that it was proposed that the originally designated zones be annulated in places where the water pollution by nitrates decreased substantially, as far as to the values of nitrate concentration 25 mg l^{-1} (expressed as maximum value).

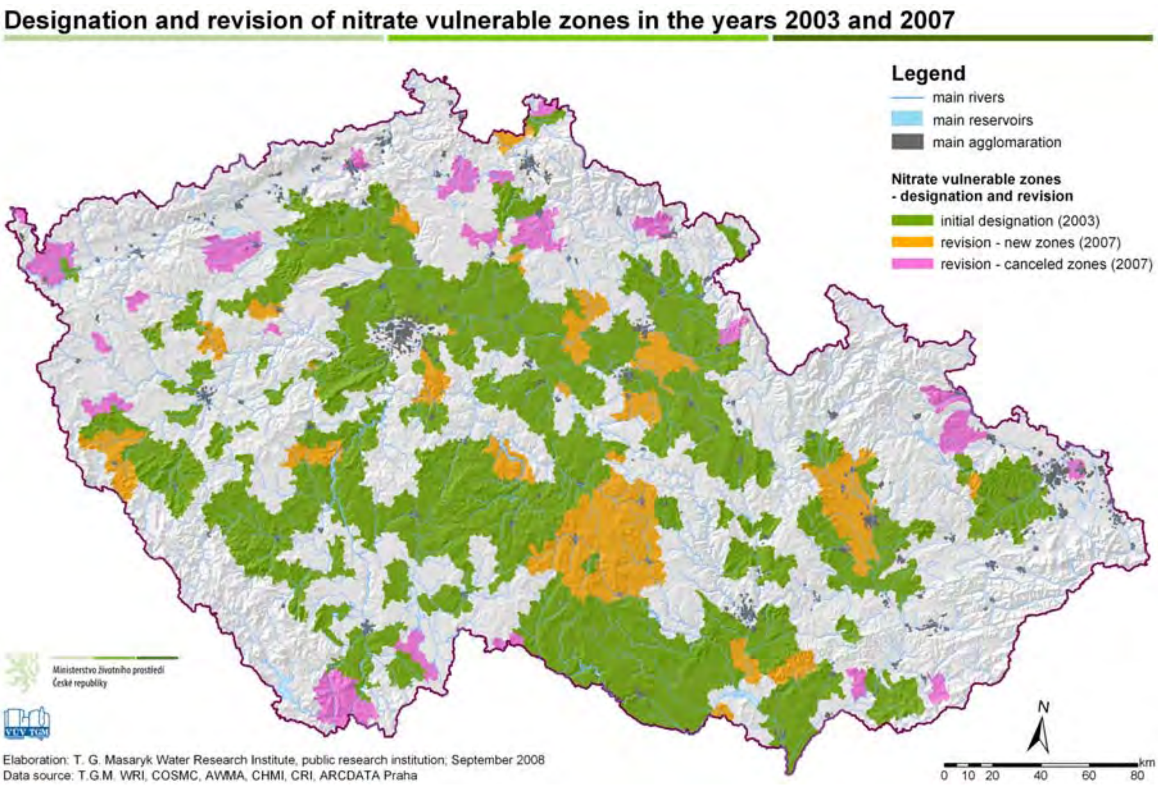


Figure 3 Designation and revision of nitrate vulnerable zones (NVZs) in the Czech Republic in the years 2003 and 2007.

For detailed evaluation of water pollution by nitrates, the entire territory of the Czech Republic was first divided into two types of areas on the basis of the predominant circulation of groundwater. This corresponded to areas with shallow groundwater circulation, where data on nitrate concentrations were jointly evaluated for surface waters and groundwater (pollution of groundwater is mostly immediately reflected in surface waters) and areas with deeper or more complex groundwater circulation, where it was necessary to perform the evaluation separately for groundwater and surface waters (the absence of pollution of surface waters does not automatically exclude pollution of groundwater).

Revision of NVZs in 2007 led to an increase in the total area of NVZs by 3.2%, as compared to 2003. Table 3 gives a comparison of the areas of NVZs in the first designation in 2003 and following revision of the designation in 2007.

Table 3 Extent of nitrate vulnerable zones (NVZs) (in percentages) following revision in 2007 compared to the extent of the first designation in 2003.

	First designation (2003)	Revision (2007)
Ratio of the area of NVZs in the area of the Czech Republic (in %)	36.6	39.8
Ratio of agricultural land† in NVZs in the total area of agricultural land in Czech Republic (in %)	42.5	47.7
Ratio of the area of agricultural land† in the total area of NVZs (in %)	71.0	69.3
Ratio of the area of arable land† in the total area of NVZs (in %)	57.0	58.0

† Extent of agricultural land and arable land according to the Corine Land Cover 90 for 2003 and the Corine Land Cover 2000 layer for 2007.

Only one Action Programme has been adopted under the conditions in the Czech Republic and applies to all the designated NVZs. However, the individual measures of the Action Programme are specified in several variants and are implemented in agricultural practice according to the soil and climatic conditions occurring in the individual agricultural properties. For the differentiation of the Action Programme variants are used, namely ‘estimated pedo-ecological units’ (EPEU).

Main measures in Action Programme to limit pollution are described shortly below. Table 4 gives the period in which application of nitrogen-containing fertilisers is prohibited.

Periods of fertilisation ban are not applicable for faeces and urine excreted by livestock during grazing or their stay on agricultural land and for fertilizing covered areas (greenhouses, plastic foil greenhouses).

Table 4 Period of prohibition of use of nitrogen-containing fertilizing substances.

Agricultural plot with cultivated crop or prepared for establishing of crop stand		Periods of fertilisation ban	
Crop or culture	Climatic region†	Fertiliser with rapidly released nitrogen	Mineral nitrogen fertilisers
Crops on arable land (with the exception of grass and clover plant-grass stands), permanent cultures	0-5	15 Nov - 31 Jan	1 Nov - 31 Jan
	6-9	5 Nov - 28 Feb	15 Oct - 15 Feb
Grass (clover plant-grass) stands on arable land, permanent grasslands	0-5	15 Nov - 31 Jan	1 Oct - 28 Feb
	6-9	5 Nov - 28 Feb	15 Sep - 15 Mar
The application of fertilisers with slowly releasable nitrogen‡ on arable land is banned in the period from 1 June to 31 July, (this provision is not applicable in the case of sub-sequential cultivation of winter crops and catch crops) and in the period from 1 December to 31 January.			

† According to estimated pedologic-ecological units (EPEU), the 1st digit of the five-digit EPEU code.

‡ Treated sewage sludge, as well.

The capacity of storage for manure is stipulated by special legal regulation and must be sufficient for storing of manure during the period of ban for the fertilisation in accordance with Table 4 and in the period when fertilisation is not possible because of the soil and climatic conditions in the NVZs and the cultivated crops. Requirements on manure storage capacity are specified in Decree No. 274/1998 Coll., on the storage and method of use of fertilisers. Technical safeguarding of storage vessels for livestock manure or bulk fodder is specified in new Decree No. 268/2009 Coll., on technical requirements for constructing (section 50).

With regard to the production of hazardous substances, buildings must prevent the spontaneous penetration of substances that jeopardise the water quality of buildings and their components into the surrounding terrain and subsoil, and subsequently into surface water and groundwater by:

a) the impenetrability of surfaces and structures that come into contact with these substances;

b) drainage, or building or technological modifications that prevent the escape of the substances from the building by leaking out, overflowing or spilling;

c) placing tanks for liquid mineral fertilisers in catch basins.

The supplementary provision of buildings apart from the requirements for their basic security applies in the case of their location in areas with increased protection of groundwater and in protection zones:

a) in liquid mineral fertiliser stores, in tanks and reservoirs for the storage of liquid manure, and in silage stores with a dry matter content of less than 30%; the storage facilities above must be provided with a control system for those parts that are covered in the building and that cannot be visually checked;

b) in silage troughs for the storage of silage that is less than 30% dry matter and middens where a spontaneous leak of liquid ingredients from their storage areas must be inspected of the prescribed quality of the building work during construction and before the building is put into operation; during the operation, the impenetrability of surfaces must be regularly inspected.

The deposition of solid manure and solid organic fertilisers prepared for their own usage from farm fertilisers on agricultural land is permissible for the period of 12 months at longest. The deposition at the same place can be repeated soonest after four years of land cultivation within the framework of land management. The deposition is possible only at places introduced in approved emergency plan, and if:

a) no danger of surface water and groundwater pollution threatens;
b) the dumping ground is in the distance 50 m at minimum from a water course or other surface water formation;
c) the dumping ground is not placed on agricultural soils ameliorated through the drainage, on waterlogged soils delimited by main soil units 65-76, neither on arable soils endangered by the erosion defined in Table 6 of Annex 2 to this regulation;
d) it is prevented that dung-water effluent and surface water inflow by means of the trenching of intercepting ditches deep minimally 0.4 m in the slope below and above the dumping ground.
e) solid manure is stacked in a layer with minimum high of 1.5 m, when belts of stacks are oriented by longer site in fall lines.

If it concerns an application of inorganic nitrogenous fertilisers or fertilisers with rapidly releasable nitrogen on arable land on follow-up winter crops, catch crops, for the support of straw decomposition or for follow-up spring crops in the period from 15 June to the beginning of ban on the use fertilisation stated in Table 4, these fertilisers can be used solely by one of the approaches introduced in Table 5.

On permanent grasslands on waterlogged soils, determined by main soil units 65-76, and if they do not have an ameliorated drainage system, it is forbidden to use any nitrogenous fertilizing substances. In the case that the mentioned soils have been drained, a single dose for the application of nitrogenous fertilizing substances is restricted to 80 kg of total nitrogen per hectare. On permanent grasslands on shallow soils and soils with undeveloped soil profiles, determined by main soil units 37-39, a single dose for the application of nitrogenous fertilizing substances is restricted to 80 kg of total nitrogen per hectare. The provision is not related to faeces and urine excreted by livestock during grazing or their stay on permanent grasslands.

For reasons of soil protection from erosion and waters from pollution, wide-row crops (maize, sunflower, soya, beans, potatoes, et cetera) cannot be cultivated on agricultural plots with the slope above seven degrees which are directly adjoining to watercourse or other water formation or are located in distance less than 25 m.

Any nitrogenous fertilizing substances, with the exception of the application of solid farm fertilisers and solid organic fertilisers worked in the soil within 24 hours after their application, cannot be used on agricultural plots with arable land of the slope above 12 degrees. This stating is not valid for retaining of harvestable crop residues.

Table 5 Approaches of the application of inorganic nitrogenous fertilisers *and* fertilisers *with rapidly releasable nitrogen on arable land within the period from 15 June to the beginning of the ban on* fertilisation [#].

	I. application zone		II. application zone		III. application zone			
					Soils with medium infiltration risk		Soils with high infiltration risk	
Condition of the fertilisation	A [†]	B [†]	A	B	A	B	A	B
For winter crop following after cereal crop	60	120	50	100	40	80	20	0
For winter crop following after other pre-crop then cereal crop	40	80	20	0	15	0	10	0
For catch crops, with the exception of pure clover plants and legume stands or for supporting of the decay of straw, with the exception of straw of oil crops, pulses and beans	60	120	50	100	40	80	0	80
For follow-up spring crops[‡]	0	120	0	100	0	100[§]	0	0

† A = maximum limit of nitrogen input in inorganic nitrogenous fertilisers, in kg N ha^{-1}; B = maximum limit of nitrogen input in fertilisers with rapidly releasable nitrogen, in kg N ha^{-1}.

‡ Use of fertilisers with rapid releasable nitrogen is possible, but not before the period from 15 October to the beginning of the ban on fertilisation in accordance with Table 4.

§ Only with nitrification inhibitor.

\# The provision is not related to faeces and urine leaved in by livestock during grazing or their other stay on permanent grasslands.

When using nitrogenous fertilizing substances the single dose is restricted to 80 kg of total nitrogen per hectare on agricultural plots with permanent grasslands of the slope above seven degrees. This provision does not apply to the input nitrogen by faeces and urine during grazing of livestock or their other stay on permanent grasslands.

The quantity of total nitrogen applied annually on agricultural land in organic and combined organic/inorganic fertilisers and manure cannot exceed on average the standard of 170 kg N ha^{-1} for the total area of agricultural land of a farm. For calculation of the amount of nitrogen applied per hectare, the total amount of nitrogen in the form of applied organic and organomineral fertilisers and livestock manure is divided by the number of hectares of farmland in use. Fallow land, non-agricultural used land, such as roads, and other land where the use of fertilisers is prohibited under other laws (nature conservation, et cetera) are not considered as farmland in use and therefore not used in calculations. For detail information about Action Programme see http://nitrat.cz/index.php (Czech language only).

1.3 Overview of trends in nitrogen and phosphorus loads and surpluses

Data for nitrogen and phosphorus balance in the Czech Republic (Figure 4) were obtained from the official data of the Czech Statistical Office and of the Ministry of Agriculture. Data on the nitrogen and phosphorus balance are based on the gross nutrient balance (gross manure nutrient input, that means, no manure nutrient losses are considered) and on the soil surface nutrient balance (net manure nutrient input, that means, manure nutrient losses are considered, namely 35% N and 5% P) results according to the OECD methodology.

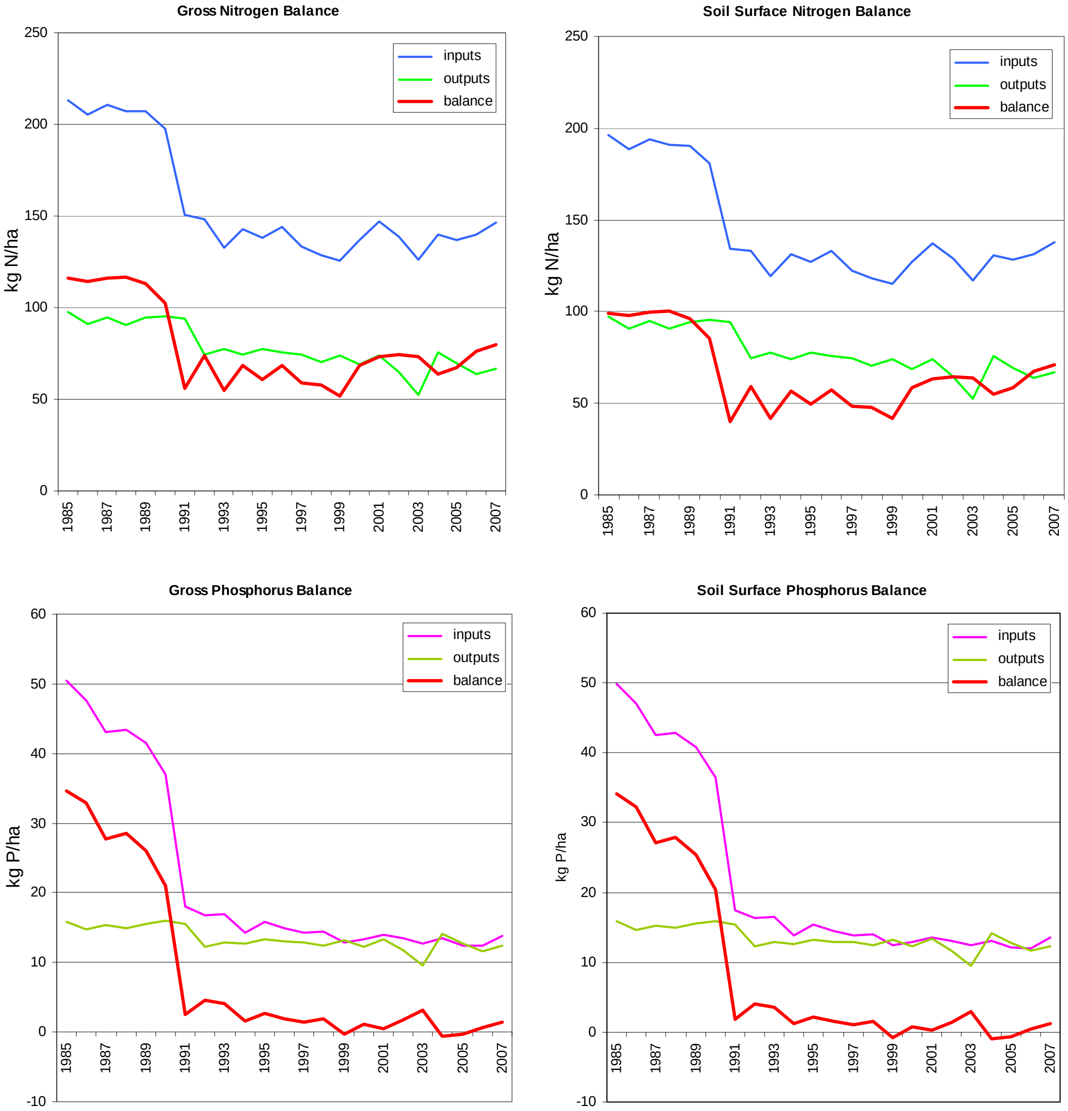


Figure 4 Changes in gross (left) and soil (right) surface nutrient balance for N (upper part) and P (lower part) in the Czech Republic since 1985. Balance is input minus output. (Source: Czech Statistical Office and Ministry of Agriculture)

Discharge of nitrogen into the environment from agricultural sources is also considered to encompass losses of N into the air through volatilisation of ammonia during storage of livestock manure and excess in the surface N balance. The excess in the surface N balance is assumed to be lost into the air in an amount of one-third and into water in an amount of two-third. The calculations for 2003 yield 40,000 tonnes of N as losses of N in storage of livestock manure and 273,000 tonnes of N as excess N balance, of which 90,000 tonnes into the air and 183,000 tonnes into surface waters and groundwater. The calculations for 2007 yield 37,000 tonnes of N as losses of N in storage of livestock manure and 265,000 tonnes of N as excess N balance, of which 87,000 tonnes into the air and 178,000 tonnes into surface waters and groundwater.

The vast majority (80%) of agricultural enterprises in vulnerable zones keep livestock. The average inputs through fertilisation (mineral + organic) per hectare of farmland equal 108 kg N ha^{-1}, outputs from harvested products equal 93 kg N ha^{-1} and the balance difference then equals 15 kg N ha^{-1}. This difference corresponds to 1.2 tonnes of N per year for an average farm area of 80.8 ha. This corresponds to a total of 24,200 tonnes N per year for 20,125 farms in NVZs.

The inputs of nutrients through fertilisation (see Figure 5) and outputs through crop harvests are balanced and there is no difference for farms without livestock raising. On farms without livestock raising, mineral fertilisation is, on an average, lower or equal to nitrogen uptake in the main harvested products, assuming that the side products (straw, rape straw, et cetera) are returned to the soil.

This simplified balance, for which results are given in Table 6, does not include other inputs (approximately 20 kg N ha^{-1} from atmospheric deposition, approximately 15 kg N ha^{-1} from symbiotic and non-symbiotic fixation of atmospheric nitrogen). Nitrogen in side products (straw, rape straw, et cetera) is not included amongst either inputs or outputs of nutrients, as it remains in the field or is returned as litter in manure. Organic fertilisation includes nitrogen inputs in livestock excrement, following subtraction of losses in stables and in storage of livestock manure.

Table 6 Difference between input and output of nitrogen (mineral + organic) for farms in NVZs in 2007, at the end of the validity of the first Action Programme after revision of NVZs.
(*S*ource: Crop Research Institute *(*CRI*)*, surveys on farms)

Type of farms	Balance result	Unit
With livestock raising		
Average per farm	1.2	tonnes per year
Total for the area	24.2	1,000 tonnes per year
With crops alone		
Average per farm	0	tonnes per year
Total for the area	0	1,000 tonnes per year

The NVZs in the Czech Republic include particularly areas with relatively intense farming. There is a high fraction of arable land (average cultivation 84%) and simultaneously concentration of raising of most of the livestock kept in the Czech Republic (80%), with a relatively high density of 0.6 Livestock Units per hectare of farmland in NVZs. The average excretion of nitrogen per hectare of land suitable for fertilisation equals 58 kg N ha^{-1}, where the input of nitrogen into the soil after deducting losses in stables and in storage of livestock manure corresponds to 40 kg N ha^{-1} (see Figure 6). Recalculated to one hectare of agricultural land in NVZs, the average excretion of nitrogen per hectare of land equals 48 kg N ha^{-1}, where the input of nitrogen into the soil after deducting losses in stables and in storage of livestock manure corresponds to 34 kg N ha^{-1}.

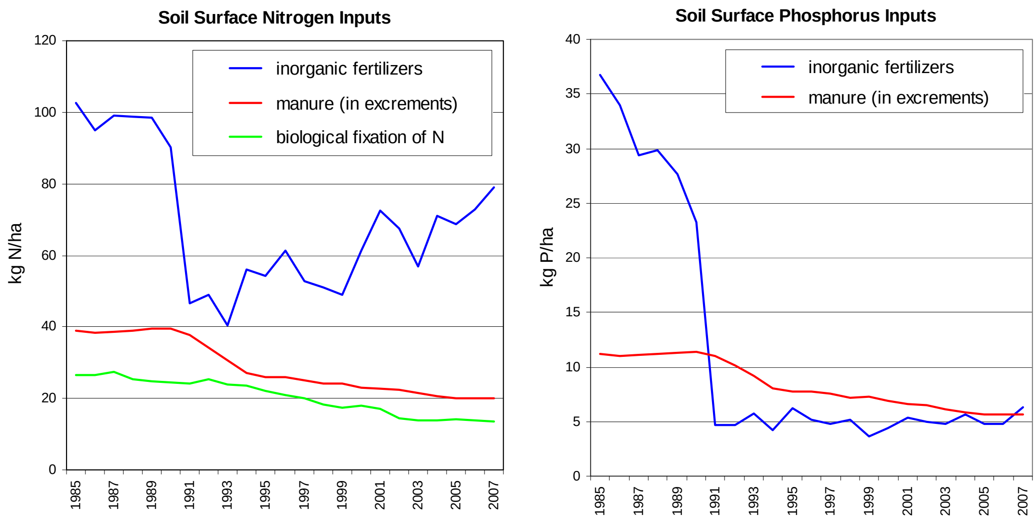


Figure 5 Changes in soil surface nutrient inputs (N and P) in the Czech Republic since 1985. (Source: Czech Statistical Office and Ministry of Agriculture)

1.4 Overview of trends in nitrate, nitrogen and phosphorus concentrations

The apparent decrease of both concentration of nitrate and phosphorus in wide range of rivers all over the Czech Republic has been detected since the mid of 1990s (Figure 7). In groundwater the apparent decrease of nitrate concentration has been detected in fewer cases than in surface water bodies. Reduction of the concentration of nitrate in waters relates well to the sharp decrease of nitrogen fertiliser input to the soils and to the reduction of livestock (especially cattle and pigs) all over the Czech Republic from 1990 (Figure 8).

From the aspect of cultivated plants, a decrease has been observed in cultivation of perennial feed crops (clover, alfalfa, clover/grass, alfalfa/grass), particularly because of a decrease in the number of head of cattle. There has been an increase in the area of cultivated rapeseed amongst winter crops, and of maize amongst spring crops. At the present time, only a third of arable land remains uncultivated over the winter. The reduction in the uncultivated area is caused particularly by cultivation of catch crops, supported by subsidies in the framework of agri-environmental measures. Cultivation of catch crops contributes to reduction of soil erosion and leaching of nitrogen. Table 7 gives trends in the area of arable land not cultivated in the winter.

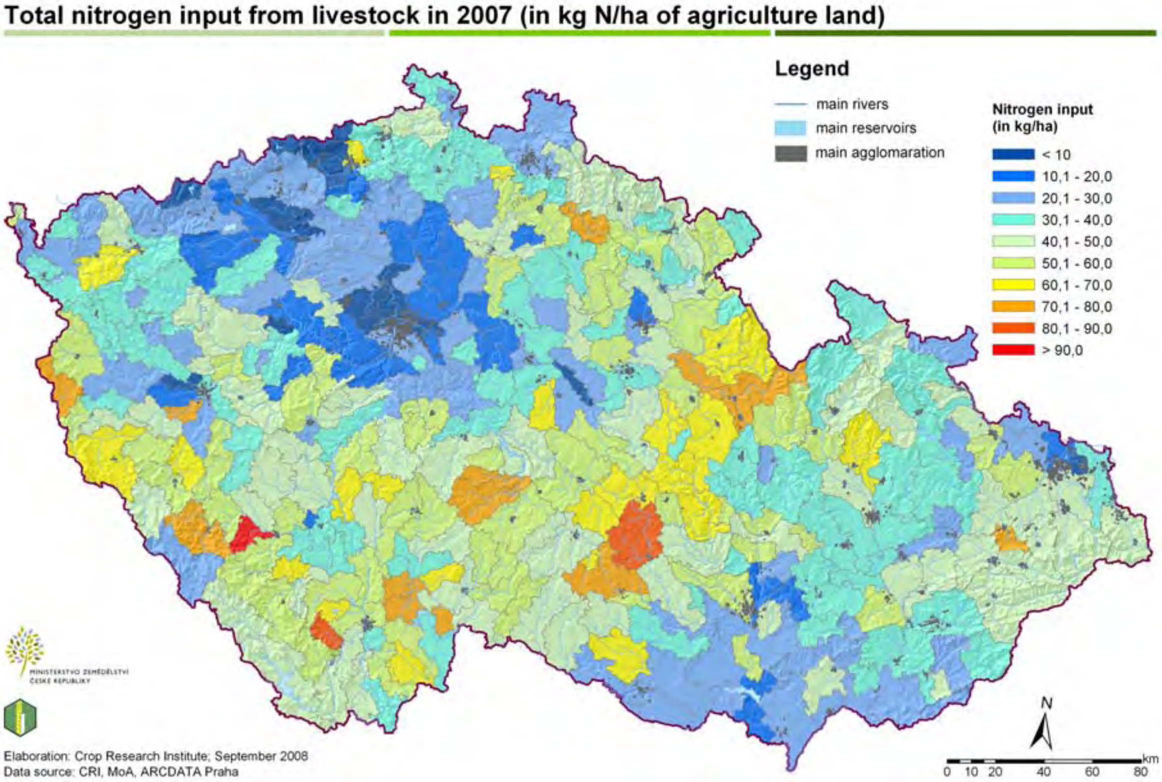


Figure 6 Total nitrogen input from livestock in 2007.

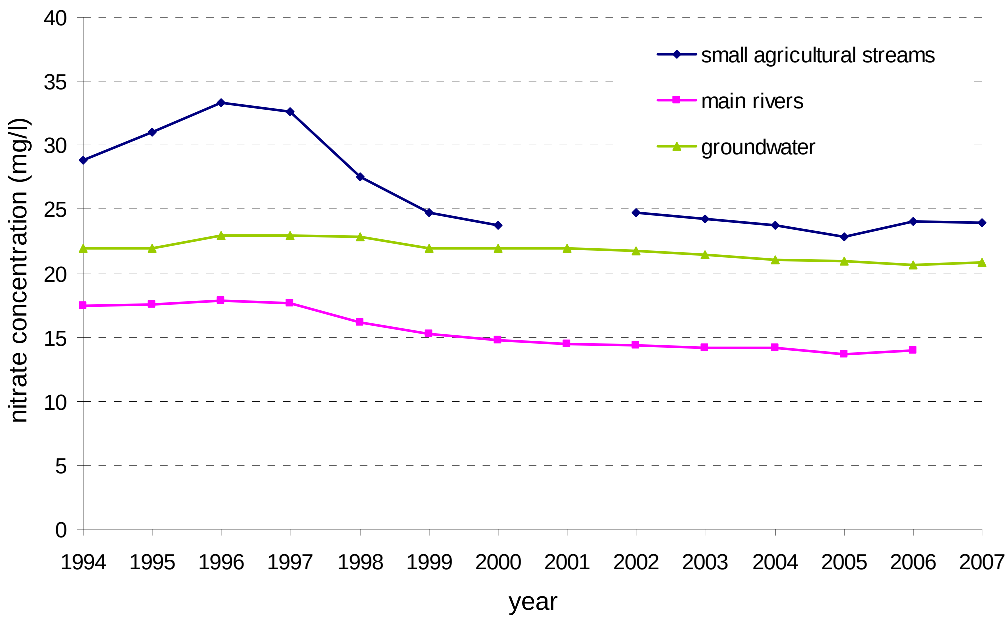


Figure 7 Nitrate concentrations in surface waters and groundwater 1992-2007. Three-year average values (number of monitoring points in small streams: 109; number of points in main rivers: 244; number of groundwater monitoring stations: 379).

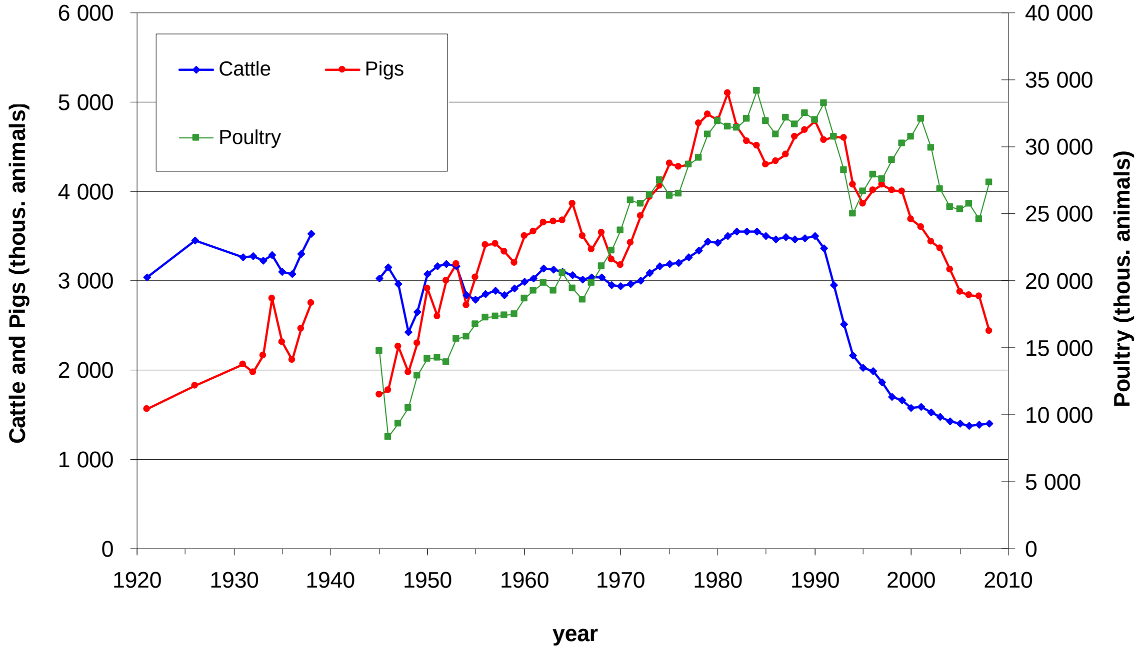


Figure 8 Changes in the number of cattle, pigs and poultry since 1920. (Source: Czech Statistical Office)

Table 7 Trends in the structure of crops cultivated on arable land and the fraction of land left uncultivated during the winter (vulnerable and not vulnerable zones)[†].

	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007
Arable land (×1,000 ha)	3,092	3,079	2,769	2,748	2,720	2,703	2,629	2,618
Winter crops (%)	46.7	47.8	48.6	36.0[‡]	48.0	47.2	45.2	50.3
Spring crops (%)	37.5	36.2	39.1	48.6	41.8	43.0	45.1	40.7
Perennial crops (%)	13.5	12.2	9.3	8.9	8.2	8.2	8.1	7.9
Uncultivated land (%)	2.3	3.8	3.0	6.4	2.0	1.7	1.7	1.2
Total (%)	100	100	100	100	100	100	100	100
Frozen catch crops (%)						7.0	7.9	7.8
Uncultivated in the winter (%)	39.8	40.0	42.1	55.1[‡]	43.8	37.7	38.9	34.0

[†] Source: Czech Statistical Office (arable land, cultivated areas, uncultivated areas) and Ministry of Environment (area of subsidised catch crops).

[§] The catch crops that are left over the winter in the field. Spring crops are planted directly to the frost disturbed catch crops residues.

[‡] Replacement of part of the frozen winter crops by spring crops.

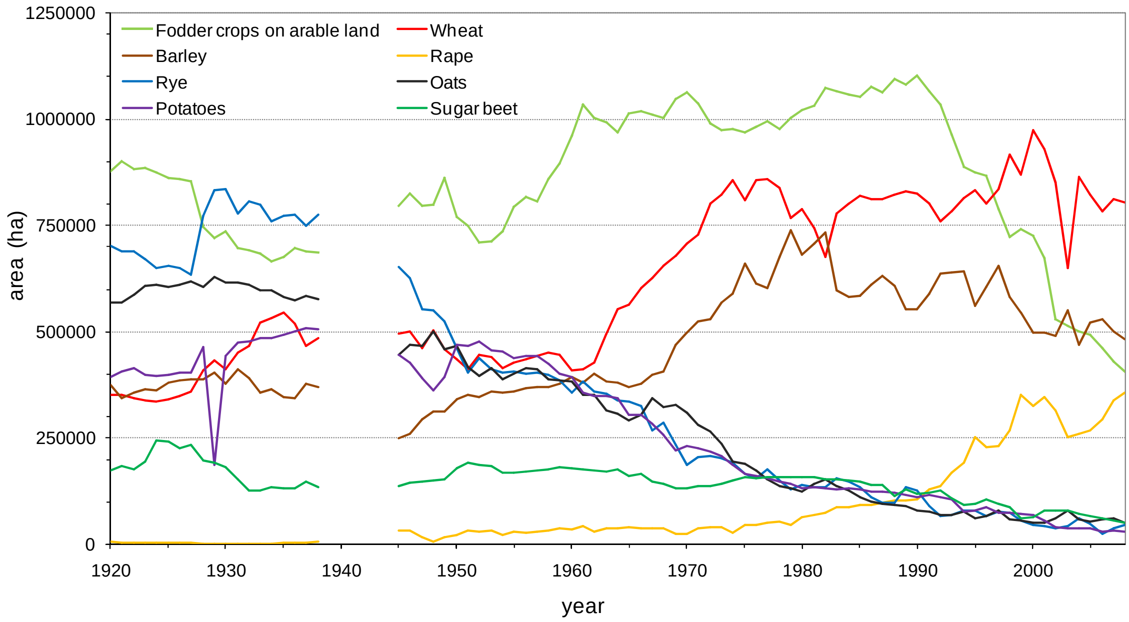


Figure 9 Changes in the sowing areas of main agricultural crops since 1920.
Source: Czech Statistical Office and Czech Office for Surveying, Mapping and Land registry.

1.5 Overview of monitoring networks

Assessment of the quality of surface waters and groundwater in relation to the Nitrates Directive was performed to identify water pollution by nitrates from agricultural sources and to prevent further such pollution. The results are used as a basis for designation and revision of NVZs and, for part of the NVZs, for the assessment of the effectiveness of Action Programmes.

Monitoring of small surface waters in relation to the Nitrates Directive is performed by the monitoring network of the Agricultural Water Management Authority (AWMA) (Figure 10). The special monitoring network for small surface agricultural waters (streams) was designed in 1993 and optimised in 2005. Currently, the second optimisation is in preparation to interconnect this network with monitoring for Water Framework Directive.

AWMA monitoring of small surface waters for the Nitrates Directive is based on a network of three types of monitoring locations – main, operational and investigative. The main monitoring locations considers more important water bodies inside vulnerable and outside vulnerable zones, and sampling is performed regularly once a month. Sites of the main monitoring network are located at locations that are representative for monitoring water bodies according to the EU Water Framework Directive, with respect to water bodies with a greater proportion of agricultural land. Operational monitoring locations include important tributaries of water bodies or parts of water courses in vulnerable and not vulnerable zones. These operational sites are monitored in a regular cycle once every four years and emphasis is placed on areas with agricultural activities. Investigative monitoring locations, in combination with the previous two types of monitoring locations, are used particularly to determine the effectiveness of implemented measures in the Action Programme. These locations monitor the most critical period from the standpoint of leaching nitrates out of the soil into waters (October-March).

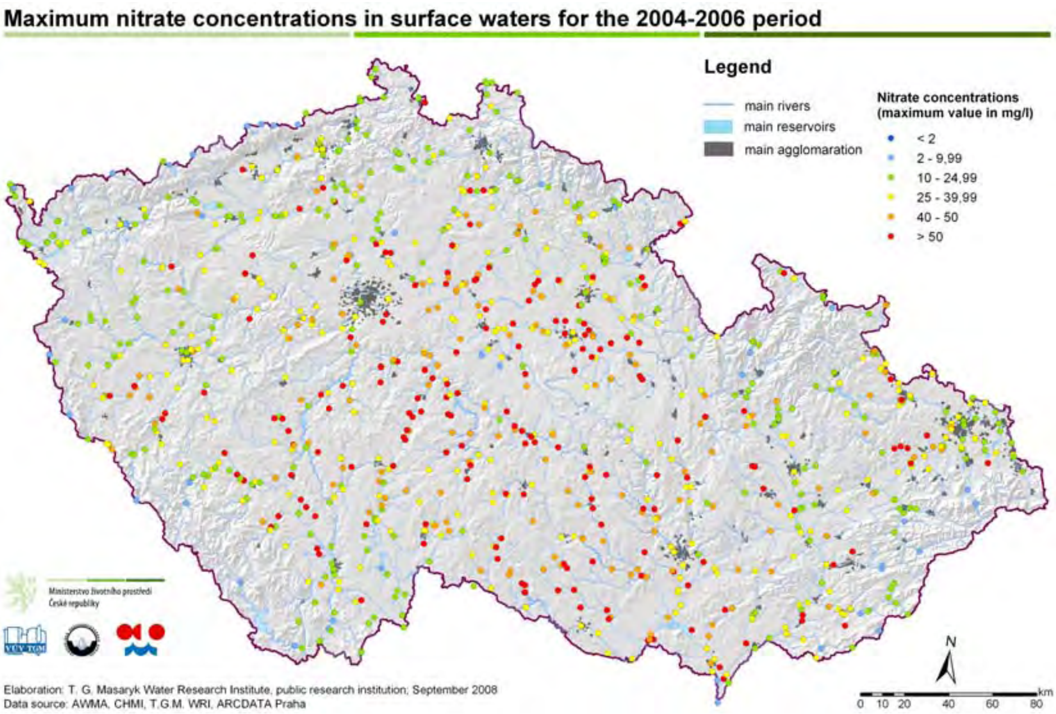


Figure 10 Maximum nitrate concentration in surface water in the 2004-2006 period (AWMA and CHMI monitoring network).

The quality of surface water is also monitored in the State observation network of the Czech Hydrometeorological Institute (CHMI), where measurements have been performed since the 1960s. This monitoring network is located on main rivers only.

The groundwater monitoring network for the Nitrates Directive is consisted of the state groundwater monitoring network of the Czech Hydrometeorological Institute (CHMI) and the monitoring points for drinking water abstractions and abstractions for other purposes (Figure 12). The monitoring of CHMI is to be performed at measuring sites that are representative for groundwater aquifers. The monitoring sites, consisting of springs and boreholes, are located throughout the Czech Republic, but have greater density in areas important for water management. The same monitoring network is used for monitoring according to the EU Water Framework Directive. At present, the State groundwater monitoring network is undergoing reconstruction. The new network is expected to be brought into operation in 2010. Groundwater is sampled each year in the spring and in the autumn (including sites with concentrations below 25 mg l^{-1}). The complete groundwater quality observation network encompasses 435 monitoring sites. In total 408 monitoring sites were selected for the Nitrates Directive (Figure 11), 331 for monitoring sites with unconfined groundwater and 77 sites with confined groundwater. Some sites representing very deep aquifers and also some sites immediately affected by point pollution sources were excluded.

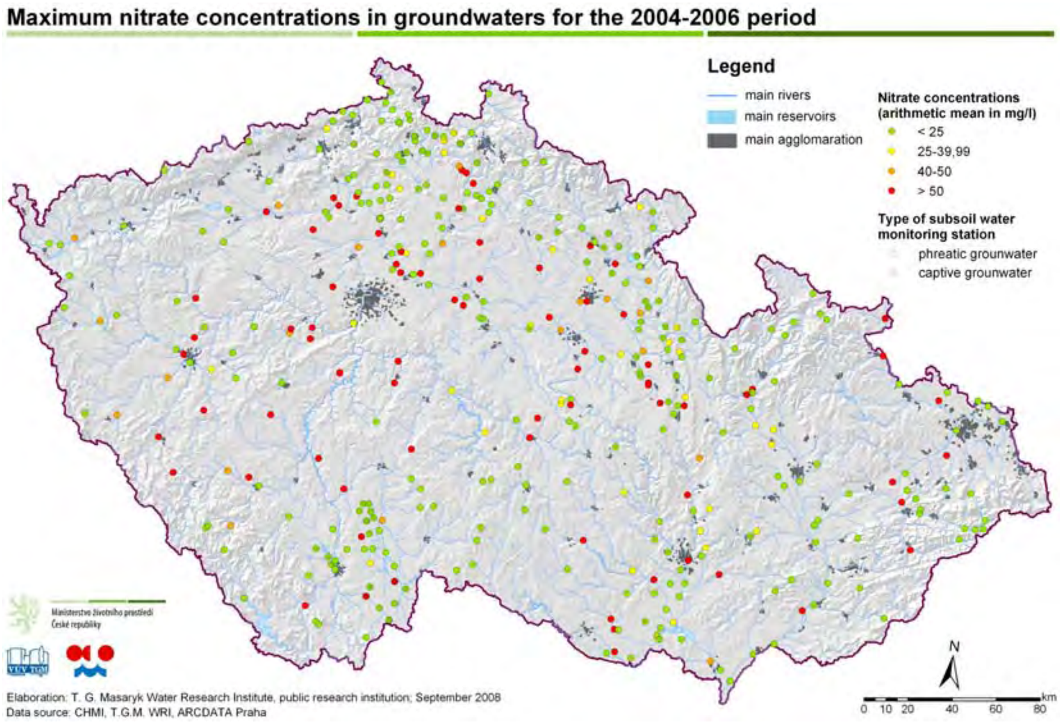


Figure 11 Maximum nitrate concentration in groundwater in the 2004-2006 period (CHMI monitoring network).

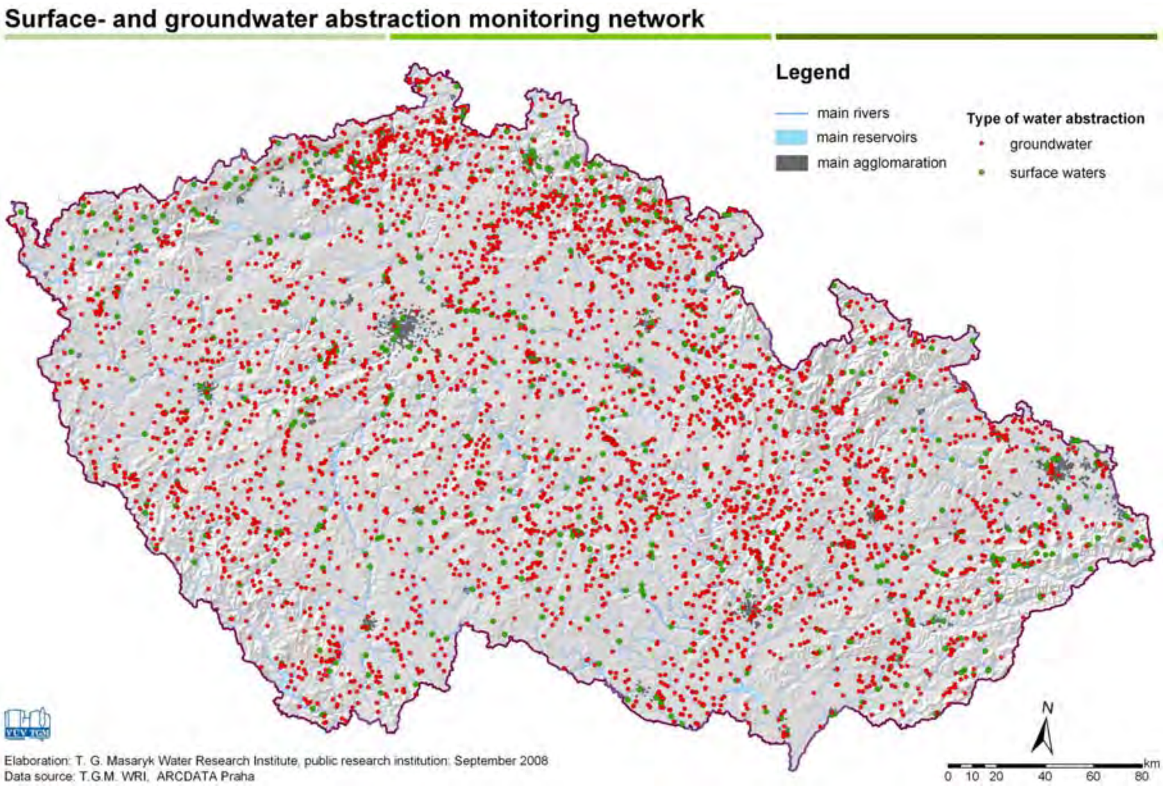


Figure 12 Surface and groundwater abstraction monitoring network (Source: private companies and municipalities).

A large number of data on groundwater quality originates from the very dense network of the drinking water abstractions and abstractions for other purposes. The data are collected according to Decree No. 428/2001 Coll., implementing Act No. 274/2001 Coll., on water supply and sewage systems (a total of 1,308 groundwater monitoring points) and according to Decree No. 431/2001 Coll., on the content of the water balance (total of 3,774 groundwater monitoring points). These data are used mainly for designation of NVZs and some of them should be used in the future for effect monitoring of Action Programme too.

2 Effect monitoring

2.1 Strategy for effect monitoring

As the NVZs according to the Nitrates Directive were designated in the Czech Republic for the first time as late as in 2003, the first four-year Action Programme was started at the beginning of the year 2004. The first Action Programme (2004-2007) was on approval mainly. The majority of the farmers was familiarised with the principles of the Action Programme and with the individual measures. Main attention was paid to critical procedures and gaps in farms. It turned out that main problem in NVZs was lack of storage capacity for liquid livestock manure in some farms and spreading the excess manure on agricultural land at inappropriate time. Surprisingly there was no problem with organic nitrogen application limit (170 kg N ha^{-1}) or winter vegetation cover and irrigation control.

It is clear that the Action Programme was running over relatively short period to be able to verify explicit effects of the measures and to distinguish its effects on the improvement of the water quality caused by the change of the Czech social system in 1989. Therefore the strategy for effect monitoring in the Czech Republic was proposed as multi-component system which will be able to detect general water quality trends independent of the agricultural sector as well as local changes caused by particular measures.

The strategy for effect monitoring is based on a multilevel approach that includes monitoring networks on national level as well as specific monitoring of small surface waters and groundwater in NVZs at close quarter to farms and monitoring or modelling of agricultural practice and nitrate leaching on selected farms and fields.

The effect monitoring of the Action Programme in the Czech Republic consists of:

- the overall monitoring network of surface- and groundwater, which is able to demonstrate long-term trends in pollution, inter-annual variability of nitrate concentration and surface water eutrophication;
- the investigative monitoring of small streams and groundwater objects inside NVZs, which is able to distinguish between heavily polluted and unpolluted parts of watersheds in NVZs and to differentiate between main sources of pollution (point and non-point);
- the agriculture field monitoring of surface- and groundwater in NVZs (under development), which is designed for observation of quick response of Action Programme measures on water quality in regions with very high

concentration of nitrate in the receiving waters; monitoring locations should be selected according to different soil and climatic condition;
- field studies on agricultural enterprises in NVZs and data collection and evaluation.

The Figure 13 represents the scheme of multi-level approach and the linkage between all components of the effect monitoring system.

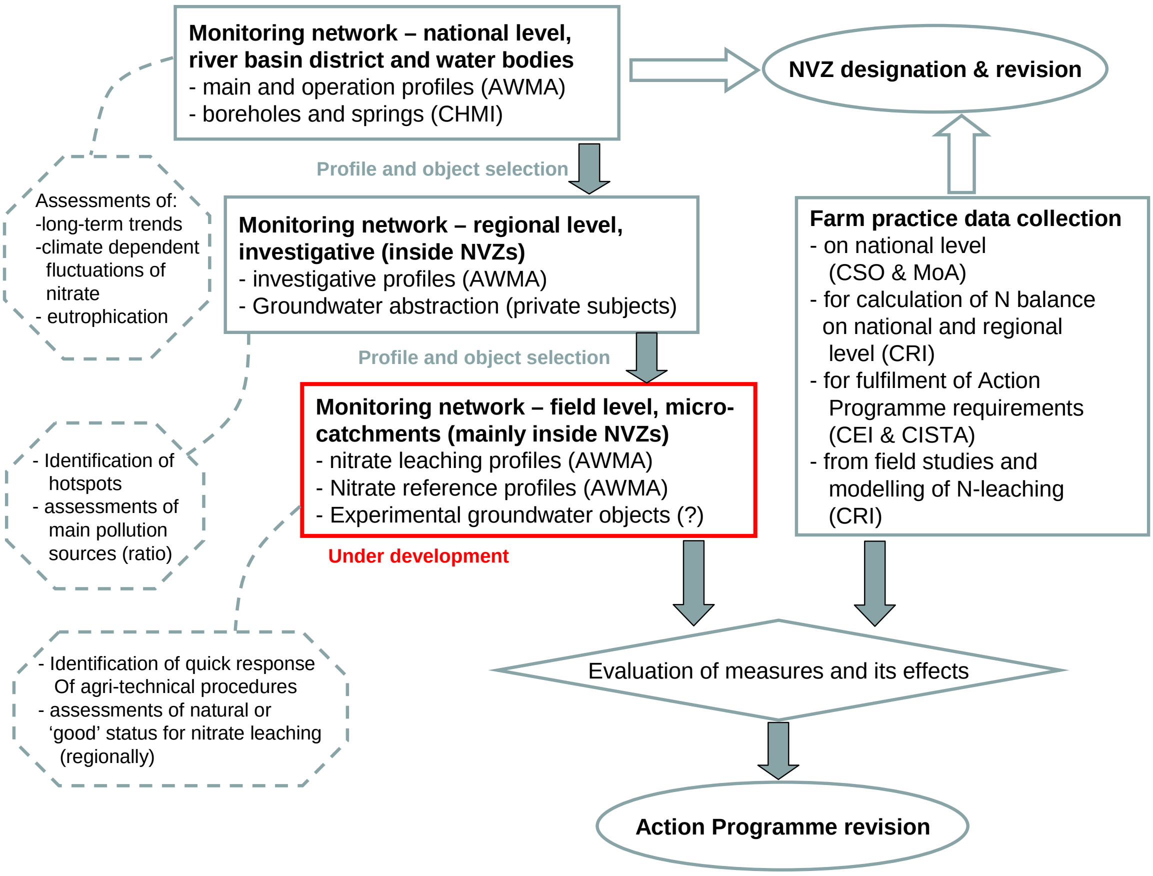


Figure 13 Schematic visualisation of the multi-level approach for the Action Programme effect monitoring in the Czech Republic.
AWMA – Agricultural Water Management Authority, CHMI – Czech Hydrometeorological Institute, CSO – Czech Statistical Office, MoA – Ministry of Agriculture, CRI – Crop Research Institute, CEI – Czech Environmental Inspectorate, CISTA - Central Institute for Supervising and Testing in Agriculture.

2.2 Detailed technical description of networks used for effect monitoring

Effect monitoring of the Action Programme in NVZs is composed of several levels (see previous section 'Strategy for effect monitoring'). Basic information about nitrate water pollution all over the Czech Republic is provided by sampling of main and operational monitoring locations of the surface water monitoring network of AWMA and sampling of boreholes and springs of groundwater monitoring network of CHMI (see section 'Overview of monitoring networks').

These long-time monitored locations and objects are suitable for trend analysis and for analysis of inter-annual changes in nitrate (phosphorus, et cetera) concentration in or outside of the NVZs. This is essential especially for evaluation of fertilisation trend after the change of the Czech social system in 1989 and the subsequent dramatic decrease of the livestock numbers in the 1990s. Some of these locations are used for identification of predominance of point or non-point sources of pollution by nitrogen. For this goal the ratio of nitrate nitrogen to total inorganic nitrogen is calculated. In case of strong predominance of nitrate nitrogen during the whole year (more than 95%) there is a clear dominance of non-point agricultural pollution. Monitoring locations in this monitoring level are predominantly fixed – main locations for surface waters and all groundwater objects; minor part – additional locations for surface waters are not fixed (mobile) (cycle every four years). Results from monitoring locations and objects of both monitoring networks are used for selection of the watersheds or hydrogeological structures where the actual nitrate concentrations are very high or trend is increasing. Especially these areas are main objects of the investigative monitoring network – the second monitoring level in the effect monitoring of the Action Programme.
The investigative monitoring network focuses on ‘hotspots’ in pollution of surface water and groundwater – monitoring locations and objects containing very high concentration of nitrates or showing increasing trend of the concentration. On the selected streams in the catchments of the ‘hotspots’ locations, sampling of water is carried out in the critical period for leaching of nitrate from fields – from October to March. From the results, streams or sub-watersheds are selected that have main influence on nitrate concentration. Monitoring locations in the investigative monitoring network are not fixed in space, they are re-allocated based on the development of the nitrate concentration in the ‘hotspots’ profiles.

Sampling and analytical determination for the first two monitoring levels for effect monitoring, the national and regional level (Figure 13), are executed under accreditation procedure in labs of five River Basin Management Authorities or in the private companies with valid accreditation.
Third monitoring level in the effect monitoring of the Action Programme (field level and micro-catchments) is at the moment under development. This monitoring level should be designed as the monitoring of the nitrate leaching from the fields and this monitoring network should be focused on direct effect of the fertilisation and agricultural practice on headwaters in NVZs. The monitoring profiles or objects should be selected in areas with high nitrate concentration using the results of the first two monitoring levels mentioned above. For the sampling, uncovered streams or drainage ditches connected with the individual fields should be selected. In regions with a high groundwater level or in regions with deep groundwater structures, adequate wells and boreholes or tiles drains should be selected for sampling. The main requirement for the selection of a monitoring point should be the absence of any point source of pollution upstream. In addition to monitoring points with a high nitrate concentration, a group of reference profiles connected to fields with a good agriculture practice and a low nitrate concentration should be selected. This reference profiles should have been suitable for identifying inter-annual changes and natural long-term trends in nitrate leaching.

Last but not least, monitoring effectiveness of the Action Programme consists of a number of activities connected to monitoring of the farming practices, modelling of nitrate leaching and evaluation of statistical data from agricultural census. This level of monitoring of the Action Programme includes:

- evaluation of the developments in soil nitrogen contents from the viewpoint of cultivated crops, agri-technical methods employed and weather conditions;
- field studies in agricultural enterprises in vulnerable zones (approximately 300 farms),
- monitoring of the impact of farming according to the Action Programme on water quality in the pilot territory of NVZs;
- evaluation of the impact of farming, soil and climatic conditions and weather conditions on water quality in the monitored measuring profiles and in 360 individual river basins in the Czech Republic;
- determination of the nitrogen flux in NVZs and modelling the migration of nitrogen in the soil and water for prediction of future developments in water quality;
- monitoring of the developments of farming methods in NVZs on the basis of data from the Czech Statistical Office, Records of Land According to User Relations and Livestock Records.

In connection with the monitoring of effects of the agricultural practice on water quality, two types of models are used for different purposes. The model CANDY (CArbon-Nitrogen-DYnamics) is used for simulation of nitrate leaching and concentration, and for examination of impacts of variable N inputs and outputs in respect to limit of nitrate concentration. For this model, data are used from pilot farms. The model CERES-Wheat is used to simulate crop production, N uptake and residual mineral N (Nmin) in soils. The model WOFOST was used to simulate demand for N of model catch crops under different dates of sowing. Besides the above mentioned models, use is made of simple leaching equations for indication of the risk of N leaching. This procedure is examined using data from monitoring (mineral N content) at pilot farms.

2.3 Data interpretation

As the last level of effect monitoring – field level in micro-catchments – has not yet been finished, it is not possible to interpret explicitly the results of the field studies and experiments. That is why all the previous studies focused on verification of the nitrogen balance on pilot farms, on monitoring of nitrogen movement in soil during critical winter period, and on checking of the obligatory requirements of the actual Action Programme in NVZs.

Nutrient balances seem to be a suitable tool for assessment of nutrient management in agriculture. The balance principle is also the basis of the majority of methodological instructions of plant nutrition. The soil surface balance is a simple calculation which results in a year difference between ‘controlled’ inputs of nutrients into soil and outputs from soil. The usual surplus of nitrogen connects soil surface balance with the nitrogen balance in the soil (accumulation), water (losses by leaching) and air (losses by denitrification and volatilisation). These losses are rather persistent but it is possible to minimise them by some agronomical measures. In the case of phosphorus and potassium balance, the surplus or deficiency is compensated in relation to the nutrient supply in soil (enrichment or mining of supplies).
The methods used for the calculation of the soil surface balance are based on the OECD approach. The calculation does not include not-harvested by-products nor removed straw in the input of balances because its nutrients return back into the soil in the form of manure. Only excrements of farm animals according

to particular categories are calculated in inputs. This approach is especially suitable for the calculation of surface balance at regional or state levels because it is not necessary (and in most cases it is not even possible) to distinguish between the various types of farm animal housing (with litter, without litter). The results of calculation of soil surface balance and categories of surplus on 287 farms in NVZs all over the Czech Republic (2009) are presented in Table 8 and in Figure 14.

Table 8 Soil surface nitrogen balance on evaluated farms in 2009.
Number of farms and amount of land (1,000 ha and percentage) per nitrogen surplus class in kg N ha^{-1} per year.

	Nitrogen surplus class (kg N ha^{-1} per year)											
	<30	30-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	>130	Total
Farms (number)	49	81	42	40	36	19	9	3	2	3	3	287
Land (×1,000 ha)	65.4	111.0	80.3	78.8	54.1	29.7	11.8	3.2	5.0	9.1	0.5	448.9
Land (%)	14.6	24.7	17.9	17.6	12.1	6.6	2.6	0.7	1.1	2.0	0.1	100

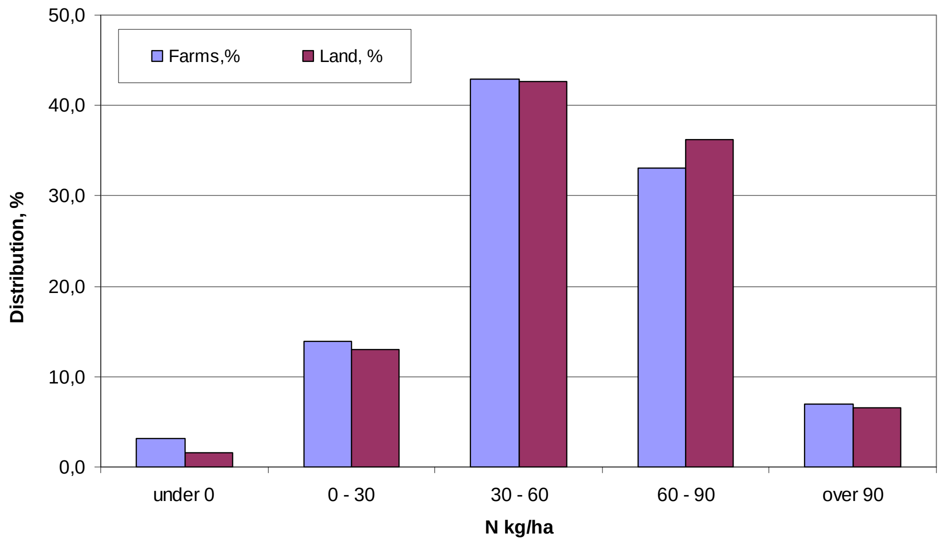


Figure 14 Nitrogen balance in the Czech Republic. Distribution of percentages of total evaluated farms per nitrogen balance class in 2009.

In effect monitoring, specific attention is paid to the effect of weather conditions on changes of inorganic nitrogen content in soil during the winter. The investigation focused on the study of the effect of variation in weather on the behaviour of nitrogen in the soil during winter season. The levels of mineral nitrogen were determined at 25 stations merged into 10 different variations according to previous crop, fertilisation and crops. The results showed that the inorganic nitrogen supply in the soil before the start of winter was moderate or good. After winter the inorganic N supply in soil was, on average, in top layer about 59 kg N ha^{-1} (that means, 70%) and in deep layer about 21 kg N ha^{-1} (that means, 39%) lower than in the autumn. The weather during the winter of 2008/2009 was relatively humid, though with normal temperatures. Overall, the average N losses from soil are significant, because most of the soil samples have shown in the autumn of 2008 an increased supply of inorganic N (see Tables 9 and 10).

Table 9 Soil mineral nitrogen content (Nmin) per soil layer in autumn 2008.

	Soil layer (cm)	No. of samples	$N\text{-}NO_3$ (mg kg^{-1})	$N\text{-}NH_4$ (mg kg^{-1})	N-min (mg kg^{-1})	Supply (kg ha^{-1})
Average	0-30	25	14.22	5.69	19.91	84
SD			12.63	4.72	16.46	69
Average	30-60	25	9.21	3.63	12.84	54
SD			13.32	2.30	15.44	65

Table 10 Soil mineral nitrogen content (Nmin) per soil layer in spring 2009.

	Soil layer (cm)	No. of samples	$N\text{-}NO_3$ (mg kg^{-1})	$N\text{-}NH_4$ (mg kg^{-1})	N-min (mg kg^{-1})	Supply (kg ha^{-1})
Average	0–30	25	3.16	3.03	6.19	25
SD			3.06	2.44	4.63	19
Average	30–60	25	5.75	2.54	8.29	33
SD			5.48	2.18	6.45	26

Action Programme requirements monitoring

A specific part of the effect monitoring multi-level approach is Action Programme requirements supervision.

Over 25,000 farms are in operation in the NVZs of the Czech Republic, of which 80% raise livestock. Each year, approximately 5% of the farms are visited within the framework of monitoring of the Action Programme and consulting in the area of water protection. Basic information on the number of farmers in NVZs is given in Table 11. Table 12 lists the fraction of farmers complying with the requirements of the Action Programme, determined on the basis of the consulting audit and a survey in agricultural enterprises (farms) in 2004-2007.

Table 11 Basic data on the numbers of farms in NVZs in the Czech Republic in 2007, at the end of the validity of the first Action Programme, after revision of NVZs.

Characteristic	Numbers
Number of farms in NVZs	25,157
of which, farms with livestock	20,125
Percentage of farms visited each year in NVZs	5%

The main problem consists in lack of storage capacity for liquid livestock manure in some farms. Liquid livestock manure is then spread on agricultural land at inappropriate times. The requirement on an increase in storage capacity was implemented in the second Action Programme for the 2008-2011 period. The new requirements on storage of livestock manure were implemented with postponement of performance to 2014 because of the high investment demands for meeting the requirements.

Table 12 Percentage of farms visited in NVZs who comply with the given requirements of the Action Programme and Code of Good Agricultural Practice in the 2004-2007 period [†].

Requirement	Percentage of compliance
Periods of fertilisation	95
Total livestock manure storage capacity	80
Rational fertiliser use	95
Physical and climatic conditions	95
Limitation of organic N (170 kg/ha)	100
Watercourse (water body) proximity	85
Rotation, permanent crop maintenance	100
Winter vegetation cover	100
Irrigation control	100
Soaked or frozen soils	80
Other	-

[†] Source: CRI, IAFI, surveys in agricultural enterprises, consulting audit.

Results of Action Programme

The results from the monitoring show that the main problem in vulnerable zones is lack of sufficient manure storage capacities. In 2007, based on the state of agriculture in the Czech Republic and results of survey on agricultural farms was achieved strategy to a contract for storage capacity for six months, when the assumption was found to meet these requirements on farms by the year 2014. On the basis of new observation obtained so far from the farms were found that for many farms to the storage capacity requirement, especially for farmyard manure for six months, will be very problematic, even when maintaining the effectiveness of the 2014. The reasons are mainly:

- territories of the number of farms are large and have increased the cost of distribution of farmyard manure to agricultural land;
- large representation of leased land in farms where it is not often possible to obtain a permit for the building from the owner of land.

During the transitional period more stringent restrictions are issued on the storage of manure on agricultural land compared with the first Action Programme, that means, no manure storage on ameliorated soils, steeply sloping land (that is, soils endangered by the erosion) near water courses and other surface water bodies. Light sandy soils and highly permeable soils located in NVZs cover approximately 16,000 ha. On these soils, storage of solid manure and organic fertilisers on agricultural land will be prohibited. In the Czech Republic, approximately 75% of agricultural land is cultivated by farmers who use more than 500 ha of agricultural land (source: LPIS system Ministry of Agriculture). Due to the large transport distances from the stables to the agricultural land, it is common practice to store manure in fields where it will be applied next year.

3 Discussion

The main limitation for the development of the effect monitoring approach in the Czech Republic is the later date of implementation of the Nitrates Directive, together with the start of the first Action Programme in 2004, compared to older

EU Member States. The measures of the first Action Programme were applied mainly as a test. The majority of the farmers was familiarized with the principles of the Action Programme and with the individual measures. Main attention was paid to the critical procedures and gaps in farming practices.

The short period since the first designation of NVZs and the persisting effects of the changes in livestock number and dramatic decrease of fertilisation in the 1990s do not make it possible to exactly identify direct effect of the Action Programme.

In spite of all these limitations, the current effect monitoring approach is prepared as a multi-level instrument which includes (or will soon include) three levels and consists of monitoring networks for surface water and groundwater and a group of activities connected to monitoring the farming practices, modelling of the nitrate leaching and the collection of data from the agricultural sector.

In the present period, data are not available from all levels of the water monitoring and monitoring of the farming practices. The missing relationship should be built up with third monitoring level of affected waters (field and micro-catchment scale) in 2010.

From the overall assessment of the water quality in NVZs, it can be concluded that from the end of the 1990s there is a change (decrease) in nitrate concentrations, especially in small agricultural streams. The positive trend in groundwater is not so clear. Regardless of generally a positive trend in water quality there is a range of regions or catchments where the nitrate leaching is always high or actually increasing. On that ground, the effect monitoring has been focused mainly on selection of hotspot catchments and corresponding adjustment of the regional Action Programme measures to achieve the target values of nitrates in waters.

The current problem of the effect monitoring is the requirement of the state authorities (Ministry of Environment and Ministry of Agriculture) for the reduction of the monitoring points in all state monitoring programmes. Main reason for this reduction was the lack of funds. For that reason, an optimisation of the nitrate monitoring network of AWMA has been made in 2009. The basis of this optimisation is consolidation of the nearby monitoring points of the nitrate monitoring network of AWMA and operational monitoring of River Basin Management Authorities. In the optimised monitoring, great emphasis was put on long-term monitoring of the water body representative monitoring points with the majority of the agriculture land in catchment and on the 'hotspots monitoring points' with very high concentration or increasing trend of nitrates. On the other hand, monitoring points were provisionally reduced where the nitrate concentration is below 25 mg l^{-1}. In addition, monitoring points affected by pollution from small point sources were removed from the network.

From a pilot project in small agricultural catchments without point sources of pollution, it follows that leaching of phosphorus from fields in condition of normal flow or base flow is very low (at most 0.05 mg l^{-1}). Therefore, the risk of eutrophication due to agricultural pollution (probably except for erosion run-off) is non-significant. The concentration of phosphorus in all agricultural catchments always increases dramatically in the presence of any source of point pollution. The effect of nitrogen on surface water eutrophication is, with only minor exceptions, irrelevant in the Czech Republic.

Finally we can summarise that a fully functional multi-level approach for the effect monitoring should be finalised probably in 2011 and its results might well be used for the revision of the Action Programme in the third cycle of implementation of the Nitrates Directive in the Czech Republic.

Acknowledgements
This work was partly funded by Research plan No. 0002071101 of the Ministry of Environment of the Czech Republic.

4 References

Act No. 254/2001 Coll., of June 24, 2001, on waters and amending some laws, as amended.

Act No. 274/2001 Coll., of July 10, 2001, on water-supply and sewer systems for public use and amending some laws (Act on Water Mains and Sewers).

Decree No. 274/1998 Coll., of November 12, 1998, on the storage and the method of use of fertilisers.

Decree No. 428/2001 Coll. of November 16, 2001, implementing the Act on water-supply and sewer systems for public use and amending some laws (Act on Water Mains and Sewers).

Decree No. 431/2001 Coll. of December 3, 2001, on the content of the water balance, means of preparation thereof and information for the water balance.

Government Regulation No. 103/2003 Coll., of March 3, 2003, on designation of vulnerable zones and on the use and storage of fertilisers and manure, rotation of crops and implementation of anti-erosion measures in these zones.

Hrabánková , A., Rosendorf, P. and Prchalová, H. (2002) Proposal for designation of vulnerable zones. Final Report of Task No. 1320, TGM Water Research Institute, Prague.

Rosendorf, P., Baudišová, D., Pavonič. M. (eds.) (2008) The effect of agriculturally managed river basins on the quality of out-flowing water, methodology of subproject 3617 for 2008. In: Mičaník, T. (ed.), Study and Protection of the Hydrosphere – study of relations and processes in the aquatic component of the environment, oriented towards the impact of anthropogenic pressures, their permanent use and protection, including legislative instruments. Research plan No. 0002071101, Methodology of work for 2008. TGM Water Research Institute, Prague.

Rosendorf, P. (ed.) (2003) Reduction of diffuse pollution of surface waters and groundwater in the CR, Project of the Council of the Government of the Czech Republic for Research and Development VaV/510/4/98, summary final report for the 1998-2002, 271 pp.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by Denmark

R. Grant[1], L. Thorling[2] and H. Hossy[3]

[1] *National Environmental Research Institute, Aarhus University, Vejlsøvej 25, DK-8600 Silkeborg, Denmark*
e-mail: rg@dmu.dk

[2] *The Geological Survey of Denmark and Greenland, Lyseng Allé 1, DK-8270 Højbjerg, Denmark*
e-mail: lts@geus.dk

[3] *Danish Environmental Protection Agency, Strandgade 20, DK-1401 København K, Denmark*
e-mail: hehos@mst.dk

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in Denmark and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). The Danish Monitoring Programme (NOVANA) originates from 1989 after the first Action Plan for the Aquatic Environment was passed by the Danish Parliament. Since then further Action Plans have been introduced with the aim of meeting the national goals as well as the requirements of the Nitrates Directive. Consequently the monitoring programme has been revised regularly. The NOVANA programme covers the entire aquatic environment, which means, agricultural catchments, streams, lakes, groundwater, coastal and marine waters. The programme is conducted in co-operation between the Environmental Protection Agency and the Agency for Spatial and Environmental Planning, the Geological Survey of Denmark and Greenland (GEUS), National Environmental Research Institute (NERI), and seven Environment Centres under the Agency for Spatial and Environmental Planning. The Programme is headed by a board with members from the involved parties. The NOVANA programme contains a network of permanent monitoring points, and long time series for nitrate concentrations in water are now available. Modelling is used for upscaling to the national level, for scenario analyses and for evaluation of action plans.

1 Introduction

1.1 General

Denmark is traditionally a farming country with about 60% of the entire country used for intensive farming with high livestock density. General characteristics of soil type and livestock density are shown in Figure 1. Agricultural activities are the main pollutant source for Danish groundwater, surface waters and seawaters. Since the mid 1980s a number of action plans with specific goals have been implemented in Denmark to reduce nutrient leaching from soils. When the Nitrates Directive was adopted in 1991, Denmark designated the whole national territory a vulnerable zone.

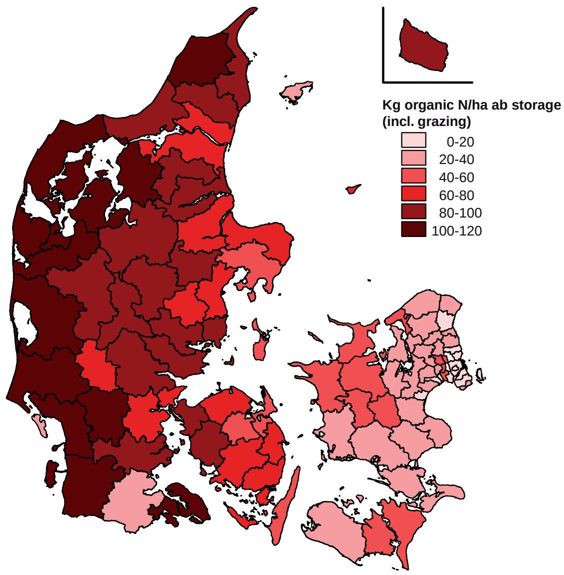


Figure 1 Left: Danish soil types. Dark (brown) colours indicate the highest clay contents. Green colours indicate peaty soils and yellowish indicate fine sands. Sandy soils occur primarily in Jutland.
Right: distribution of livestock manure production in kg N per hectare of agricultural land in each municipality in 2005.

1.2 Environmental goals and measures

Goals

The Danish Parliament agreed on the first Action Plan for the Aquatic Environment (APAE I) in 1987 and on APAE II in 1998, and thereby on fulfilment of the Nitrates Directive. The aim of these plans was to reduce nitrate leaching by 49%. The final evaluation of the APAE II in December 2003 showed a reduction of the yearly total nitrogen discharge from agriculture of around 149,000 tonnes N. This corresponds to a reduction of 48% compared to the baseline in the mid 1980s of 311,000 tonnes N.

In 2004 the Danish Parliament agreed upon APAE III, 2004-2015. This plan encompasses broad efforts to reduce the impact of agricultural activities on the aquatic environment and on nature. APAE III focuses on the surplus of phosphorous in the agriculture sector, the aim being to reduce the surplus by 50% compared to 2001/2002. Nitrate leaching from agriculture is to be reduced by further 13% compared to 2003. The targets must be fulfilled by 2015.

In 2008 a mid-term evaluation of APAE III showed that the nitrate leaching was not reduced as expected. In 2009 the Danish government launched the Green Growth Plan, which also deals with the problems formerly encountered in achieving expected goals in APAE III.

Measures

The Action Plans for the Aquatic Environment (APAEs) are a comprehensive regulation regarding the aquatic environment. They precede the implementation of the Nitrates Directive, as the first plan was adopted in 1987. The Action Plans include the Danish code of good agricultural practice as mandatory measures and further restrictions in the use of nutrients. The Action Plans deal with nutrient-related measures, for example, mandatory fertiliser accounts, improved utilisation of nitrogen in manure, reduced nitrogen standards for crops as compared to the economic optimum, and area-related measures, for example, re-establishment of wetlands and afforestation. An overview of the action plans are given in Table 1.

Up until 2003 the Action Plans only included measures to reduce nitrogen loads from agriculture. Action Plan III from 2004 was expanded to include measures for phosphorus, such as a specific tax on inorganic fodder-phosphate, research on improved utilisation of phosphorus in fodder and financial support for establishment of buffer strips.

With the Commission Decisions 2002/915/EC, 2005/294/EC and 2008/664/EC cattle holdings in Denmark are allowed to derogate from the general rules in the Nitrates Directive. If 70% or more of the area available for manure spreading is cultivated with beets, grass or grass catch crops, cattle holdings can apply manure compared to 2.3 livestock units (LU) per hectare per year. In 2007 3.2% of the total number of agricultural holdings in Denmark made use of the derogation. The number of livestock units on these holdings corresponded to 9.5% of the total number of livestock units, and arable land encompassed by the derogation corresponded to 4.0% of the total arable land.

1.3 Overview of nitrogen and phosphorus loads and surpluses

The nitrogen and phosphorus surpluses (farm gate balances) are used in Denmark as indicators for the development of nutrient loads from agriculture at the national level. The surpluses have been reduced steadily since the Danish Actions Plans were first introduced in 1987 (Figure 2). However, from 2003 this trend has levelled off. The total reduction in surpluses of nitrogen and phosphorus amount to 40% and 57%, respectively, over the period 1988-2007.

Figure 2 shows a temporary increase in the surplus of both nitrogen and phosphorus in 1992-1993. This was partly due to a severe drought in 1992, resulting in low harvest yields.

Table 1 Overview of the Danish Action Plans for the Aquatic Environment (APAE).

Year of publication	Sub-components of the Action Programme	Principal measures taken under the APAE
1985	NPo Action Plan to reduce N and P pollution NPo = with focus on nutrients (N, P) and organic matter (o) from agriculture and sewage	Target: general reduction of N and P • Minimum 6 month slurry storage capacity • Maximum stock density 2 Livestock Units ha^{-1} • Various measures to reduce run-off from silage clamps and manure heaps • A floating barrier mandatory on slurry tanks
1987	Action Plan on the Aquatic Environment I (Action Plan I)	Target: 49% reduction in nitrate leaching compared to mid 1980s • Minimum 9 months slurry storage capacity • Ban on slurry spreading manure between harvest and 1 February • Winter green fields required (percentage increasing from 45% to 65%) • Mandatory fertiliser and crop rotation plans • Mandatory incorporation of manure maximum 12 hours after application
1991 1996	Action Plan for Sustainable Agriculture Follow-up	• Mandatory fertiliser and manure account • Increased utilisation rates for manure
1998	Action Plan on the Aquatic Environment II (Action Plan II)	• Catch crops (6%) • Nitrogen standard rates for use at individual field level set at 10% beneath economic optimal application rate • Tightened livestock density demands • Increased utilisation rates for manure • Subsidies for: forestation, organic agriculture and wetlands
2001 2001	Midterm evaluation of Action Plan on the Aquatic Environment II Ammonia Action Plan	• Reduced fertilisation norms to grassland and restrictions on additional N application to bread wheat (2000) • Ban on slurry application using spreader plates (2001) • Mandatory covering of all dung heaps
2003	Final evaluation of Action Plan on the Aquatic Environment II	The target of 49% reduction in nitrate leaching was attained
2004	Action Plan on the Aquatic Environment III	Target: 13% reduction in nitrate leaching and 50% reduction in phosphorus balance compared to 2003, 50,000 ha buffer zone • Catch crops (10-14%) • Subsidies for: forestation, environmental friendly agriculture and wetlands • Tax on inorganic fodder phosphate • Conversion of set-aside to buffer strips along streams with extra subsidies

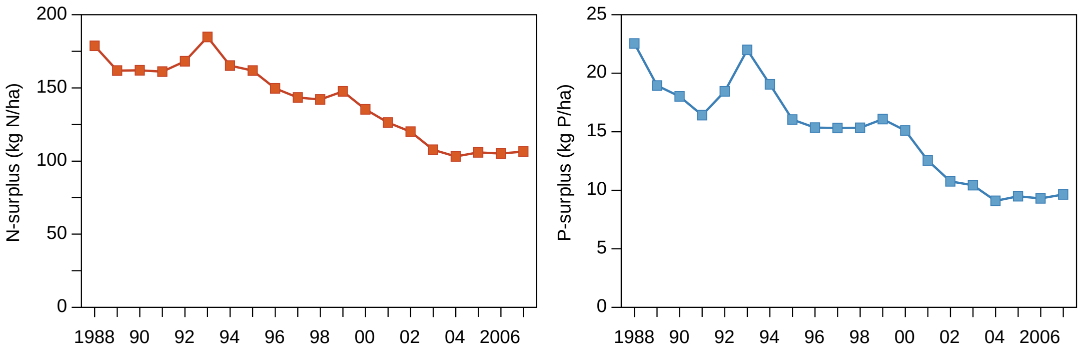


Figure 2 Average nitrogen and phosphorus surplus in Denmark, 1988-2007. The surplus represents the farm gate balance.

Figure 3 shows that the input of organic nitrogen and phosphorus fertilisers has been almost constant throughout the period 1990-2007 whereas the input of inorganic fertilisers has decreased substantially (47% for nitrogen and 67% for phosphorus). This is due to a better utilisation of the organic manure, allowing a reduction in the input of inorganic fertilisers without any reduction in harvest yields.

Figure 3 also shows a starting decrease in phosphorus content of organic manure from 2003 onwards. This is a result of research work on improved utilisation of phosphorus in fodder by application of phytase and thereby decreasing the application inorganic fodder phosphates.

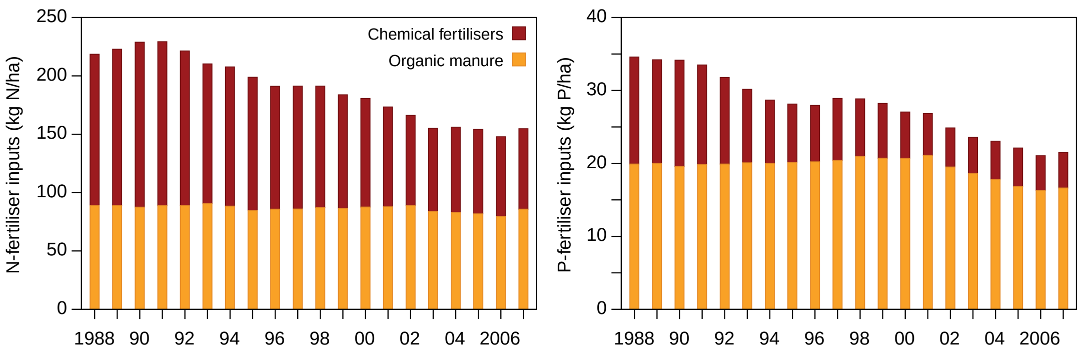


Figure 3 Average input of inorganic and organic nitrogen and phosphorus fertilisers in Denmark, 1988-2007.

1.4 Overview of trends in nitrate, nitrogen and phosphorus concentrations

Nitrogen

The National Monitoring programme allows a continuous evaluation of the nutrient transport and the state of the aquatic environment.

Nitrate concentrations in the root zone water (1 m below soil surface) from five small agricultural catchments are shown in Figure 4. Although the flow weighted concentrations of nitrate vary from year to year a significant decrease since 1990 has been documented. The decrease is higher for the sandy soils than for the loamy soils. A similar decrease is found for the upper groundwater (1.5-5.0 m) for the sandy soils but not for the loamy soils.

The flow weighted concentrations of total nitrogen in 63 streams draining agricultural catchments have decreased significantly by 31% during the period 1989-2007 (Figure 5). However, the concentrations have been almost constant during the last 4-5 years.

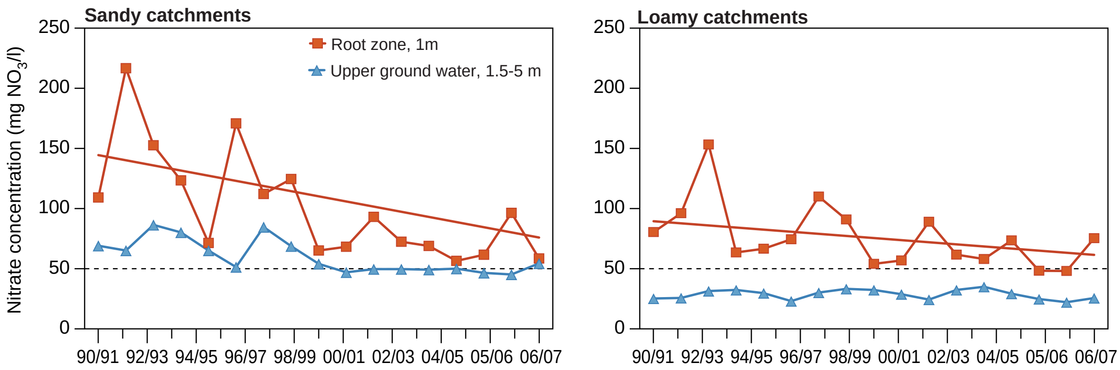


Figure 4 Annual flow weighted nitrate concentrations in root zone water and annual average nitrate concentrations in upper groundwater, the Agricultural Catchment Monitoring Programme 1990/1991-2006/2007.

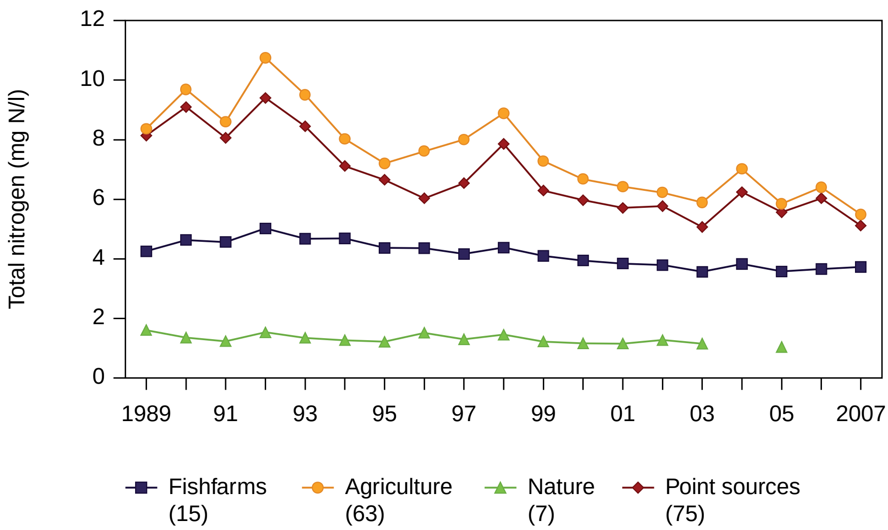


Figure 5 Trends in annual flow weighted concentrations of total nitrogen in streams since 1989 (the Stream Monitoring Programme).
The number of monitored streams draining different categories of catchments are shown in brackets. In the point source catchments, agriculture is still the main contributor to nitrogen transport.

Also for the marine waters a decrease in concentrations of total nitrogen has been documented (Figure 6). The decrease has mainly occurred from 2000 onwards and is the highest for the estuaries and near coastal waters. In the open marine waters the reduction is lower.

Phosphorus

Phosphorus concentrations in 63 streams draining agricultural catchments have on average been reduced by 12% (± 9% points) since 1989 (Figure 7). However, both reductions and increases have been observed. Phosphorus emissions from agricultural catchments include losses from fields, and point source losses from scattered dwellings and small towns. In 2004 these diffuse losses amounted to about 40% of the total emission of phosphorus to the marine waters, but large variations occur between years depending on the climate.
In the marine waters the concentrations of total phosphorus have been reduced by almost 50% due to the removal of phosphorus from sewage water at the beginning of the 1990s due to the action plans.

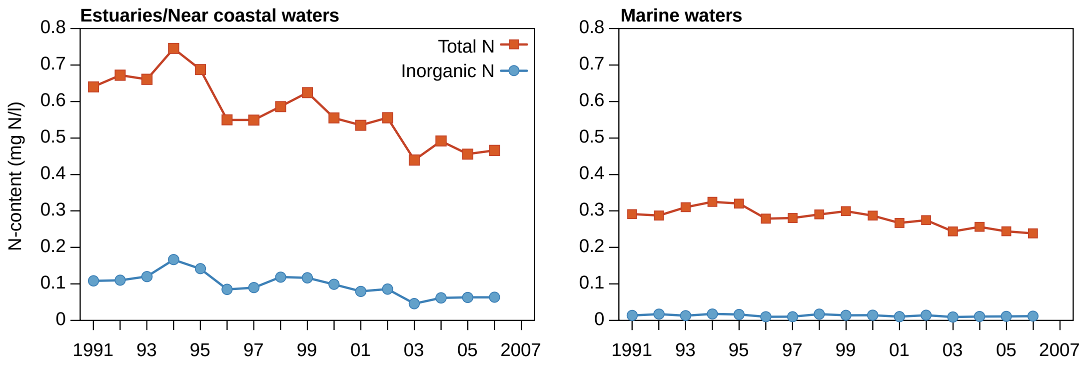


Figure 6 Concentrations of total nitrogen and nitrate nitrogen in estuaries/near coastal waters and open marine waters, 1991-2006. (Source: the Marine Monitoring Programme)

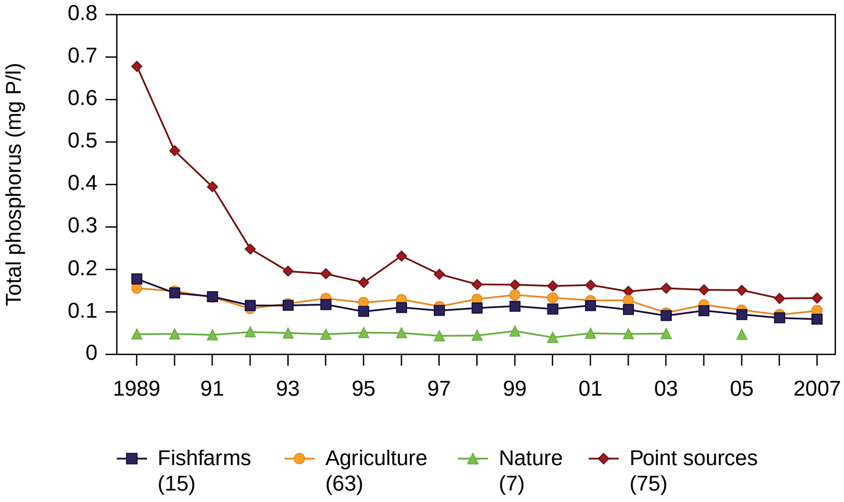


Figure 7 Trends in annual flow weighted concentrations of total phosphorus in streams since 1989. (Source: the Stream Monitoring Programme)
The number of monitored streams draining different categories of catchments are shown in brackets.

1.5 Overview of monitoring networks

The Danish National Monitoring Programme for the Aquatic Environment was established in 1989/'90, covering all elements of the environment (Kronvang et al., 1993). It has been revised regularly, the present programme, NOVANA (national monitoring programme for water and nature) running from 2004 till 2010. The detailed strategies for this monitoring are outlined by Svendsen et al. (2005). The main structure of the programme has been maintained throughout the entire period, thus providing long time series of measurements as shown in the previous section.

2 Effect monitoring

2.1 Strategy for effect monitoring

The NOVANA programme is directed by political and administrative demands, to monitor EU directives (including the Nitrates Directive), national regulations, conventions, et cetera. This means that all monitoring must relate to environmental goals.

The NOVANA programme is part of the strategic environmental planning. The monitoring serves to document if the state of the water and nature environment is developing in the right direction and if the environmental goals are fulfilled. It also serves as the scientific base to identify demand for new activities.

2.2 Detailed technical description of networks used for monitoring

Organisation

In 2007 a major structural change in the public sector was introduced in Denmark, also implying changes in the organisation of the NOVANA programme.

The NOVANA programme is conducted in co-operation between the Environmental Protection Agency (EPA) and the Agency for Spatial and Environmental Planning (ASEP), the Geological Survey of Denmark and Greenland (GEUS), the National Environmental Research Institute (NERI), and seven Environment Centres under ASEP.

The programme is headed by a board with members from the involved parties. Chairman and secretariat are from the Agency for Spatial and Environmental Planning. The board has four annual meetings and decisions are taken in consensus. All decisions on economy must be taken by the board.

Topic Centres are bodies with special knowledge on the relevant media. The seven topic centres cover the fields of atmosphere, leaching from cultivated areas, groundwater, freshwater, seawater, point sources, biodiversity and terrestrial nature. The majority of the topic centres is situated within NERI, groundwater is covered by GEUS and the EPA covers point pollution.

The topic centres are responsible for the scientific level of the monitoring. They develop guidelines, collect the monitoring data and ensure the national database on the topic. Under the board seven steering groups, in co-operation with the topic centres manage the programme. The Topic Centres provide annual reports for their specific topics.

The Environment Centres under ASEP are the implementing bodies that establish and maintain the monitoring facilities, assure the sampling, chemical analyses and data reporting to the topic centre.

Data from the laboratories are returned in a special format (STANDAT) that is readable by all partners in the programme. However, Common Databases, some with public access, and Systems for online reporting are being developed. These databases are hosted by GEUS and NERI, and they support detailed quality control of data.

In the following the network monitoring for agricultural catchments, streams and groundwater is described in further detail.

Agricultural catchment monitoring

The monitoring is carried out in five small agricultural catchments which have been chosen to represent the main soil types and the variation in livestock density, crops and climatic conditions. The monitoring encompasses intensive collection of information on agricultural practise at field and farm level by interviews. The monitoring employs direct measurements of soil water, drainage water, upper groundwater and stream water (Table 2). A schematic diagram of this strategy is shown in Figure 8.

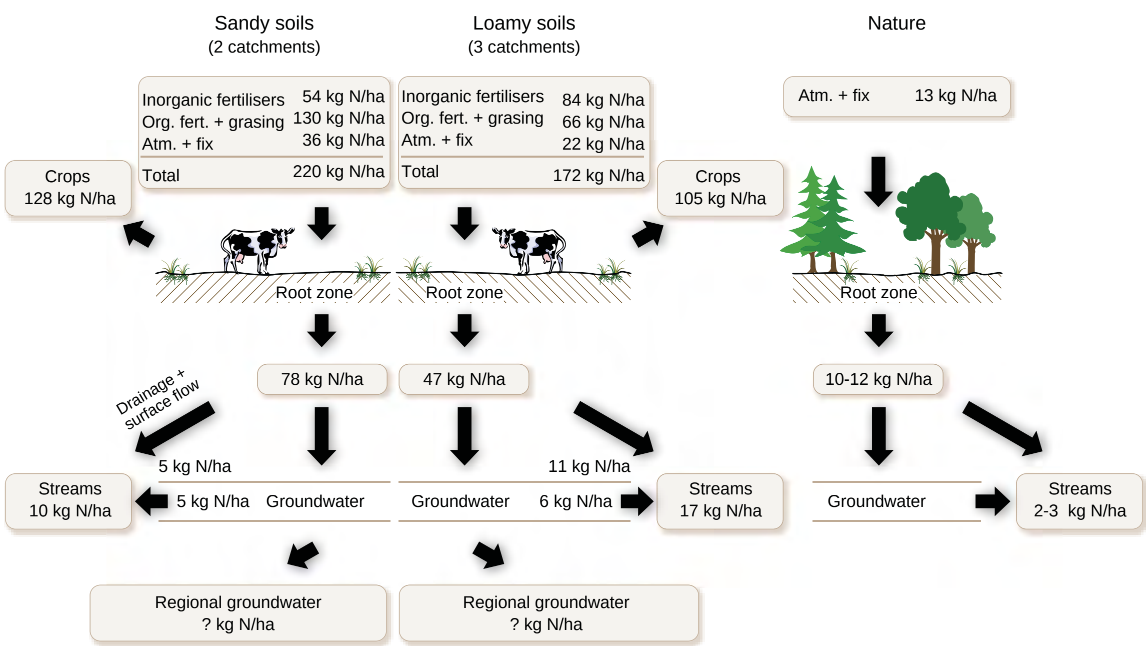


Figure 8 Diagram of the nitrogen circulation in sandy and loamy agricultural catchments and for nature catchments for the years 2002/2003-2006/2007. The Agricultural Catchment Monitoring Programme.

Table 2 Overview of Danish national monitoring programme for water and nature (NOVANA), 2004-2009.

	Number of stations	Sampling frequency (Sampling frequency per stations per year)
Agricultural catchment monitoring (five catchments)		
Interview on agricultural practises in the catchment	5	1
Root zone soil moisture (1 m)	31	30
Drainage water	5	26
Upper groundwater	100	6
Streams	5	26
Stream monitoring		
Nutrient measurements		
Uncultivated rural catchments	7	12-26
Agricultural catchments without point sources	63	12-26
Agricultural catchments with point sources	75	12-26
Catchments with freshwater fish farms	15	12-26
Ecology measurements		
Intensive	50	1
Extensive	800	1 every 3 years
Lake monitoring		
Intensive programme for lakes > 5 ha	20	12-26
Extensive programme for lakes > 5 ha	204	1 every 3 year (6 samples)
Extensive programme for lakes, 0.1-1 ha	354	1 every 6 year (5 samples)
Extensive programme for small lakes and waterholes, 0.01-1 ha	456	1 every 6 year (only biological measurements)
Marine monitoring		
Inland waters [1)]	26 (1-2 depths)	20-26 per year in 2 out of 3 years
Open waters[1)]	26 (3-23 depths)	3
Inland water, intensive[2)]	7	20-52
Open waters, intensive[2)]	9	6-35
Groundwater		
Older groundwater (> 60 years old)	350	1/6
Younger groundwater (< 60 years old)	1,050	1 - 1/6
Data from Water works wells	5,000	1/3 – 1/5

1) Profile measurements, chlorophyll-ɑ, nutrients, oxygen.

2) Profile measurements, nutrients, oxygen.

The catchments may be regarded as study areas, the main objectives are:
- to determine and evaluate the current agricultural practice;

- to establish time series of nutrient concentrations in waters of agricultural catchments representative of Denmark;
- to extrapolate observations to the national level;
- to set up models for the nutrient circulation in the entire hydrological pathway of agricultural catchments;
- to carry out scenarios on the effect of measures introduced in agriculture, to carry out scenarios of climate changes, et cetera.

The results from this programme have provided data and information specifically for evaluation of Danish Actions Plans and for justification of the Danish derogation from the Nitrates Directive.

Groundwater

Groundwater monitoring in Denmark is based on information from 75 groundwater monitoring areas typically with 20-25 monitoring screens in each area (Figure 9), five agricultural catchments and about 5,500 water supply wells. As a whole they provide the most qualified information on groundwater chemistry and pollution at national scale. The groundwater monitoring programme is designed to monitor phreatic groundwater only, and about 75% of the monitoring is on groundwater dated by CFC to be recharged after 1940.

Approximately 17% of the monitoring screens have nitrate concentrations above the maximum admissible concentration (MAC: 50 mg l^{-1} nitrate) for drinking water, and almost 50% of the screens have nitrate concentrations above 5 mg l^{-1}. Thus, about 33% of the groundwater holds contents below the MAC. The rest of the screens are monitoring nitrate free, reduced groundwater.

In the monitoring areas the focus has turned towards the upper groundwater over the last four years, and about 250 new observation wells have been established. The new screens are typically placed in the upper 5-10 m of the aquifer (10-20 m below surface).

Stream monitoring

The stream monitoring programme is designed to provide estimates of water and nutrient transport to lakes and marine water, and to follow the trends in stream quality. The monitoring programme also elucidates the relationship between inputs from the catchments and nutrient concentrations in the streams.

A large number of marine loading stations and lake inflow stations have been established. However, they do not cover the entire country and inputs from unmonitored catchments have to be calculated separately based on information about their size and characteristics. The sources of the nutrient transport are quantified, based on knowledge of wastewater discharges and land use in the individual catchments. Nutrient turnover in the streams and lakes is determined by such means as calculating denitrification and phosphorus retention in lakes.

The monitored streams can be grouped according to the natural and anthropogenic conditions in the catchments (Table 2). Thus, the monitoring results can be used to assess the current state and trends in water quality and nutrient transport for each of the catchment loading category networks (Figures 5 and 7).

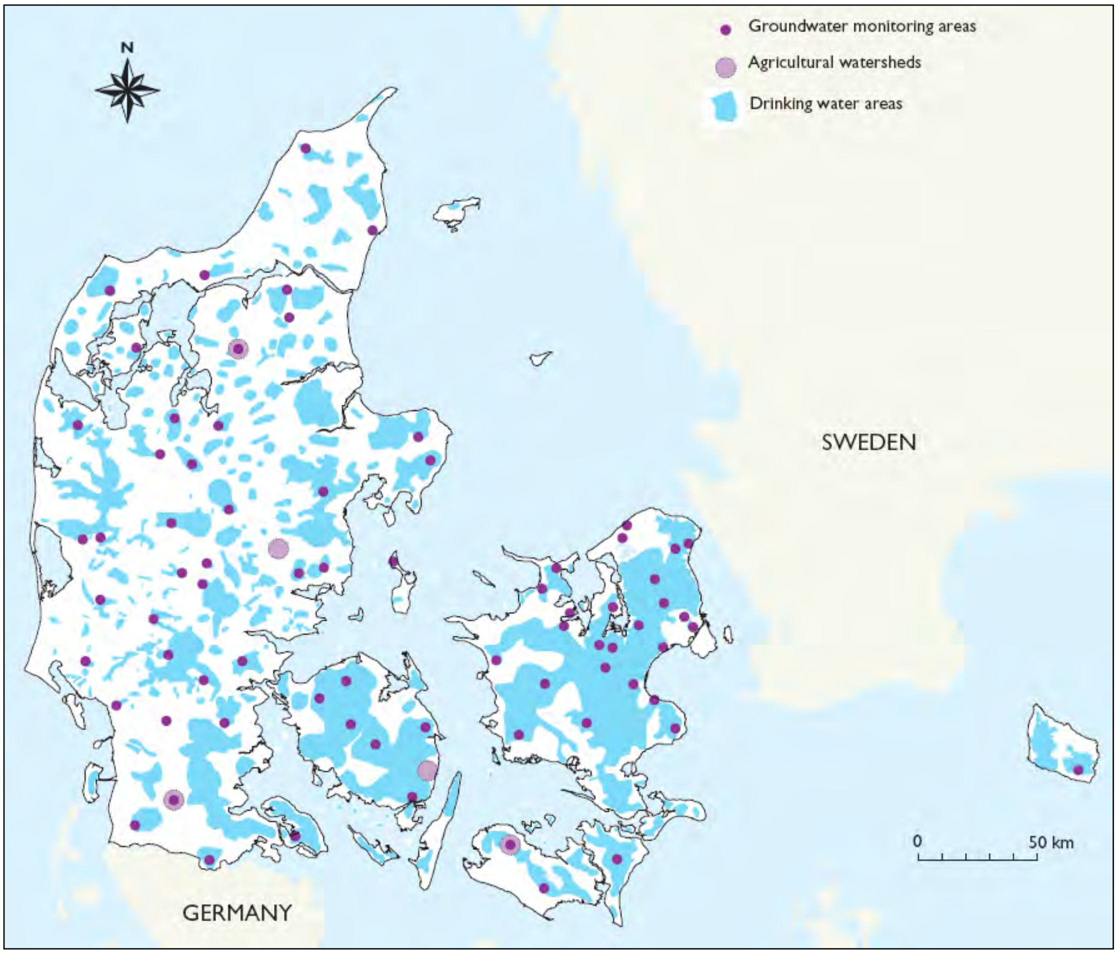


Figure 9 Groundwater monitoring areas in Denmark, status 2009 (Jørgensen and Stockmarr, 2009).

Average nitrogen concentrations in stream water at monitoring stations are shown in Figure 10. It may be seen that nitrogen concentrations are higher on the loamy soils of east Denmark than on the sandy soils of west and north Denmark. This is because water in the loamy soils drains through the upper soil layers where nitrate reduction is low. On the sandy soils the hydrological pathways are much deeper, often through nitrate reducing aquifers. Hence nitrate reduction is much more pronounced. These pathways are supported by observation from the Agricultural Catchment monitoring programme (Figure 8).

Additional data

The Ministry of Food, Agriculture and Fisheries collects large numbers of agricultural data for administrative (cross compliance) purposes. There are three main sources: fertiliser accounts, livestock register and general agricultural register.

Fertiliser accounts

The Danish Action Plans involve tight regulations on nutrient utilisation employing nitrogen quotas and requirements to the effectiveness of nitrogen utilisation in organic manure. All farmers are given a nitrogen quota based on nitrogen fertiliser standards for each crop. The nitrogen standards refer to the effective nitrogen, that means, nitrogen immediately available for plant growth. All nitrogen in inorganic fertilisers is regarded as effective. For organic manure only part of the nitrogen is readily available for plants. The legislative requirement to utilize nitrogen in organic manure are considered as effective (Table 3). The use of inorganic nitrogen fertiliser and required utilisation of nitrogen in organic manure must not exceed the nitrogen quota at the farm level. We can write this as follows:

$$\text{Inorganic fertiliser N} + \text{Required utilisation of N in organic manure} \leq \text{Farm N quota}$$

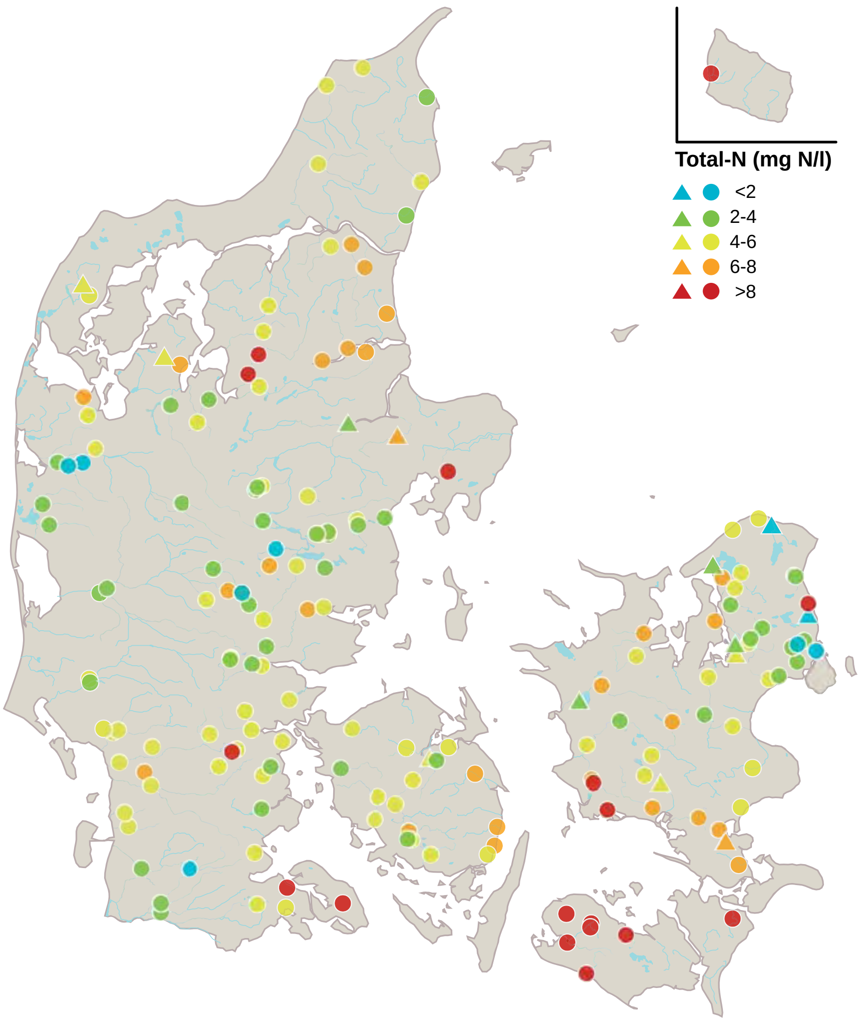


Figure 10 Concentrations of total nitrogen concentrations in streams in 2007. Concentrations are shown as yearly flow weighted concentrations.
Circles represent monitored catchments; triangles represent catchments where concentrations are calculated.

Table 3 Required efficiency (%) of nitrogen utilisation in organic manure.
The required efficiency has been tightened several times throughout the Action Plan periods.

	1994	2000	2003
Pig slurry	55	65	75
Cattle slurry	50	60	70
Farmyard manure	40	55	65
Deep litter	30	35	45

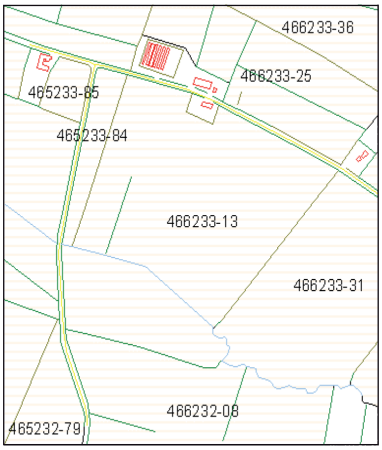
In additions, farmers are obliged to grow catch crops on a certain percentage of the area (Table 1).

In order to ensure that farmers comply with these regulations, all farmers must submit a fertiliser account to the Plant Directorate under the Ministry of Food, Agriculture and Fisheries. The accounts must include information at the farm level on:
- total arable land on the farm;
- arable land available for application of livestock manure;
- data on plant cover;
- type and number of livestock (LU);
- production of livestock manure (kg N);
- consumption of livestock manure, including manure contracts;
- consumption of fertilisers and organic matter other than livestock manure;
- the farm's nitrogen quota, and
- information on whether the farmer has used the derogation or not.

In 2007 about 51,000 farmers reported to the Plant Directorate. The data are stored in a 'fertiliser account' database. This submission has since 2006 been integrated with the Central Husbandry Register (CHR) which is the central database used for registration of holdings and animals. The integration with the CHR has led to a very reliable registration of animal units and the use of manure in the fertiliser accounts, due to the fact that information on animals on the farm is printed in the fertiliser accounts in advance.

Central Husbandry Register
All livestock farms supply information on their farm size, and number and type of animals.

General agricultural register
All farmers applying for EU single payment subsidies supply information on their crops, the data being linked to geographical blocks as shown in Figure 11. Denmark is divided into about 300,000 blocks and into about 750,000 fields.



Block system

- Center for Block 466233-*13* is given by the coordinate: 466*1*00 meter E 6233*3*00 meter N
- 300,000 blocks
- 1-10 fields per block
- Average 10 ha per block

Figure 11 Example of Field Block Map of Denmark.
All farmers applying for EU single payment subsidies supply information on their crops with reference to the Block number.

2.3 Data interpretation

Farming data

Farm registry data are widely used in Denmark for planning and evaluation purposes. In order to make use of the data the three registries for crops, fertiliser and livestock respectively are combined and the total amount of fertilisers at farm level are divided onto individual blocks/fields. In doing so, information of agricultural practice from the Agricultural Catchment Monitoring Programme is taken into consideration. Furthermore, standard values for harvested crops are linked to this data set taking account of the region and soil type. The final data set is used partly for modelling nitrate leaching, partly for working out nutrient balances at the field level.

Nutrient balances

Nutrient balances are key indicators in the evaluation of the effect of agricultural measures. In Denmark two concepts are used:

Farm gate balance at the national level
This balance estimate is based on inputs to the agriculture sector (fodder, inorganic fertilisers, deposition from the atmosphere and nitrogen fixation) and outputs from agriculture (crops, animal products). This is a robust estimate as all the products are imported and/or exported and therefore registered in National Statistics. Nitrogen fixation is likely to be the most uncertain variable. The balance (= surplus) represents the entire nutrient loss from agriculture, that means, ammonia volatilisation from livestock kept in buildings and from fields, nitrate leaching from the fields, denitrification and possibly a change in the soil pool. This estimate is used as a means of evaluating the National Action Plans.

Field balances at catchment/regional level
This balance estimate is based on inputs of inorganic and organic fertilisers to the fields, deposition from the atmosphere, and nitrogen fixation, and on

outputs by harvested crops. This estimate is much more uncertain than the farm gate balance, particularly due to the difficulty in estimating the true production of nutrients via organic manure. Furthermore, the balance does not include the ammonia volatilisation from the livestock kept in buildings. Field balances are used for evaluation of agricultural measures in catchment and/or regions as statistical data are not available for working out farm gate balances at this level.

Modelling nitrate leaching from the root zone

The primary goals of the Danish Action Plans are to reduce nitrate leaching from the root zone. Measurements of nitrate leaching are performed at selected sites (soil water stations – Table 2) only, therefore modelling nitrate leaching is an important part of the data interpretation.

Model development
Data on agricultural practise at field level and simultaneous measurements of root zone leaching form the basis for establishing empirical statistical models. Thus, the widely used NLES (Nitrogen Leaching EStimator) model in Denmark has been developed based on data partly from the Agricultural Catchment Monitoring Programme, partly from other research programmes in Denmark. The model is updated regularly, the latest version is of 2008 (Kristensen et al., 2008). The model yields an annual leaching value and includes parameters such as major soil type, organic matter in soils, annual percolation from the root zone divided into three seasons, the main crop, the previous crop, the crop in the following autumn and winter, application of inorganic and organic fertilisers divided into two seasons (spring/summer and autumn/winter), grazing and N fixation.

Upscaling from point measurements to catchment level
In the Agricultural Catchment Monitoring Programme two models are employed for estimating nitrate leaching from the catchments. In both cases data on agricultural practice at field level in the catchments and information on soil type form the basis for the modelling. Firstly, the NLES model is used for all fields in the catchments. Secondly, the deterministic soil-water-plant model, DAISY, is set up and calibrated for the soil water stations and the model set-up is applied for all the fields in the catchment. Thus, in both cases data from the soil water stations have been used for upscaling to catchment level.

Upscaling to the national level
For the purpose of evaluating the effects of Action Plans estimates of nitrate leaching at the national level must be established. This is a very uncertain calculation and for the mid-term evaluation of Action Plan III in 2008 three procedures were employed:

- Using the national agricultural registry data and employing standard DAISY calculated leaching values for each field. The standard values are calculated for a very large number of combinations of crops, soils, and fertiliser use.
- Using the national agricultural registry data and employing NLES for all individual fields in Denmark.
- Using the DAISY model results from the Agricultural Catchment Motoring Programme and upscaling to the national level by main soil types (sand and loam). In this case it is assumed the catchments are representative for these main soil types.

The results of these modelling procedures are shown in Table 4 for 2003-2007.

Table 4 Modelling nitrate leaching at the national level employing three different methods
From the mid-term evaluation of Action Plan III (Waagepetersen et al., 2008).

Year	DAISY National agricultural data 1,000 tonnes N	NLES National agricultural data 1,000 tonnes N	DAISY Agricultural catchments 1,000 tonnes N	Average 1,000 tonnes N
2003	182	163	148	164
2004	184	163	148	165
2005	170	161	154	162
2006	162	161	157	160
2007	170	155	-	

Trend detections

The long-term trend analyses of nutrient concentrations in soil water and stream water (Figures 4 and 5) show large variations between years, as affected by the actual climate. In order to evaluate the effect of changes in agriculture we perform a ‘Kendall seasonal test’ (Hirsch and Slack, 1984) on yearly flow weighted concentrations. This is a non-parametric statistical test which is robust for seasonal changes.

In terms of modelling nitrate leaching for the mid-term evaluation of Action Plan III (Table 4) we used a standard climate (1990-2005) thus allowing for variations in climate. This was done by modelling nitrate leaching for each year of agricultural practise with the 16 years of climate. Finally, the average leaching for each year of agricultural practise was calculated.

In groundwater CFC age-dating indicates that the majority of the monitored groundwater recharged before 1995. As a consequence, a large share of the groundwater samples represent nitrate recharged before the implementation of the Action Plans from 1985, and thus the beneficial impacts of the Action Plans may yet only be recognised by careful data analysis.

Figure 12 shows the nitrate concentration of the groundwater as a function of the estimated year of recharge of the groundwater based on CFC dating and chemical modelling. This gives an indirect picture of nitrate leaching to the groundwater as a function of time. Geochemical modelling is used to calculate the original leached nitrate in oxygen free samples, and the red line gives a mean value of the nitrate content recharging to groundwater as a function of time. A tendency towards a decrease in the nitrate content of the groundwater of Denmark over the last 15 years is found. The fraction of groundwater with very high nitrate concentrations is also decreasing, and the average nitrate concentrations are just below 50 mg l^{-1} in the youngest groundwater. The latest data points are sparse, resulting in a large uncertainty of the data with a CFC age younger than about 1995 (Thorling, 2009).

3 Discussion

Farm compliance

In Denmark the farm compliance with the Action Plans is checked by means of the obligatory fertiliser accounts. Each year a new nitrogen standard for each and all crops are calculated by a described procedure: the Faculty of Agricultural Sciences (Aarhus University) calculates the economical nitrogen optimum for crops based on field trials conducted on farms by the National Agricultural Advisor Service. The Plant Directorate then calculates a reduction of these optimums, aiming at a constant nitrogen quota at national level. Each year farmers must comply with the reduced nitrogen standards as stipulated by the Plant Directorate. After the growing season the farmers submit a fertiliser account to the Plant Directorate where the accounts are being checked. The Plant Directorate also undertake physical spot checks on a number of farms. These data are at a later stage used for evaluation of the Action Plans.

Evaluation of Action Plans

The Danish Action Plans have been evaluated regularly. Thus Action Plan III (2004-2015) was evaluated in 2008. The mid-term evaluation in 2008 was carried out by the National Environmental Research Institute (NERI) and the Faculty of Agricultural Sciences (Aarhus University). The main point in this work with respect to nitrogen was to evaluate the trend in nitrate leaching. This was done by employing three different model procedures based on data from the monitoring programme and the agricultural registries (Table 4). In order to account for various model approaches – each of them justifiable and in its own way realistic – the average values of the three models were used for the evaluation. A further quality check was performed by comparing individual measures of nitrogen losses, that means, modelled nitrate leaching, total ammonia volatilisation and denitrification, with the total nitrogen surplus from the farm gate balance. Figure 13 shows that the losses fairly well sum up to total balance. There is a small residual value, which includes all uncertainties and a possible change in soil organic pool.

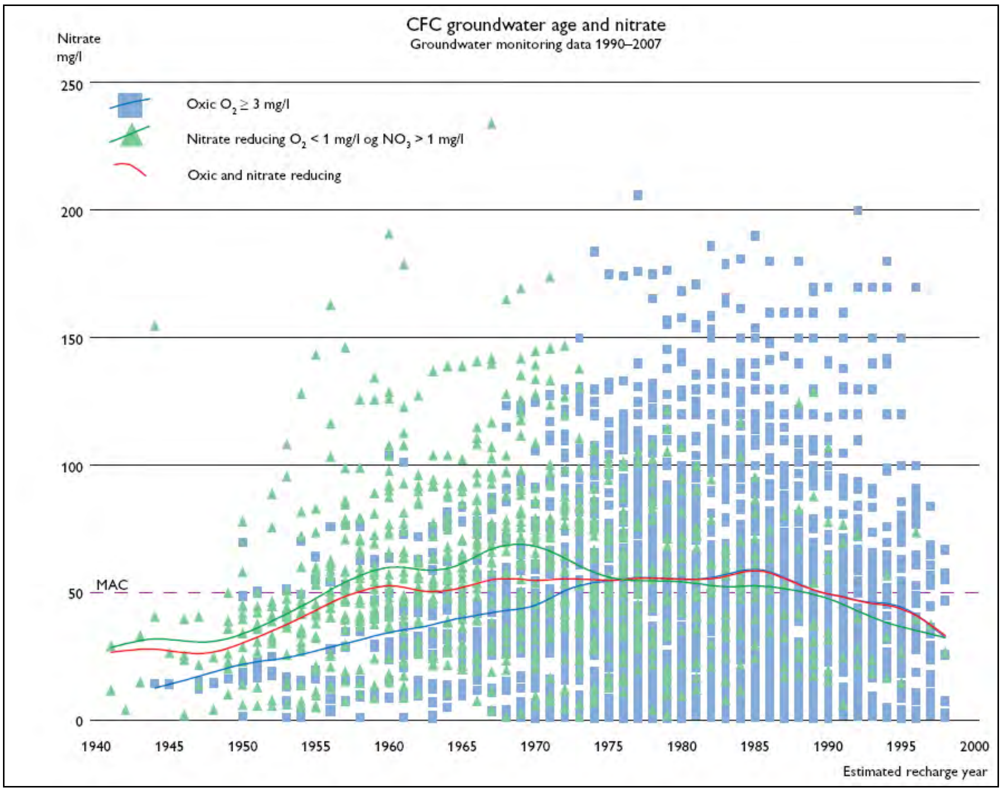


Figure 12 Nitrate as a function of the estimated date of recharge of the groundwater based on CFC dating and chemical modelling.
The CFC date is the (mean) date the groundwater in the sample lost contact to the atmosphere. The red line illustrates a model for the original mean nitrate content in groundwater as a function of the year the groundwater was formed.

Finally, the modelled nitrate leaching may be compared with measurements in the aquatic environment (Figures 5 and 6). Here we find that a constant nitrate leaching during the years 2003-2007 is followed by similar tend in nitrate concentrations in streams (Figure 5).

The conclusion from the mid-term evaluation of the Action Plan III was that the nitrate leaching has not decreased in the period 2003-2007. Fertiliser regulations cannot be tightened further without a reduction in yields implying that the environmental benefit will be rather small. The recommendations to obtain a further reduction in nitrate leaching were to focus on extensive use of efficient catch crops and minimum soil tillage in the autumn. This will lead to a build up of the soil organic pool. The present monitoring system, however, is not designed for documenting changes in soil organic matter. Furthermore, the deterministic nitrate leaching models are often weak with respect to the soil organic components. For future evaluations there is a need for simultaneous research on such growing systems.

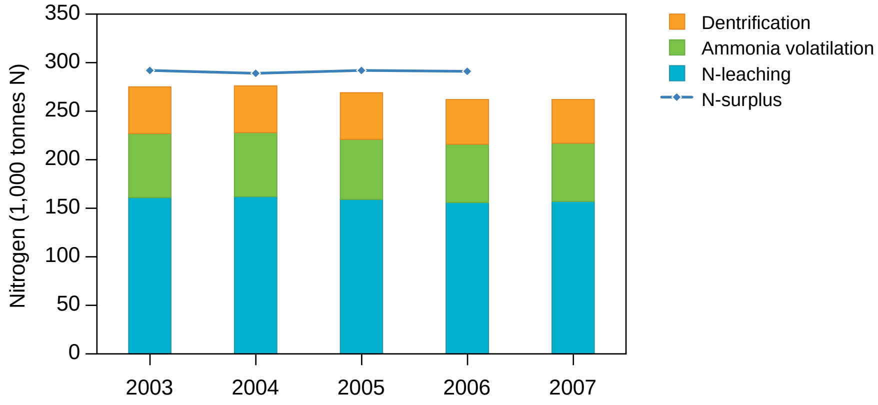


Figure 13 Development in estimated nitrogen surplus in agriculture and individual measures of losses, that means, modelled nitrate leaching, total ammonia volatilisation and denitrification, at the national level.
From the mid-term evaluation of Action Plan III (Waagepetersen et al., 2008).

The Action Plan III was planned to run from 2004 to 2015, but was in 2009 replaced by the new Green Growth Plan (2009-2015), a plan that ensures better conditions for nature and environment while allowing agriculture to develop. The Green Growth Plan also deals with the problems formerly encountered in achieving expected goals in Action Plan III.

Groundwater

It appears that the nitrate concentration in the youngest groundwater is developing in the desired direction, and that the effects of the Action Plans now can be seen in the groundwater. The highest nitrate concentrations are in groundwater recharged in the mid 1980s and a decrease is found thereafter, indicating that changed agricultural practices has an effect on groundwater quality. This covers large variations in agricultural practices, soil type, crops, et cetera. However, in the youngest groundwater more wells show reduced nitrate content as compared to the situation before the Action Plans.

Only a few results from water supply wells exceed the maximum admissible concentration (MAC) for drinking water. This is due to the fact that wells with exceedances have been closed and often replaced by new deeper wells, meaning that polluted groundwater is not used any more for drinking water production. Nitrate thus diminishes the available groundwater resource, as nitrate removal from drinking water is prohibited in Denmark.

Revision of the NOVANA monitoring programme in relation to the Water Framework Directive

The NOVANA programme has proven very efficient in terms of evaluating the effect of the Action Plans at the national scale. However, the Water Framework Directive (WFD) requires documentation of the ecological status of the waters and evaluations of measures at the catchment and/or regional scale. At present the monitoring programme is being revised in order to meet these demands.

In the future, the Agricultural Catchment Monitoring Programme will still provide the necessary information on interpreting agricultural data. However, it is expected that much focus will be placed on the utilisation of the agricultural registry data as these are geographically distributed thus allowing interpretations at various scales.

The present monitoring system for groundwater is not in compliance with the strategy expressed in the WFD, since the Danish monitoring system is based on monitoring areas which are meant to be representative on a national scale, but do not reflect the new assignment of groundwater bodies and river basin districts. Thus, there is a large challenge in redesigning the monitoring network, so that it can support the River Basin Plans with the knowledge of groundwater bodies at risk. Nitrate is the most important reason for groundwater bodies to fail having good chemical status.

The present groundwater monitoring system is also designed with the aim of monitoring drinking water interests. There is also a large need to redesign the monitoring network so that more monitoring points representing shallow groundwater feeding surface waters and dependent terrestrial ecosystems are included.

Nitrate reduction maps

As we have seen above, data are available for modelling nitrate leaching at various scales. However, as nitrate reduction processes will take place in groundwater, this estimate does not provide any information on the amount of nitrogen emission to surface waters.

The Statutory order on permission and authorisation of animal husbandry of 2006 prescribes an evaluation of the farm emissions of nitrate to surface waters. In order to obtain such estimates, a nitrate reduction map has been developed. For each water body shown in Figure 14 the nitrate leaching was estimated for the year 1989/1990, assuming that year represents the previous 10-20 years of agriculture. Data from the Stream Monitoring programme are used for calculating the nitrogen transport to streams of the same water bodies. This estimate is based on the annual flow weighted concentrations and a water flow corrected for climatic variations. The ratio between nitrate leaching and estimated corrected stream transport is taken as the nitrogen reduction percentage (Figure 14). In catchments with no stream measurements, model estimates were employed. The procedure is described by Windolf and Tornbjerg (2009).

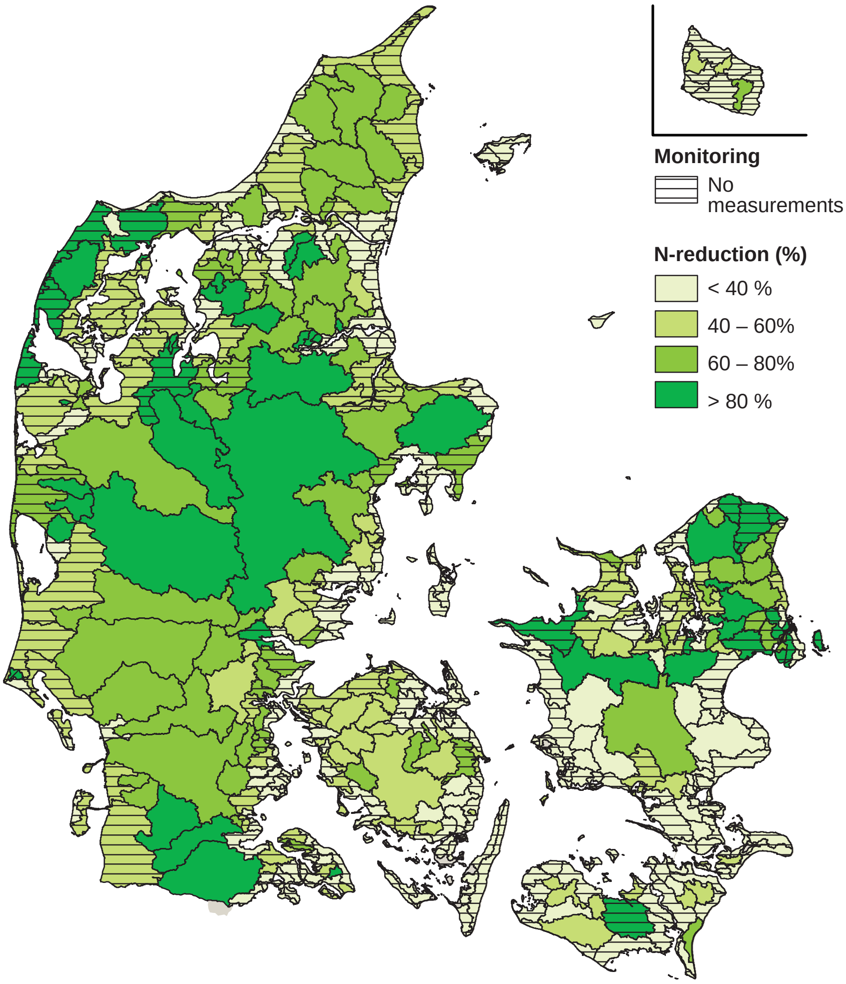


Figure 14 Nitrogen reduction map of Denmark (a first attempt).
The percentage shows the amount of nitrate leaching from the root zone which is reduced in groundwater before reaching the streams.

4 References

Hirsch, R.M.S. and Slack, J.R (1984) A non-parametric trend test for seasonal data with serial dependance. Water Res. Res. 20, 727-732.

Jørgensen, L.F. and Stockmarr, J. (2009) Groundwater monitoring in Denmark: Characteristics, perspectives and comparison with other counties. Hydrogeology Jounal 17, 827-842.

Kristensen, K., Waagepetersen, J., Børgesen, C.D., Vinther, F. P., Grant, R. and Blicher-Mathiesen, G. (2008) Reestimation and further development in the model N-LES. LES3 to N-LES4. Faculty of Agricultural Science, Aarhus University. DJF Plant Science no. 139.

Kronvang, B., Ærtebjerg, G., Grant, R., Kristensen, P., Hovmand, M. and Kirkegaard, J. (1993) Nationwide monitoring of nutrients and their ecological effects: State of the Danish aquatic environment. Ambio 22, 176-187.

Svendsen, L.M., van der Bijl, L., Boutrup, S. and Norup, B. (2005) NOVANA. National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environment. Programme Description - Part 2. NERI Technical Report, No. 537 at www.dmu.dk.

Thorling, L. (2009) Groundwater monitoring , state and development 1989-2007. GEUS Technical report. www.geus.dk (in Danish with English summary).

Waagepetersen, J., Grant, R., Børgesen, C.D. and Iversen, T.M. (2008) Midtvejsevaluering af VMPIII (Midterm evaluation of Action Plan III) (in Danish). Faculty of Agricultural Science, Aarhus University and National Environmental Research Institute, Aarhus University. www. dmu.dk

Windolf, J. and Tornbjerg, H. (2009) Nitrate reductions maps (in Danish). Vand og Jord 16. årgang, nr 2.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by France

PH. Jannot[1], V. Maquere[2] and C. Gozler[1]

[1] *MEEDDAT Ecology, Energy, Sustainable Development and Spatial Planning Department, 20 avenue de Ségur, F-75007, Paris, France*
e-mail: philippe.jannot@developpement-durable.gouv.fr; cecile.gozler@developpement-durable.gouv.fr

[2] *Ministry of Agriculture, MAP/DGPAAT/Bureau des sols et de l'eau, 3 rue Barbet de Jouy, F-75007, Paris, France*
e-mail: valerie.maquere@agriculture.gouv.fr

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in France and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). The monitoring campaigns of nitrate concentrations in water take place every four years. The network on which they are based is mainly built up from existing networks. It has been gradually extended with new monitoring sites on the basis of a historical network monitored since 1992-1993. Changes in agricultural practices are monitored inside and outside nitrate vulnerable zones (NVZs) using statistical surveys performed periodically (2001 and 2006) by the statistical service of the French Ministry of Agriculture (SSP). Research and development structures specify their research priority and objectives according to the scientific and societal stakes on which their want to focus their action. The conclusions of research studies as well as the statements made from the monitoring networks are mobilised by task forces organised by the government. The task force decides which part of the regulation needs to be reinforced given the results in terms of water quality and agricultural practices. This methodology was used for example to establish the guidelines of the fourth Action Programme which will come into force at the end of June 2009 and will require the use of catch crops and buffer strips in the whole NVZ.

1 Introduction

1.1 Environmental goals and measures

The Nitrates Directive is implemented in nitrate vulnerable zones (NVZs) (Figure 1). France is divided into 101 administrative units called ‘département’, 74 of these units have NVZs. Each one of these départements decides about its own Action Programme according to national guidelines. NVZs are designated on the basis of a network for monitoring the nitrate concentrations in surface waters and groundwater (cf. part II for further description of the monitoring network). NVZs have been extended when revised in 2001 and 2003. The last revision in 2007 confirmed the designation of 2003.

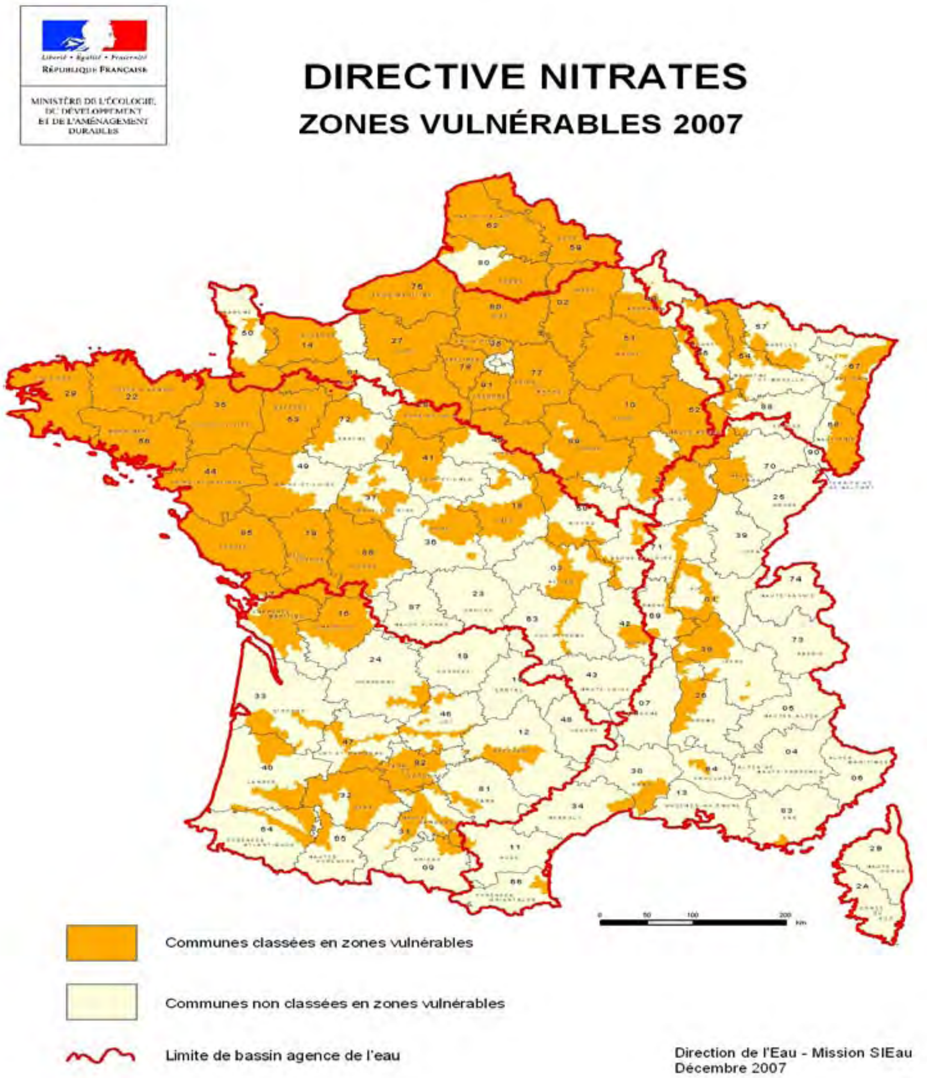


Figure 1 Nitrate Vulnerable Zones (NVZs) in France, revision 2007.
NVZs are areas in orange; red line is the border of the water basin region.

NVZs covered about 15 millions hectares of the utilised agricultural area (UAA), that is, about 55% of the French UAA. About 75% of the arable farms, 75% of the pig and poultry farms, half of the dairy farms and half of the market gardening farms are located in NVZs. About 60% of the nitrogen excreted by livestock and a large part of the mineral nitrogen used in France are used in NVZs.

The first, second and third Action Programmes mainly aimed at reducing nitrogen surpluses by adjusting the nitrogen applications to plant export capacities. Different actions were included in the programmes in order to make sure that the nitrogen is used at the right dose, time and place. The limit of 170 kg ha per year of organic N prescribed by the Nitrates Directive was also

included, as well as the compulsory establishment of fertilisation plans on a farm-by-farm basis and the keeping records on fertiliser use.
The fourth Action Programme, expected to come into force at the summer of 2009, will include two additional actions in the scope of land management in order to limit the impact of potential N losses on water quality: buffer strips with a width of 5 m will have to be installed along both sides of all water courses in NVZs, and N catch crops will have to be realised in autumn preceding spring crops to prevent N leaching from bare soils during the period of intense rainfall.

1.2 Overview of trends in nitrogen loads and surpluses

Trends in nitrogen loads and surpluses are observed at the national scale and at the regional scale according to seven agricultural regions, including the Grand Ouest, the Grand Bassin Parisien, the south-west and the east of France (Ministère de l'écologie, de l'énergie, du développement durable et de l'aménagement du territoire, 2008).

In the 1990s, the amount of mineral nitrogen used in France showed a marked increase in response to the expansion of the areas covered with oil seed rape, cereals and maize (Figure 2). Since 2001, the use of mineral nitrogen has been decreasing.

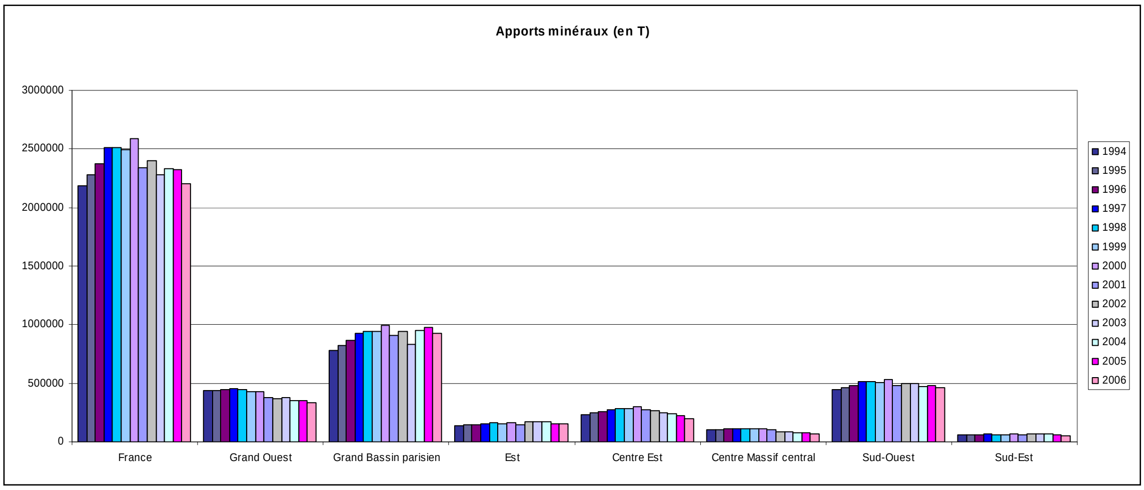


Figure 2 Mineral nitrogen use from 1994 until 2006 in France and for each of the seven water basin regions.
Data from Union des industries de la fertilisation (UNIFA).

This late decreasing trend is particularly marked in the west of France, Grand Ouest, where the use of mineral nitrogen decreased by 18% in 10 years. On the contrary, the use of mineral nitrogen remained unchanged in the Grand Bassin Parisien since 1998. This particular behaviour may be explained by the expansion of arable areas as a consequence of cultivated set-asides and high-quality wheat development, grassland ploughing, and pea substitution by mineral N consuming crop.

In 2006, the production of organic N by livestock was estimated in France at about 1.34 million tonnes, that is, about 100,000 tonnes less than in 1994. This decrease has been particularly marked since 2002 (Figure 3).

The Grand Ouest is the region producing the greatest amount of organic N from livestock but this production is actually decreasing (-12% in 12 years from 1994 until 2006) (Figure 3). Such a decrease may be explained by a decrease in livestock number (milk quotas, avian influenza crisis in 2005), and by the strengthening of the nitrate regulation in the areas of intensive livestock breeding in the last 10 years. An example of the latter is the prohibition to increase the livestock number in the cantons – administrative units within a department – where the area available for manure application is not sufficient enough to apply all the manure produced in the canton in the limit of 170 kg N ha^{-1} per year, these areas are called in French ‘zones en excédent structurel’.

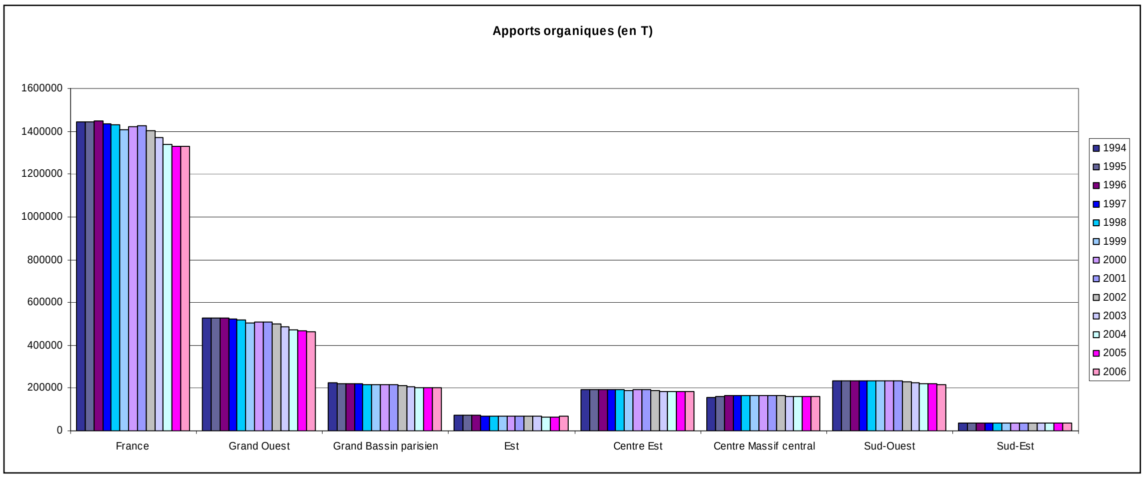


Figure 3 Organic nitrogen produced by livestock from 1994 until 2006 in France and for each of the seven water basin regions.

This decreasing trend is also observed in other regions except in the Centre Massif Central and in the south-west of France where the organic N production remains more or less constant over time (Figure 3).

The nitrogen balance for the whole French territory is highly dependent on the climatic conditions and, as a consequence, shows a great inter-annual heterogeneity (Figure 4). For example, the severe drought which occurred in 2003 in France led to poor yields and consequently to less nitrogen exported by crops and to a positive nitrogen balance.

The N balance is mostly positive. When comparing years with the same level of N exported by crops, for example the years 2000, 2002 and 2004, it can be observed that the general trend for the whole French territory is a decreasing one, which confirms that the decreasing trends already observed for N use and production may be explained by a more rational use of nitrogen fertilisers.

However, changes observed in N balances over time are contrasted among regions: the west of France shows a strong decrease in the N balance since 1996 (-44% in 10 years) whereas the N balance has been increasing in eastern France until 2003, probably due to the expansion of large scale farming in this region.

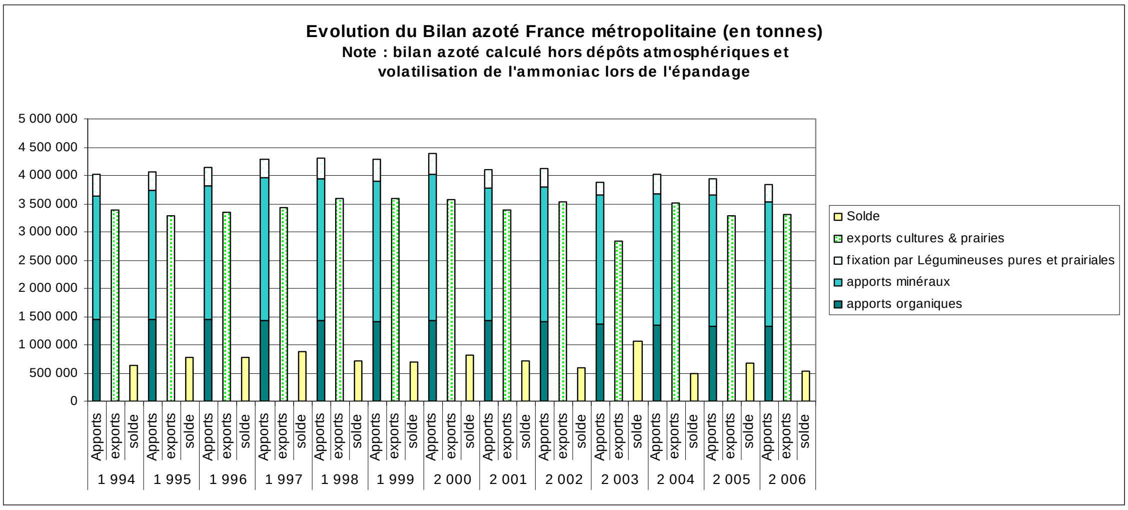


Figure 4 Changes in N import (apports in French), N export, and N balance (solde) (in kg ha^{-1}) from 1994 till 2006.
Imports accounted for are N fixation (white), mineral fertiliser (blue), and organic fertilisers (green). Source SCEES UNIFA and MAP.

1.3 Overview of trends in nitrate concentrations

For surface waters, 1,344 sampling sites were monitored in 2006-2007, located inside as well as outside NVZs. These sites were drawn up from the general network for monitoring surface water quality in French water courses. For groundwater, 1,437 sampling sites were monitored in 2006-2007 mainly drawn up from the network used to monitor the quality of the water intended to produce drinking water.

The average nitrate concentrations in 2006-2007 exceeded 25 mg l^{-1} in surface waters at 338 monitoring sites, that is about 25% of the monitoring sites in surface waters (Figure 5). About 25% of the sites monitored in groundwater exhibited average nitrate concentrations exceeding 40 mg l^{-1} for years 2006-2007 (Figure 5). The nitrate concentrations exceeded the 50 mg l^{-1} at half of these sites.

From 1992-1993 until 2006-2007, the average nitrate concentrations in surface waters decreased in the west of France whereas it increased in the Grand Bassin Parisien and in the region Poitou-Charentes (Figure 6A). In groundwater, a large part of the monitoring network shows increasing trends in nitrate concentrations since 1992-1993 (Figure 6B).

Thus, the monitoring of nitrate concentrations in waters and of the nitrogen use and production since 1992-1993 show that surface waters respond quickly to changes in agricultural practices. Indeed, the average nitrate concentrations show the same trends as the changes in nitrogen pressure (decrease in the organic nitrogen production and in the N balance in the west of France, no decrease or even increase in the nitrogen pressure in the Grand Bassin Parisien). On the other hand, groundwater shows a great inertia regarding the effect of agricultural practices and therefore the nitrate concentrations in groundwater still record the increase in nitrogen use and production which occurred in the 1990s.

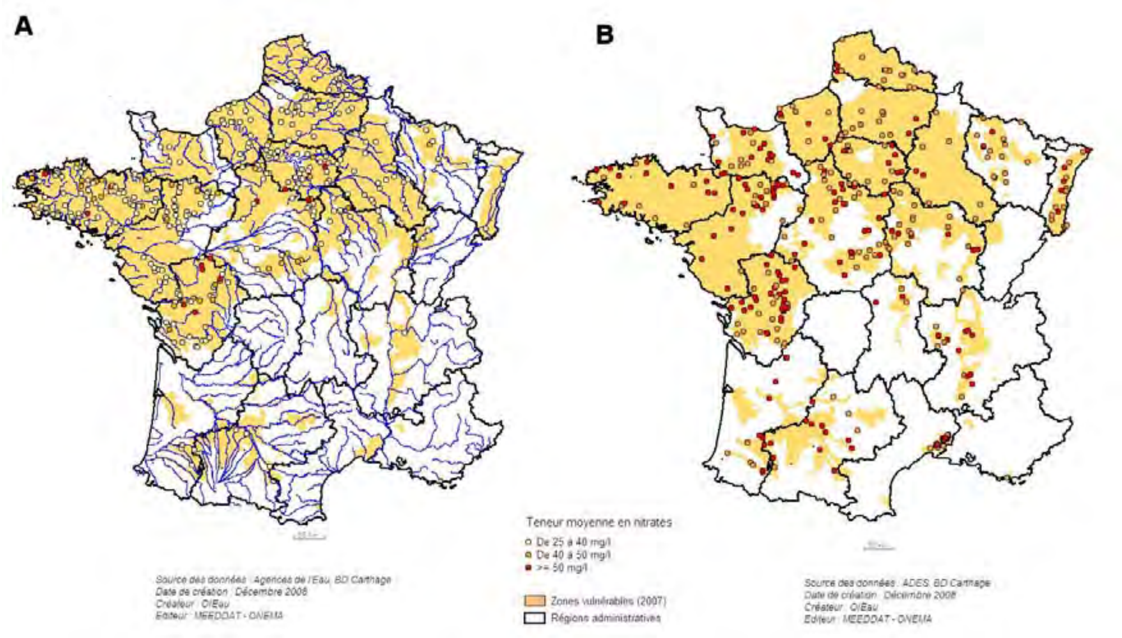


Figure 5 Monitoring sites at which the average nitrate concentration in 2006-2007 exceeded 25 mg l^{-1} in surface waters (A) or exceeded 40 mg l^{-1} in groundwater (B).
Colours of circles: yellow 25-40 mg l^{-1}, orange 40-50 mg l^{-1}; red ≥ 50 mg l^{-1}.
Areas in orange are NVZs.

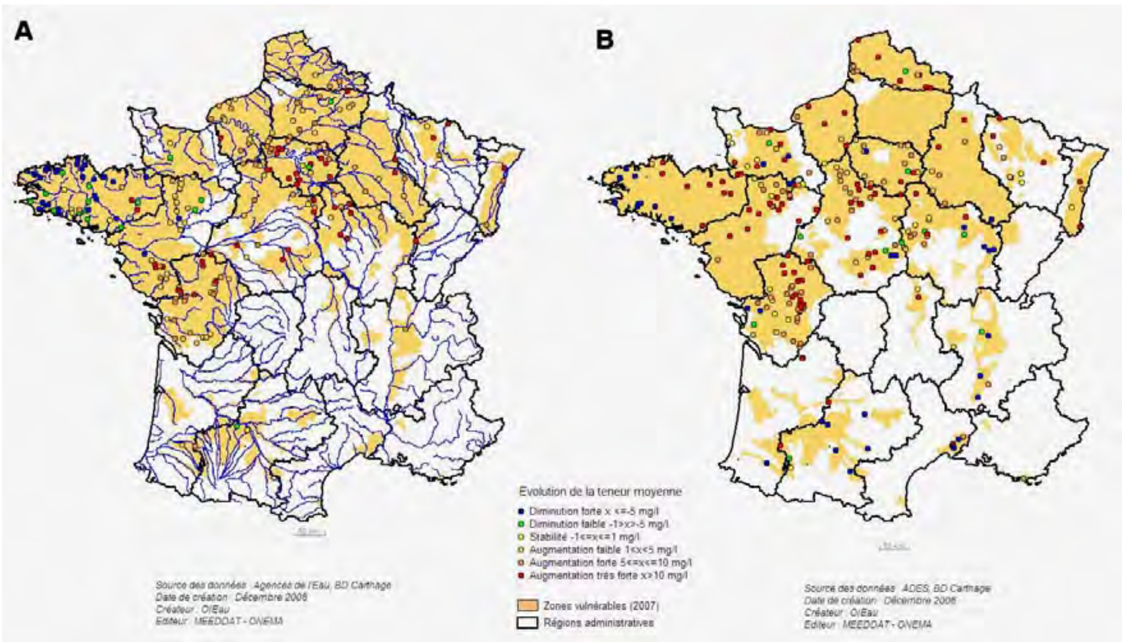


Figure 6 Changes observed in the average nitrate concentrations in surface waters (A) and in groundwater (B) from 1992 until 2007.
Colours of circles: blue strong decrease (≤ -5 mg l^{-1}); green small decrease (> -5 – -1 mg l^{-1}); white stable (≥ -1 – ≤ 1 mg l^{-1}); yellow small increase (> 1 – 5 mg l^{-1}); orange large increase (≥ 5 – ≤ 10 mg l^{-1}); red very large increase (≥ 50 mg l^{-1}).

Such conclusions were confirmed in Bretagne by the modelling of nitrogen fluxes in soils and in waters at the scale of nine catchment areas (BRGM-INRA, 2008).

1.4 Overview of monitoring networks

The monitoring campaigns take place every four years. The network on which they are based is mainly built up from existing networks. It has been gradually incremented with new monitoring sites on the basis of a historical network monitored since 1992-1993, that consisted of 1,047 sites in surface waters and 1,242 sites in groundwater. During the last monitoring campaign in 2004-2005, the network consisted of 1,719 sites in surface waters, mainly in water courses, and 2,625 sites in groundwater. Two-thirds of these sites were located in NVZs.

2 Effect monitoring

2.1 Strategy for effect monitoring

The French strategy in terms of effect monitoring is determined by the great diversity of the French territories, by the territorial administrative organisation which assigns the region as the coordinator of the environmental databases and the prefect of the 'département' as the proper authority which decides on the Action Programmes, as well as by the organisation of the French research and technical institutes.

Thus, the coordination of the monitoring networks at national scale mainly focuses on large-scale networks (mainly water quality data and agricultural practices). The network for monitoring nitrate concentrations in water mainly aims at delimiting NVZs and at assessing whether a strengthening of the regulation is needed or not, given the results in terms of water quality. The monitoring of agricultural practices allows identifying the scope of the regulation which needs to be strengthened.

Research and development structures specify their research priority and objectives according to the scientific and societal stakes on which they want to focus their action. They may thus decide to install experimental sites with specific monitoring devices such as ceramic cups or lysimeters, or to focus on more specific themes or finer geographical scales. Such studies may also focus on upscaling nitrate fluxes from catchment area to larger territorial units, or to developing, parameterising and validating models to simulate or even predict the influence of agricultural practices on nitrate fluxes. Such experimental designs are not presented in the present article but their conclusions can be read in the scientific literature of the corresponding area.

Some specific assessment devices may be promoted by the central government in specific cases, such as the assessment of the implementation of specific measures which benefits from state or governmental subsidies (for example, for increasing manure storage capacity, see PMPOA programme further in this paper) or for the assessment of specific Action Programmes such as in Bretagne on the nine catchment areas in the European infringement case against France.

The conclusions of research studies as well as the statements made on the basis of the monitoring networks are initiated by task forces organised by the government. The task forces decide which part of the regulation needs to be reinforced given the state of water quality and agricultural practices.

2.2 Detailed technical description networks used for effect monitoring

The MEEDDAT (Ecology, Energy, Sustainable Development and Spatial Planning Department) is in charge of the network for monitoring nitrate concentrations in fresh waters. It delegates the selection of monitoring sites to their regional departments. The data recorded by the network are sent to the International Water Agency (Office international de l'eau) which is in charge of the data management and processing, of the statistical studies, and of communication media (in particular, cartographic representations), as prescribed by the Draft guidelines (EC, 2003).

In NVZs, the monitoring network has two goals: monitoring the nitrate concentration changes in waters and assessing the efficiency of Action Programmes. Outside the NVZs, the network is less dense and mainly aims at monitoring changes in nitrate concentrations in waters (Table 1 and Figure 7).

Table 1 Number of monitoring points inside and outside NVZs in France in 2004-2005 for surface waters and groundwater.

	Surface waters (water courses)		Groundwater	
	NVZ	Outside NVZ	NVZ	Outside NVZ
Number of monitoring sites	1,071	617	1,639	986
As percentage	63%	37%	62%	38%
Sites per 1000 km^2 total area	4.5	2.0	6.8	3.3
Sites per 1000 km^2 agricultural area	7.1	5.0	10.9	8.0

This network has always been relying on existing networks for surface waters as well as for groundwater; the monitoring sites were drawn up from the general network for monitoring surface water quality in French water courses and from the network used to monitor the quality of the water intended to produce drinking water. The network was completed by additional sites in order to better characterise some areas where the knowledge of water quality was scarce.

Sampling is always performed in the upper part of the water table since the majority of the sampled sites are used to produce drinking water.

Groundwater monitoring points have been selected to assess as a priority the impact of agricultural activity on nitrate concentrations in waters so that the sites downstream urban agglomerations were discarded. The direct consequence of this is that the concentrations monitored by the Nitrate Monitoring Network slightly differ from the concentrations measured by the general network for monitoring groundwater water quality in France (Table 2).

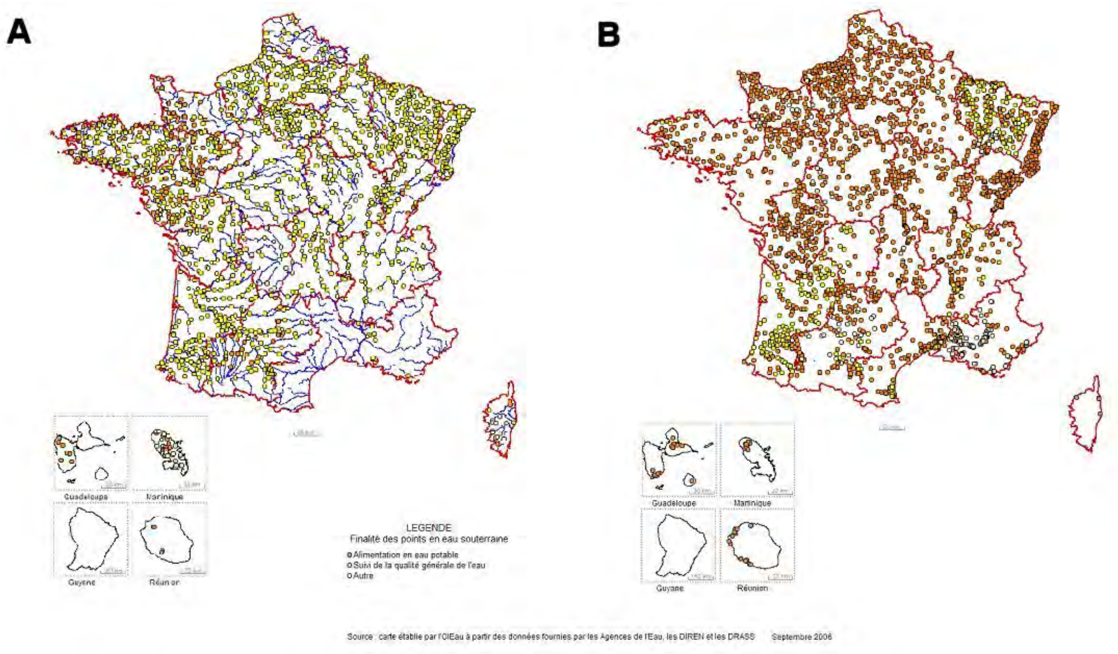


Figure 7 Location of the monitoring points in surface waters (A) and groundwater (B) in France in 2004-2005.
Colours of circles: orange drinking water production site; yellow monitoring site for general water quality; white other monitoring sites.

Table 2 Average nitrate concentration as percentage per concentration class for the General groundwater water quality monitoring network and the Nitrate monitoring network (groundwater sites in agricultural areas) in France.

General monitoring network 2002		Nitrate Monitoring Network 2000-2001	
NO_3 range	Percentage of sites	Percentage of sites	NO_3 range
> 50 mg l^{-1}	10%	18%	> 50 mg l^{-1}
40-50 mg l^{-1}	10%	16%	40-50 mg l^{-1}
20-40 mg l^{-1}	27%	32%	20-40 mg l^{-1}
10-20 mg l^{-1}	15%	25%	10-20 mg l^{-1}
< 10 mg l^{-1}	38%	10%	< 10 mg l^{-1}

Monitoring campaigns occur every four years. During the 2004-2005 campaign, water samples were analysed at least every trimester in groundwater (37% < 4 times, 27% = 4 times and 36% > 4 times), and at least every month in surface waters (30% < 12 times, 48% = 12 times, 22% > 12 times). For each site monitored, the annual average nitrate concentration was calculated. Since the 2004-2005 campaign, an annual monitoring has been installed for part of the network for which data are easily available.

Changes in nitrate concentrations are analysed using the sites common to all the monitoring campaigns since 1992-1993. The deviation to the mean concentrations among all campaigns is compared for each site.

Changes in agricultural practices are monitored inside and outside NVZs using statistical surveys performed periodically (2001 and 2006) on a representative sample of plots at the catchment scale and at the regional scale. These surveys are performed by the Statistical Service of the French Ministry of Agriculture (SSP) and benefit from the financial support of the water agencies. They mainly focus on arable crops (soft and durum wheat, barley, grain and silage corn, sugar beet, sunflower, oilseed rape, pea, potatoes) and intensive grazing (permanent and rotation pastures). Structural data (livestock number, type of agricultural exploitation, et cetera) are obtained thanks to specific surveys performed periodically by the SSP such as the agricultural survey in 2000.

Data are collected at the plot scale for each farm enquired upon and enable to characterize the agricultural practices in terms of nitrogen management, that means, use of mineral fertiliser and organic amendment – doses and time of each fertiliser application, N split and use of fertilisation management tools, land-use management.

All these surveys are not only performed for nitrate monitoring purposes but specific data extractions are performed to differentiate data inside the NVZ from data outside the NVZ. They are completed when needed by questions designed specifically for the assessment of the Nitrates Directive.

These data, their nature and the statistical analysis performed on them, are presented on the SSP website (www.agreste.agriculture.gouv.fr).

2.3 Data interpretation

Use of monitoring data inside and outside NVZs: designation of NVZs

The designation of NVZs is made by the Basin State Services which prepare the project of delimitation and submit for approval to the departmental state services and to the Basin Committee. The final decision is made by the prefect who is in charge of coordination for the basin.

The Basin State Services use the results from the Nitrate concentration monitoring network which they cross-correlate to the agricultural data from agricultural surveys generalised from different administrative scales (most often the canton scale). This data concerns, for example, the percentage of arable land and permanent crops, the livestock density or the characteristics of the farm type (OTEX, according to the European classification as defined by the Commission Decision 78/463/EEC; Figure 8). They may also use other composite indicators at the scale of small water catchments like the nitrogen surplus (Figure 9).

The basin state services submit a list of municipalities (commune in French) to class in NVZ. The municipality is the smallest administrative unit allowed to define a regulation. Catchment limits would be more relevant units to manage diffuse pollutions but they are much more difficult to integrate in a regulation since they differ from the administrative units. This solution is thus retained only on small water catchments where the restoration of water quality is particularly at stake (water catchments showing nitrate concentrations > 50 mg l^{-1} like in Bretagne).

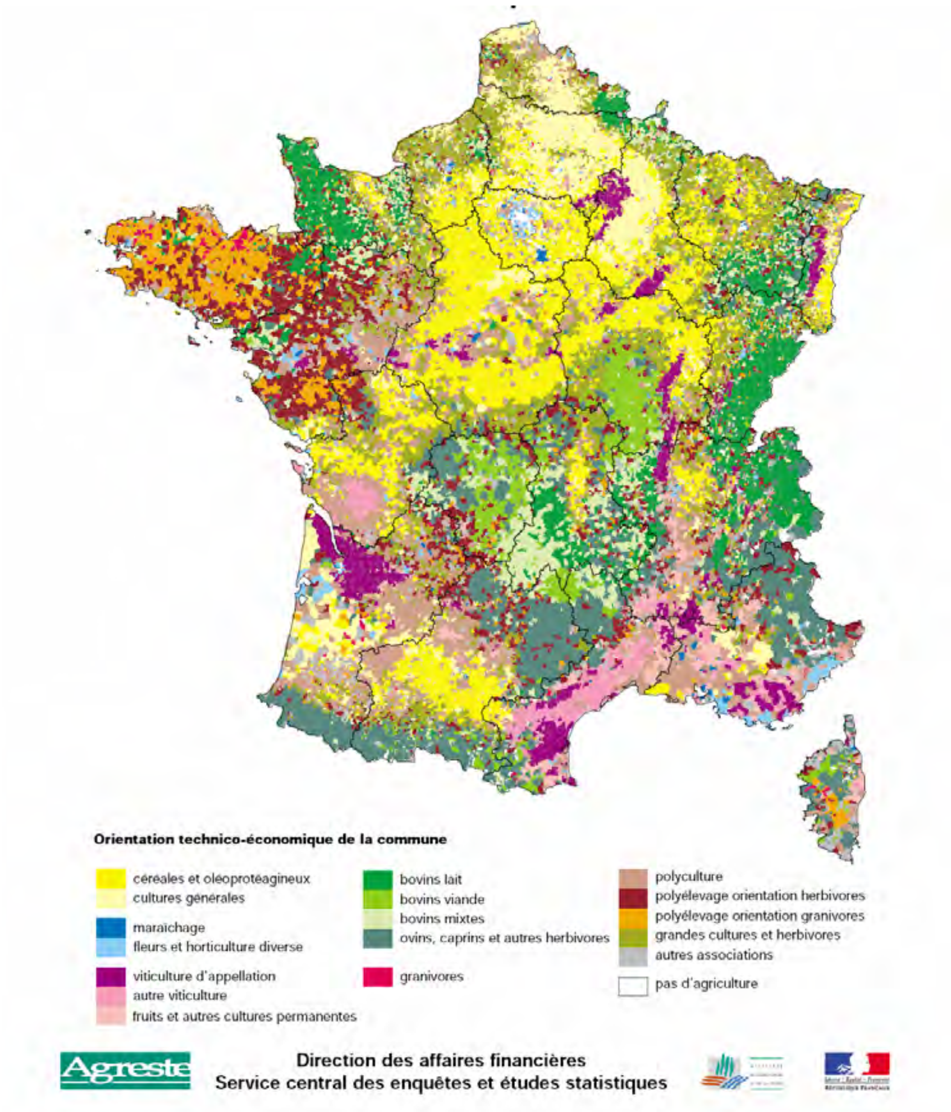


Figure 8 Main land use in each municipality in France (OTEX) from the agricultural survey of 2000.

Use of data inside NVZ to assess the effect of nitrate policies on agricultural practices

Comparing data of nitrate concentrations in waters to agricultural practices enables to assess the efficiency of the policies implemented on water quality.

The simplest qualitative approach is to superimpose the map of nitrate concentrations onto the map of statistical agricultural data and to observe the different trends which show up in terms of changes in nitrate concentrations relation to the main agricultural activities in the area where the point was monitored.

A statistical approach was lately developed by the animal husbandry institute (Institut de l'Élevage) to assess the impact of the implementation of the agricultural pollution control policy on water quality (maîtrise des pollutions d'origine agricole, PMPOA)(Manneville et al., 2008; Ferrand et al., 2009). The PMPOA is a programme of financial support to livestock farmers to invest in sufficient storage capacity to apply their manure over very small periods adapted to the different crops of the farm. This programme targeted in its first phase (1994-2000) the biggest breeders, mainly landless production operations and dairy cattle.

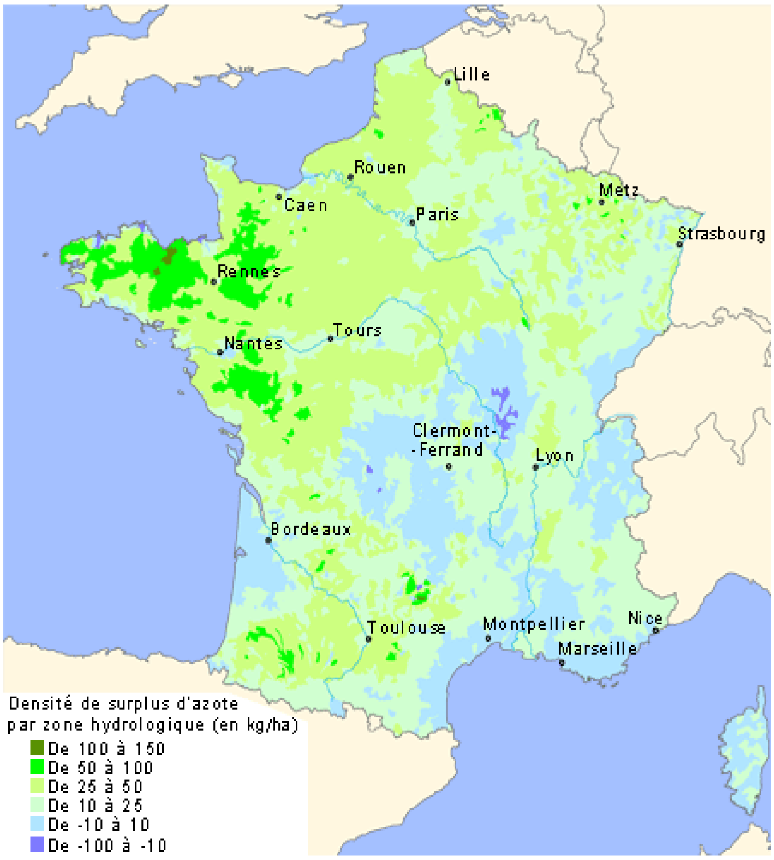


Figure 9 Nitrogen surplus (in kg ha^{-1}) per hydrological region in 2000.
Source: IFEN-Beture. Cerec-, Oieau-, and Solagro-agences de l'eau (logiciel Nopolu).

A statistical methodology (multidimensional factor analysis) was used to compute a nitrate indicator for each canton by cross-correlating the agricultural production activities at the canton scale to the nitrate concentrations measured at sites of the Nitrate Monitoring Network.

Water quality data were extracted from the Nitrate Monitoring Network for 1992-1993 (before PMPOA started), 2000-2001 (during the PMPOA) and 2004-2005 (at the end of PMPOA). Data on agricultural activity were taken from the agricultural survey of 2000 at the cantonal scale (including the UAA, livestock number expressed in kg N per type of animal per operation size, arable crops areas, forage areas and permanent pastures).

The cantonal nitrate indicator (NI) was calculated following two steps:

– The nitrate concentration measured in surface waters was transformed in an equivalent groundwater concentration by using a transfer coefficient from hydrographical data available on the studied area.

– Then, for each canton, the indicator was calculated from the nitrate concentrations measured in groundwater and from the equivalent concentrations calculated for surface waters weighted by their distance to the centre of gravity of the canton.

Statistical processing enabled to define a characterisation of the different cantons visible on a map. The different types of canton differed from one another by the variables which explained the value of the nitrate indicator. Consequently, the cantons which belong to a same class presented similar features with respect to changes in nitrate concentrations and to agricultural features.

In NVZs, three types of canton of similar importance may be observed depending on the changes of the nitrate indicator over time (Table 3). This table shows that animal husbandry activities explain the main part of the nitrate indicator in the cantons where the indicator decreases. The nitrogen load from manure is about 60 kg per hectare of utilised agricultural area (UAA) in areas with a decreasing nitrate indicator, which is twice as much as in the cantons where the nitrate indicator increases. In the same way, the forage crops areas stand for about one-third of the UAA whereas they account for less than 10% in the cantons where the nitrate indicator increases.

Table 3 Agricultural characteristics for all NVZs and for areas with a different trend in the nitrate indicator (NI) for the period between the 1997-1998 sampling campaign and the 2004-2005 campaign.

	Average for all NVZs	Area with increasing NI	Area with stable NI	Area with decreasing NI
Change in NI	-2.15	+ 9.00	+ 0.10	-12.7
UAA (ha) †	14,151,157	4,593,625	3,515,813	6,154,353
UAA (%) †	100	32	25	43
Forage crops (% of UAA) †	18	10	14	28
Permanent grassland (% UAA) †	16	14	18	15
Organic N application (kg ha^{-1})	45	30	40	59
Nitrate Indicator 2004-2005	35.8	41.0	32.5	33.7

† UAA = utilised agricultural area

Figure 10 shows that the cantons in NVZs where the nitrate indicator is decreasing are mainly located in the west of France (Bretagne, Pays de la Loire, and Basse-Normandie).

Further analysis of these cantons shows that 25 different types of cantons can be defined. Four types out of these 25 are explained here as an illustration. For these four types, changes in the nitrate indicator are mainly explained by the participation of the farmers in the PMPOA programme and by the importance of the animal husbandry in the canton. The nitrate indicator decreases in the cantons where animal husbandry and participation in the PMPOA programme are important, showing the efficiency of the programme on water quality (Table 4).

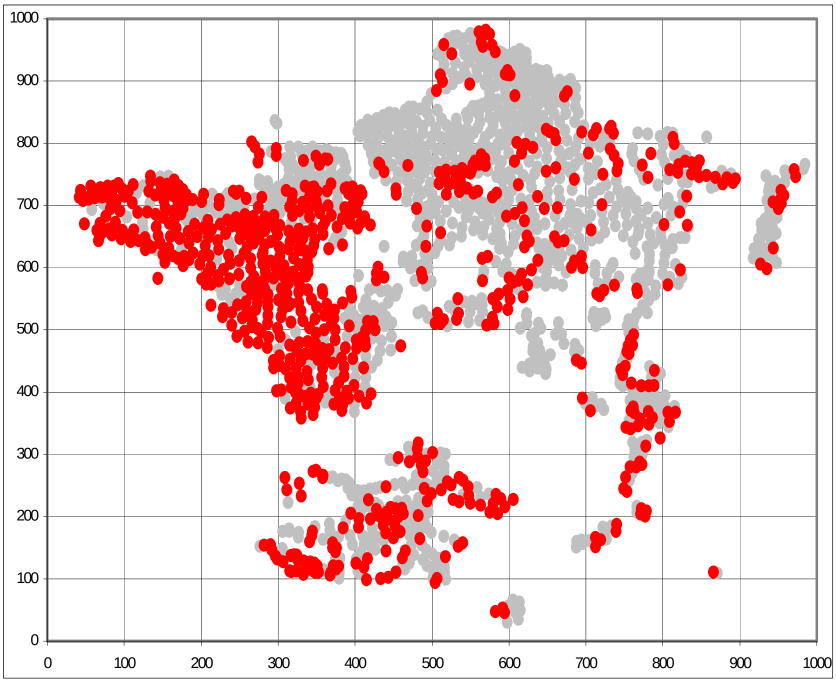


Figure 10 Cantons with decreasing nitrate indicator (NI) between 1997/1998-2004/2005.

Table 4 Change in nitrate indicator (NI) in cantons as a function of intensity of animal husbandry and of the participation in the PMPOA programme.

Participation in PMPOA (weight)	Intensity of animal husbandry	
	Very high	Average
Strong	Decrease	Decrease
Weak	Stable	Increase

The first two examples of Figure 11 show that the PMPOA programme (large scale pigs and poultry farms and large scale dairy cattle operations) explain a great part of the nitrate indicator when it decreases. In the canton located at the west of the Bretagne (Figure 11A), the nitrate indicator decreases but its value remains high (39.5 mg l^{-1}); these cantons are characterised by a high organic N pressure (97 kg N ha^{-1} of UAA), 25% of the organic nitrogen coming from animal husbandry operations that participated in the PMPOA programme (mainly pigs and poultry farms).

In the cantons located at the south of the Bretagne and in Pays de la Loire (Figure 11B), the nitrate indicator decreases sharply and its absolute value is less than in figure 11A. The organic N pressure is high (83 kg ha^{-1} of UAA) and 20% of the nitrogen comes from breeding which contracted in the PMPOA mainly dairy cattle, pigs and poultry.

On the contrary, Figure 12 shows that the points for which the nitrate indicator is stable or increases may be explained by a poor influence of the PMPOA programme.

The cantons located at the east of Bretagne and in Basse Normandie (Figure 12A) exhibit a nitrate indicator more or less constant but with a high absolute value (52.3 mg l^{-1}). The organic N pressure is high (110 kg N ha^{-1} of UAA), animal husbandry is mainly dairy and fattening cattle of medium to small size less concerned by the PMPOA programme.

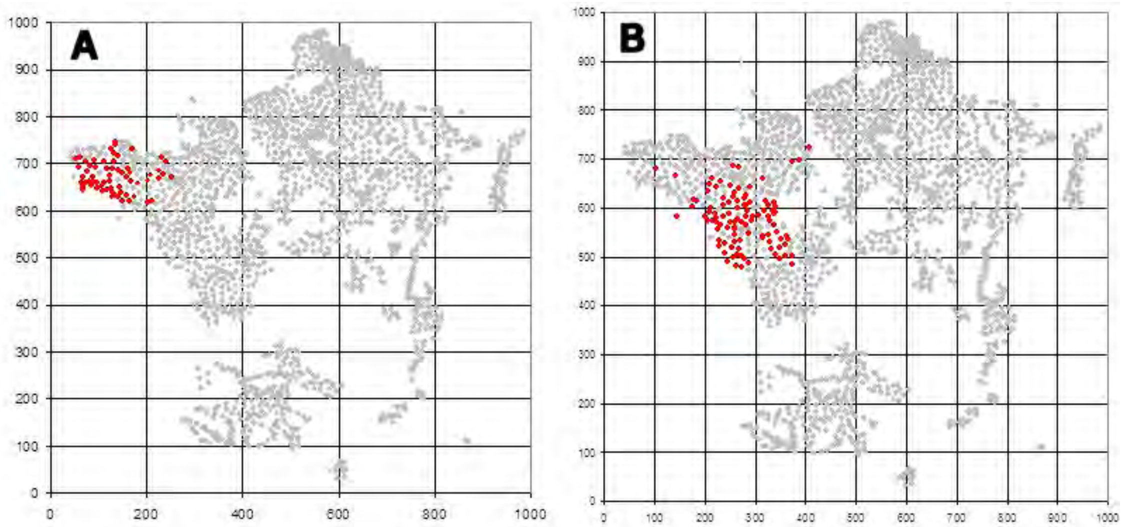


Figure 11 Cantons showing a decrease in the nitrate indicator (NI) as explained by the influence of the PMPOA programme, depending on the importance of animal husbandry in the studied cantons: intensive operations (A) and less intensive operations (B).

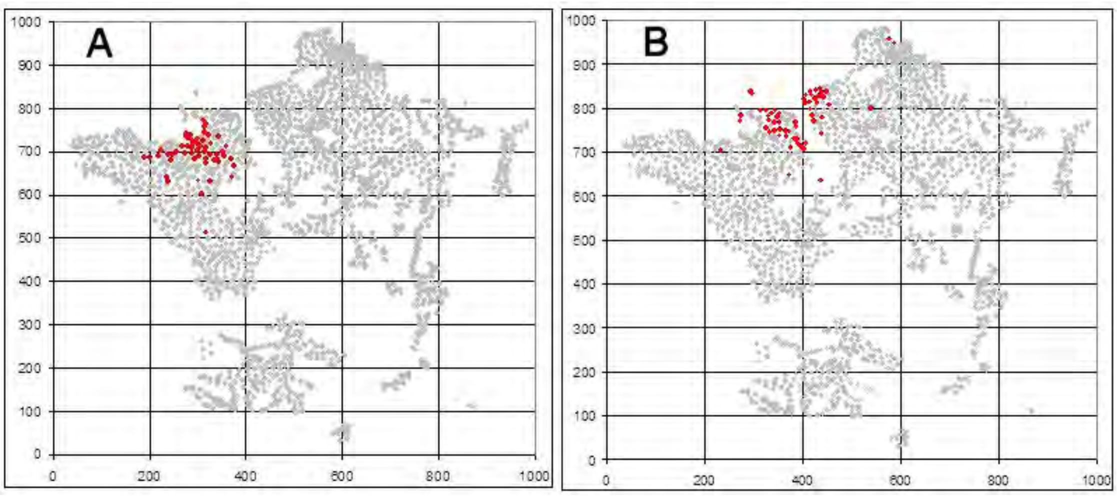


Figure 12 Cantons with an intense animal husbandry but for which the PMPOA programme does not explain much of the changes in nitrate indicator (NI): (A) cantons for which the NI remains stable; (B) cantons for which NI increases.

The cantons from one part to another of the Baie de Seine show an increasing nitrate indicator with a high value (39 mg l^{-1}). The organic N pressure is medium (64 kg N ha^{-1} of UAA), animal husbandry is scarce and large arable farms use about half of the agricultural area of the region.

This study allows drawing a statistical link between nitrate concentration changes in waters and changes in agricultural practices, that is an increase in the storage capacity of the manure, thus contributing to a more rational and adapted use or manure N fertilisers and to the decrease in the use of mineral N fertilisers.

Examples of experimental studies

Some examples of particular studies focused on the experimental study at the catchment scale or at the plot scale to measure and analyse the influence of change in agricultural practices on nitrate leaching

All experimental studies which have been conducted at the catchment scale recorded the efficiency of agricultural practices consisting of mixed balanced fertilisation to catch crops and/or introduction of buffer strips along the water courses.

These studies used different methods of monitoring and modelling of nutrient flux. Some of them are presented here but this list is far from exhaustive. Further detail on these topics may be found in the scientific literature.

The very first site was installed in the 1980s by the fertiliser producing firm 'la Grande Paroisse', at Auradé (Gers) in a region cultivated, on large scale, with sunflower and wheat. This resulted in a hydrological system where mainly in surface waters short time reaction existed to agricultural practices, thus leading to frequent peaks in nitrate concentrations higher than 50 mg l^{-1}.

The introduction of balanced fertilisation of nitrogen was tested together with the introduction of buffer strips along the water courses. The 15 years of experiment showed that the combination of buffer strips together with balanced fertilisation enabled to reduce nitrate concentrations in water and to reduce seasonal variations in nitrate concentrations.
The experimental site of Villamblain in Loiret, installed by the Chambre of Agriculture in the 1990s monitored the influence on nitrate concentrations in the limestone aquifer of the Beauce region of adjusting N fertilisation to plant requirements by in-and-out balance analysis combined with the introduction of an N catch crop in the autumn between two successive crops. The crops present were wheat and corn. This land management approach enabled to reduce significantly the nitrate concentrations in water.

Two more sites at Bruyères (Aisne), installed by the INRA, and at Thibie (Marne), installed by the Chambre d'agriculture together with technical institutes, on other type of soils and crops (for example beet) confirmed the positive effect on nitrate concentrations of combining balanced fertilisation to catch crops (Beaudoin, 2006; Beaudoin et al., 2004, 2005, 2008).

These results were especially used to establish the guidelines of the fourth Action Programmes which will come into force at the end of June 2009 and will generalise to the whole NVZ catch crops and buffer strips.

3 Discussion

Difficulties encountered in monitoring of nitrate concentrations in waters

During the monitoring campaigns, some new sites were chosen to complete the initial network but other sites were discarded because of the lack of results. These sites mainly came from the network of water quality monitoring for water used for human consumption. When the water quality is poor, the drinking water production site is closed and the monitoring is no longer possible. Thus, the nitrate monitoring network tends to lose its sites with relative high nitrate concentrations.

It is particularly difficult to use a pool of monitoring sites which is stable over time, and the pool of sites which are common to all monitoring campaigns tends to become smaller and smaller over time. This is a major difficulty to monitor long time changes in nitrate concentrations. Actually, among the 1,719 points of the Nitrate Monitoring Network in 2004-2005 in surface waters, only 1,047 (47%) had been monitored since 1992-1993. In groundwater, only 1,242 out of the 2,625 monitoring sites used in the 2004-2005 campaign had been monitored since 1992-1993.

Moreover, the monitoring campaign is organised every four years, and the collected data are highly dependant on the hydrological and climatic conditions of the year recorded, which favours either a dilution of nitrates in waters or on the contrary to a higher concentration. Continuously monitoring of nitrate concentrations in waters enables to distinguish the effect of annual variability in rainfall from long term changes in concentrations due to agricultural practices. However, this type of monitoring is particularly costly, given the number of points monitored and the different parties which act in the data acquisition and its postprocessing. Such approach has been tested since the 2004-2005 campaign on part of the Nitrate Monitoring Network for which the data acquisition is easiest.

Influence of the monitoring networks on Action Programmes

The conclusions drawn from the observation of changes in nitrate concentrations in waters allowed to re-assess the first Action Programme in 2001 and more particularly the third Action Programme in 2009. These networks justified the introduction of new mandatory measures in the fourth Action Programme.

The results on water quality observed in 2004-2005 and the analysis of the application of the second and third Actions Programmes showed that the results in terms of water quality were encouraging but not sufficient enough to reach the objective of a good state of quality regarding nitrate concentrations. One major reason for this, as was identified by the different monitoring networks, was that it had been quite difficult to control the fertilisation balance in the field.

It was thus decided to generalise preventive measures in all NVZs and to make compulsory catch crops preceding all spring crops and buffer strips 5 m wide along all water courses to prevent the potential nitrate losses to reach water courses and groundwater table.

Nevertheless, the monitoring approach adopted by France does not allow for quantifying the measures to be introduced to reach the objectives in terms of water quality. For example, it is not possible to assess the nitrogen pressure that should be reached to guarantee an adequate level of nitrate leaching towards waters. This requires development of models to first simulate and then predict the influence of agricultural pressures on water fluxes. Such models are being developed at the catchment area scale and were already tested in Bretagne (BRGM-INRA, 2008) but we are still not able to generalise them to large-scale territories showing a great diversity in agricultural practices, climatology, soil types, geomorphology, and other factors.

Water Framework Directive

The implementation of Water Framework Directive (WFD) led to creation of two networks to monitor water quality: the surveillance monitoring network (réseau de contrôle de surveillance, RCS) and the operational monitoring network (réseau de contrôle opérationel, RCO). It is now necessary to think in terms of coordination among all monitoring networks. Some work is being conducted to compare the different points from all these networks and to analyse the possibility of merging them with the Nitrate Monitoring Network. One problem which is encountered relates to the historical network of the Nitrate Monitoring Network which has been monitored since 1992-1993 and which is not encompassed by the WFD networks. This historical network is crucial to observe long-term changes in water quality.

Conclusions

The monitoring of water quality for the Nitrates Directive is of major importance to assess the efficiency of its implementation and to define the measures of the Actions Programmes.

The approach adopted by France relies on the monitoring of nitrate concentrations in surface waters and in groundwater for a large pool of observation sites, including an historical network monitored since 1992-1993 which allows the observation of long-term changes.

The collaboration with the research centres and the technical institutes enables (a) to exploit the conclusions drawn from research facilities at the plot or at the catchment scale, (b) to study the effect of agricultural practices on nitrate fluxes, and (c) to use modelling tools to design the measures of the Action Programmes.

Changes in water quality monitoring networks in the context of the Water Framework Directive will influence the nitrate monitoring network.

4 References

Beaudoin N., Parnaudeau, V., Mary, B., Makowski, D. and Meynard J.-M. (2004) Simulation de l'impact de différents scénarios agronomiques sur les pertes de nitrate à l'échelle d'un bassin hydrologique. In Organisation spatiale des activités agricoles et processus environnementaux. P. Monestiez, S. Lardon et B. Seguin Eds, Coll. Science Update, INRA Editions, p 117-141.

Beaudoin, N., Saad, J., Van Laethem, C., Maucorps, J., Machet, J.M., Mary, B. (2005) Nitrate leaching in intensive agriculture in Northern France: effect of farming practices, soils and crop rotations. Agric Ecosyst Environ; 111: 292–310.

Beaudoin, N. (2006) Caractérisation expérimentale et modélisation des effets des pratiques culturales sur la pollution nitrique d'un aquifère en zone de grande culture. PhD thesis INAPG; 210 pp.

Beaudoin, N., Launay, M., Sauboua, E., Ponsardin, G., Mary, B. (2008) Evaluation of the soil crop model STICS over 8 years against the 'on farm' database of Bruyeres catchment. European Journal of Agronomy; 29 (1); 46-57.

BRGM-INRA (2008) Etude sur les bassins versants en contentieux 'nitrates eaux brutes' (catchment areas in Brittany in the European infringement case against France) L'Institut national de la recherche agronomique, Bureau de Recherches Géologiques et Minières, 154 pp.

EC (1991) Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Communities, L375, 31/12/1991, 1-8.

EC (2003) Draft guidelines for the monitoring required under the Nitrates Directive (91/676/EEC). Version 3, with annexes 1 through 3. European Commission, Directorate-General XI (Environment, Nuclear Safety and Civil Protection), Directorate D Environment.

Ferrand, M., Lequenne, D., Manneville, V., Jannot, P. and Lopez, C. (2009) Apport de la spatialisation des données en analyse multidimensionnelles pour évaluer l'impact des activités agricoles sur la teneur en nitrates des eaux Revue Modulad n°39 pp. 81-94.

Manneville, V., Lequenne, D., Le Gall, A., Lucbert, J. (2008) Evaluation du programme de maîtrise des pollutions d'origine agricole.

Ministère de l'écologie, de l'énergie, du développement durable et de l'aménagement du territoire (2008) Bilan de la mise en œuvre de la directive nitrates en France (2004-2007).

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by Germany

R. Wolter[1], B. Ostenburg[2] and B. Tetzlaff[3]

[1] *Federal Environment Agency (UBA), Wörlitzer Platz 1, D-06844 Dessau-Roßlau, Germany*
e-mail: ruediger.wolter@uba.de

[2] *Institute of Rural Studies of the Johann Heinrich von Thünen-Institute (vTI), Federal Research Institute for Rural Areas, Forestry and Fisheries, Bundesallee 50, D-38116 Braunschweig, Germany*
e-mail: bernhard.osterburg@vti.bund.de

[3] *Research Centre Jülich, Institute for Chemistry and Dynamics of the Geosphere, ICG-IV: Agrosphere, D-52425 Jülich, Germany*
e-mail: b.tetzlaff@fz-juelich.de

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in Germany and its developments since 2003. The legal basis for this monitoring is Article 5 (6) of the Nitrates Directive. Besides the Nitrates Directive, all Member States also have to implement the EU Water Framework Directive (WFD) and the Groundwater Directive. Europe-wide, contamination by nitrate is the most frequent cause of failure to achieve good groundwater chemical status and the need to carry out Action Programmes. The fact that the WFD – unlike the Nitrates Directive – lays down, for the first time, time limits for achieving good status increases the pressure on Member States towards a sustained reduction of nitrogen inputs.
In Germany, the Nitrates Directive is implemented throughout the country. The legal basis for this is the Use of Fertilisers Ordinance, whose implementation is the responsibility of the Federal States (Länder). The effectiveness of the implementation is monitored using mainly the measurement data of the national EU nitrates monitoring network. In addition, there are separate programmes and investigations at local and regional level, which are carried out and monitored mostly by the Federal States' agricultural authorities. Overall, the measurement data show that nitrate concentrations in groundwater have decreased considerably in recent years at measuring stations with high nitrate levels.

1 Introduction

1.1 General

The inventory of German river basin districts under the EU WFD has shown that about 50% of all groundwater bodies are at risk of failing to achieve good status by 2015. About 45% of all groundwater bodies are at risk due to high nitrogen inputs.

In Germany, Action Programmes according to the Nitrates Directive are applied to the whole country. Therefore, effect monitoring on the national scale is based in many cases on trend analysis at groundwater observation wells. Since 2003, strategies and methodologies for the reduction of nitrate inputs to groundwater and the improvement of effect monitoring have been fructified by the implementation of the Water Framework Directive, in particular by setting up programmes of measures to achieve a good chemical groundwater status and by realizing appropriate agri-environmental schemes. Even so, it has to be expected that many groundwater bodies will continue to be at risk or in poor status after the end of the first management period (2015) even though measures were realised. Therefore, a need is seen for extending the time limit for achieving the objective. It will be necessary to demonstrate that management plans and measures were implemented in accordance with the requirements of the Water Framework Directive and are effective even if the aims of the directive could not be achieved until 2015.

1.2 Description of natural factors influencing nitrate occurrence

Climatic zones

Germany has a variable climate with frequent weather changes from day to day. Summer and winter weather patterns may also change from year to year depending on whether oceanic or continental influences dominate. The country can be divided into six climatic zones: North Sea coastland, Baltic coastland, North German Plain, central and southern uplands, upper Rhine valley, and Bavarian Alps.

The North Sea coastland, which includes the coast from the mouth of the river Ems to the mouth of the river Elbe, the East Frisian Islands and the west coast of Schleswig-Holstein, is the mildest area of Germany in winter although cold fronts are brought into it with eastern winds. Prolonged periods of temperatures below 0 °C are rare. While autumn is the wettest season, precipitation occurs all year round. The region is open to the influences of Atlantic storms.

The Baltic coastland includes the eastern coast of Schleswig-Holstein. It has a more severe winter than the North Sea coast although long freezing spells are not frequent. The wettest months are July through September, but there is rainfall all year round. Rain in the summer tends to be thundery.

In the North German Plain, a low-lying area, winter is significantly colder and severe cold spells may last for several months. However, some years these spells may be short and infrequent. Although it is the wettest season, rainfall in summer is often thundery and of short duration.

Central and southern Germany includes all uplands south of the North German Plain up to the alpine foothills west of the Rhine gorge. Temperatures vary mainly as a function of altitude so that the higher parts of Bavaria and the Harz mountains have the coldest winters and the longest duration of snow cover. Summer is generally warm despite the heavier rainfall. As in much of central Europe, summers may vary in character from one year to another, some being warm and dry, others cloudy and wet.

The upper Rhine valley, a small district in south-western Germany, is the warmest part of Germany in spring and summer and can be very sunny. On the other hand, winters can be cold because of the proximity of the Alps and the distance from the ocean. Rainfall is relatively evenly distributed throughout the year, summer having the wettest months.

In the Bavarian Alps, the wettest months are the summer months with rainfall above 130 mm month^{-1}. Temperatures can be below zero over periods of three months or more, with the lowest values in December and January.

Distribution of rainfall and groundwater recharge

Precipitation is quite unevenly distributed all over Germany. The mean annual rainfall is about 660 mm (Figure 1).

Figure 1 Distribution of annual rainfall in Germany.
(Source: www.schimke.de/niederschlag.htm)

Neuman and Wycsk (2002) calculated groundwater recharge rates for Germany. The average was 137 mm year^{-1} with a range between < 25 and > 400 mm year^{-1} (Figure 2).

Another important factor influencing nitrate occurrence is the type of aquifer. Under comparable conditions with respect to depth, type of overlying strata and agricultural use, aquifers in unconsolidated rock are generally less vulnerable than comparable ones in fractured rock.

Description of human factors influencing nitrate occurrence

Approximately 50% of the land area in Germany is used for agriculture, mostly intensively. The area covered by forests is slightly less than 30%, and only 4% are nearly natural areas (nature reserves and national parks). The total agricultural area is about 17 million hectares, of which 11.9 million ha are arable crops and 5.3 million ha are grassland and pastures. From the remaining land, about 10.5 million ha is covered by forest.

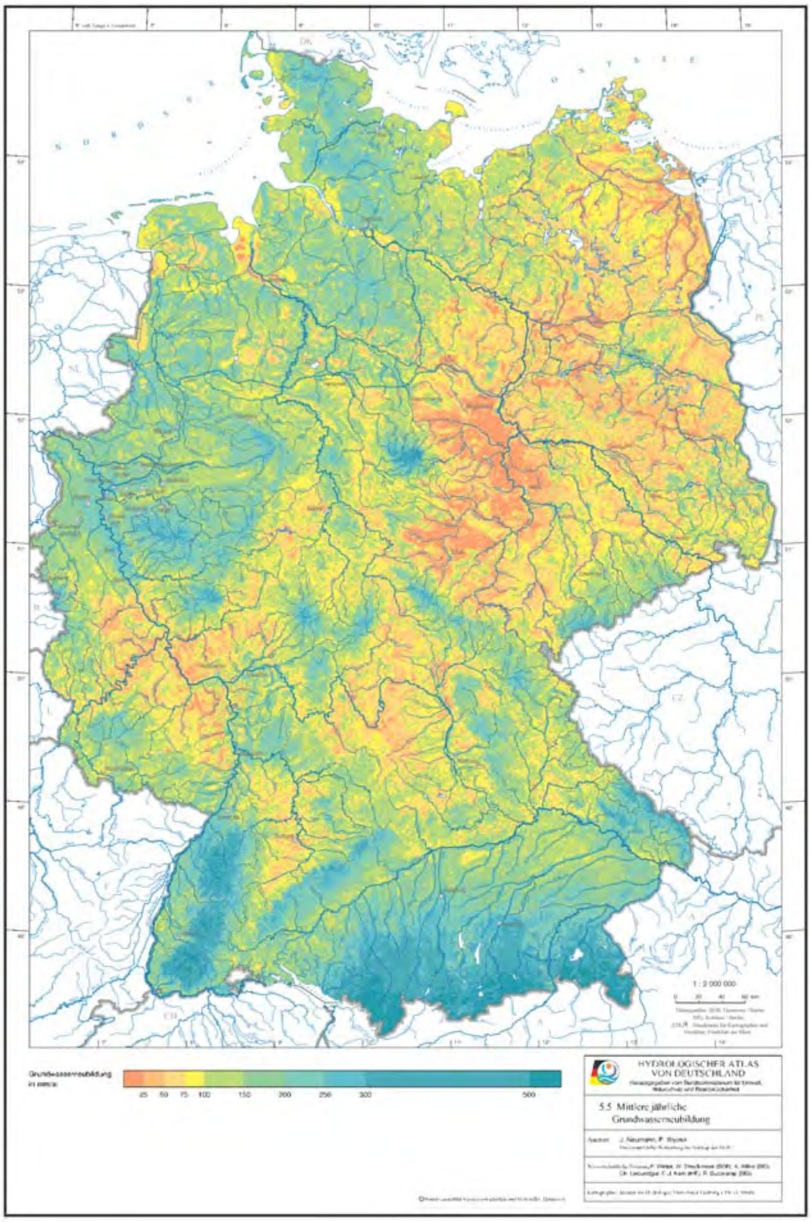


Figure 2 Average groundwater recharge rate (mm year^{-1}) in Germany.
(Source: Hydrologischer Atlas)

.

1.3 Environmental goals and measures

In Germany the Water Framework Directive and the Groundwater Directive have to be implemented. Environmental goals are described by quality targets and threshold values. For nitrate the quality target in Germany as well as in the whole of Europe is 50 mg l^{-1}. For ammonium a threshold value of 0.5 mg l^{-1} is foreseen in Germany. If necessary for the protection of sensitive aquatic and terrestrial ecosystems more stringent threshold values can be set for selected groundwater bodies or groups of bodies. For surface water the quality target for nitrogen is < 2.5 mg l^{-1} (about 11 mg NO_3 l^{-1}) (class II).

The rules of Good Farming Practice (GFP) according to the Nitrates Directive are implemented through the Federal Fertilisation Ordinance (Düngeverordnung, DüV), defining a code of GFP for fertilisation . Because requirements for manure storage are not included in this ordinance, there are additional ordinances by the German Federal States (Länder) on the storage of slurry, liquid manure, farmyard manure and silage effluent (JGS-Anlagenverordnungen). These ordinances constitute the basis of the German Action Programme and are mandatory in Germany. The Federal Fertilisation Ordinance was first published on 26 January 1996. Major revisions were adopted on 10 January 2006, and additional provisions concerning the coefficients for animal manure excretions were laid down in an amendment of 27 January 2007.

Code of Good Farming Practice in the Federal Fertilisation Ordinance

The Federal Fertilisation Ordinance defines a code of GFP in accordance with the Nitrates Directive, Article 4 and Annex II. These have been specified below. The following list is cited from the German Nitrates Report 2008 (Keppner and Ambros, 2008, pp. 34-36), comments are in italics:

1. Period during which the application of fertilisers to land is prohibited
Arable land: 1 November to 31 January, Grassland: 15 November to 31 January.

2. Distances to surface water bodies and watercourses
Minimum distance of 3 metres, or 1 metre if a precision fertiliser spreader is used. There must be no direct input and no run-off of nutrients into the watercourse or water body. Terrain and soil conditions must be given adequate consideration. Additional water-rights-related distance and management regulations (Länder regulations) must be observed.

3. Fertiliser applications on steep slopes
A minimum distance of 3 metres with no exceptions applies to steeply sloped arable land (land which has an inclination of 10% or more within the first 20 m from the top of the bank). Fertilisers must be incorporated immediately; for top dressings crop development must be at an adequate stage.

4. Fertiliser application on waterlogged, frozen or snow-covered ground
Fertilisers with significant nutrient contents must not be applied to waterlogged, frozen or snow-covered ground.

5. Appropriate fertiliser applications (including nitrogen balance, soil analysis, analysis of farm wastes, incorporation into soils)
In order to achieve a balance between the plants' expected nutrient demand and supply, the crop requirement in relation to the application of fertilisers must be established prior to fertiliser applications, having regard to the site's crop yield

level, site conditions (climate, soil texture and type), lime content and organic matter content. Soil analysis for phosphorus is mandatory, while for nitrogen calculation methods and methods of estimation or analysis of comparable sites as well as recommendations issued by the authorities with responsibility for agricultural advisory services are used in accordance with the regional legislation of the Länder. Total nitrogen content and phosphorus content must be determined for fertilisers and farm wastes; for liquid manure, slurry and other liquid fertilisers as well as poultry manure ammonium-N must also be determined.

6. Incorporation of fertilisers
Liquid manure, slurry and other liquid fertilisers as well as poultry manure must immediately be incorporated into the soil on uncultivated arable land in order to prevent ammonia volatilisation.
The term ‘immediately’ has been poorly defined and is currently under debate due to still high ammonia emissions from German agriculture. This poses problems in terms of achieving the objectives of the National Emissions Ceilings Directive (NEC), with a maximum of 550,000 tonnes NH_3 emissions in Germany.

7. Land spreading methods and equipment
Fertiliser spreaders must be in compliance with acknowledged rules of technology. From 1 January 2010 certain machinery (as set out in Annex 4 of the Federal Fertilisation Ordinance, in German …..) will no longer be permitted.
Broadcast application of slurry (‘Breitverteiler’), however, will not generally be subject to prohibition, but only selected, older technologies. Thus, NH_3 emissions from slurry application are expected to remain comparatively high.

8. Limits on the amount of livestock manure to be applied
The amount of livestock manure applied in any year to agriculturally used land on a holding, together with that deposited on land by livestock, must not exceed 170 kg of nitrogen per hectare. The amount of nitrogen produced by livestock and the nitrogen content of livestock manure is to be calculated in accordance with Annex 5 of the Federal Fertilisation Ordinance. On arable land, following the harvest of the main crop, a maximum of 40 kg ammonia-N ha^{-1} or 80 kg total N ha^{-1} from liquid manure, slurry or other liquid organic or organic-mineral fertiliser or poultry manure may be applied to meet the nitrogen demand of subsequent crops or as compensatory fertilisation to accelerate straw decomposition.

9. Keeping of records
For nitrogen and phosphorus, nutrient input/output budgets must be drawn up at farm level. Nutrient inputs are compared to nutrients removed from the system. The difference (nutrient balance) must be established per plot or area. The following data must be recorded:
- soil nitrogen content and method of determination;
- soil analysis results for phosphorus;
- total nitrogen and total phosphorus contents of fertilisers and method of determination; also the ammonium-N content in the case of slurry, liquid manure, other liquid organic or fertilisers and poultry manure;
- baseline data and results of input/output budgets.

10. Regulations regarding manure storage (*not part of Federal Fertilisation Ordinance*)
Statutory instruments issued by the Länder generally prescribe a minimum storage period of 26 weeks for slurry/liquid manure and storage facilities must be of sound construction. The 26-week minimum storage period applies to facilities constructed since the statutory instruments came into force. Older facilities must be brought up to standard by the end of 2008.

11. Maximum N and P surpluses (*this is a rule not covered by the Nitrates Directive*)
In addition to the requirements set out in Annexes II and III of the Nitrates Directive, maximum permitted surpluses at farm level have been set for nitrogen and phosphorus. The N balance, calculated as the average of the three preceding fertiliser years (period of 12 months, either calendar year or from July to June of the following year), must not exceed the following values:
- 90 kg ha^{-1} in the fertiliser years 2006 to 2008;
- 80 kg ha^{-1} in the fertiliser years 2007 to 2009;
- 70 kg ha^{-1} in the fertiliser years 2008 to 2010;
- 60 kg ha^{-1} in the fertiliser years 2009 to 2011 and thereafter.

For phosphorus (P_2O_5), calculated as the average of the six preceding fertiliser years, the maximum excess permitted is 20 kg ha^{-1} per year. However, exceeding the maximum N and P surplus is not subject to fines, so that breaches will lead in the first instance to 'soft measures' such as consultation with the advisory service.

Through the definition of the above rules, the German Action Programme seeks to achieve the objectives of the Nitrates Directive. Strikingly, the prescriptions stemming from Annex II of Nitrates Directive focus on fertilisation techniques and management, and not on results of this management. The only requirement addressing outcomes of fertilisation management are the maximum values for N and P surplus, which are based on additional requirements of the German Action Programme going beyond EU legislation.

Most of the provisions of the Federal Fertilisation Ordinance are binding for all farm holdings. The recording of nutrient data is mandatory for all farms larger than 10 hectares. Smaller farms are exempted as long as they have an animal manure N input below 500 kg per year, and less than one hectare of vegetables, strawberries or hops. Also farms with no essential fertiliser input do not need to provide records.

As the Federal Fertilisation Ordinance regulates fertilisation, the accounting and storage of manure in commercial farms without own land is not subject to the defined codes. Accounting of and trade in manure from these farms is regulated through the Fertilisers Act (Düngemittelgesetz, DüngMG) and the Fertilisers Ordinance (Düngemittelverordnung, DüMV). The allocation of manure from commercial farms poses a problem for the assessment of regional N balances, as manure traffic is not documented if neighbouring farms use this manure. A recent reform of the Fertilisers Ordinance (DüMV) will improve the documentation of trade in manure.

The implementation of the code of GFP in the Federal Fertilisation Ordinance (DüV) is supported by training, education and information measures established by the Länder. Also, farm individual technical advice contributes to implementation. Breaches of the provisions of the Federal Fertilisation Ordinance have decreased considerably in recent years. Since the introduction of Cross Compliance controls by 2005, there are harmonised regular controls of compliance, and the threat of reductions of farm subsidies helps to enforce mandatory rules. However, this relatively new tool, which focuses on control and sanctions, hampers co-operative approaches in water protection.

There is an exemption from the 170 kg manure N per hectare ceiling (derogation), accepted by the European Commission for the period 2006-2008 as well as for 2009-2013, for intensively used, mowed grassland and ‘field grass’, allowing for application of up to 230 kg manure N per hectare on this specific land. Procedures to extend the duration of the derogation are under way. Prerequisites for farms applying for this exemption are a nutrient surplus below the limits defined under point 11, use of improved slurry application, and reporting of the fertiliser records, so that farmers consider the requirements as quite restrictive. These demanding rules are seen as a reason that applications remained far below the expected numbers, with between 500 and 800 farms instead of several thousands. Farms that have applied for the derogation are situated mainly in regions with high livestock stocking densities in the federal states North Rhine-Westphalia and Bavaria. The additional manure applied in derogation farms amounts to about 0.1 of total animal manure N in Germany, and even in the regions with the most applications it remains well below 5% of regional manure amounts. Thus, only minor shifts in N loads can be expected due to this exemption in spite of clear and restrictive requirements.

At Länder level, there are also voluntary measures such as agri-environmental measures as part of EU co-financed Rural Development Programmes, co-operative approaches in designated areas for drinking water, and investment aid for slurry storage capacity or improved machinery (slurry application technology, seeding machines for reduced tillage systems). However, due to the fairly aggregated monitoring and reporting of such measures, and the federal structure of support through the German Länder, there is no comprehensive overview available on support measures focussed on water protection. The German Nitrates Report 2008 lists in Annex 1 measures reported by the Länder in varying detail.

1.4 Overview of trends in nitrogen and phosphorus loads and surpluses

As shown in Figure 3 the nitrogen surplus clearly decreased from 1992 to 2006. Data on the development of phosphorus surplus are not available. In parallel with the decrease of the nitrogen surplus a significant reduction in nitrogen concentrations at contaminated sites is readily identifiable.

Reduction of agricultural N surplus

Table 1a and Table 1b show the development of N inputs and outputs for the German agricultural sector. While N inputs fell between 1990 and 2006, especially animal manure, N outputs in agricultural commodities increased. Thus, sectoral N efficiency, calculated on the basis of the surface balance, improved from below 50% to almost 60%. In terms of the sectoral farm gate balance, N efficiency increased from 30% to about 40%. From these figures, a general downward trend can be stated for diffuse N pollution from agriculture. In 2003, due to drought and low yields the N surplus was much higher compared to previous and subsequent years. As shown in Figure 4, the calculated N surplus is spatially quite unevenly distributed and depends mainly on livestock density.

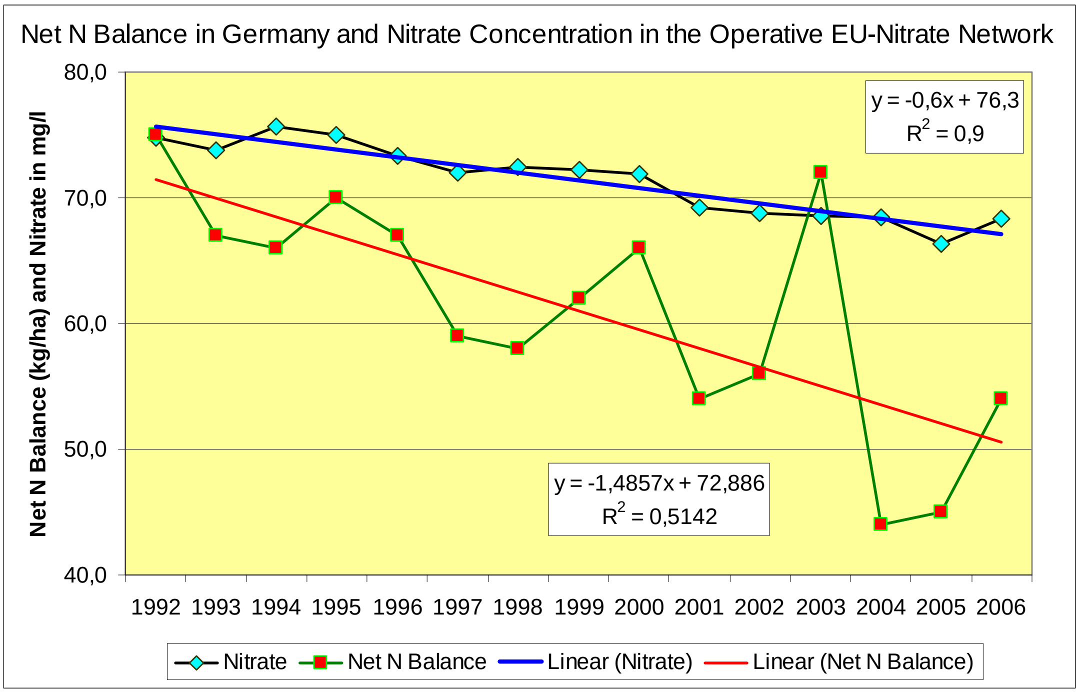


Figure 3 Trend in nitrogen surplus (net balance in kg ha^{-1}) and average nitrate concentration (mg l^{-1}) in the Nitrate Monitoring Network from 1992 to 2006.

Apart from the yearly turnover of N fertilisers and N uptake, N is both immobilized in the soil organic matter, and mobilised through tillage, amelioration and land use change. These N amounts can be crucial for N leaching when mobilisation occurs within a short timeframe so that mineralised N amounts are higher than plant uptake. Relevant are especially ploughing of grassland and of long-term permanent set-aside on arable land, and subsequent conversion into arable crop land. There has been a continuous loss of grassland in Germany since 1991, except in mountainous regions of the federal states Hesse and Rhineland-Palatinate. Between 2003 and 2007 alone, about 90,000 hectares of permanent grassland were lost. These figures are net balances, so that locally grassland area may still increase, while elsewhere losses are even higher. As the total utilised agricultural area (UAA) is decreasing, too, the fate of grassland remains unclear.

However, from increase in the area of arable land it can be deduced that some grassland has been converted into arable land. On organic soils (peat) and wet soils, conversion of grassland often goes together with soil amelioration, for example, installation of artificial drainage, which may contribute to a further mineralisation of soil N stocks.

Data from the Integrated Administration and Control System (IACS) on the management of area-related support payments for farmers as part of the Common Agricultural Policy (CAP) indicate high grassland losses especially in the years after the last CAP reform implemented in 2005. Price increases for agricultural commodities and favourable support for biogas in Germany based in non-food crops came together with a deregulation of eligibility rules for CAP area payments. Before 2005, areas stemming from grassland were excluded from arable crop payments, a rule which constituted an implicit protection of permanent grassland (Nitsch et al., 2008). There are two Länder implementing Cross Compliance rules for the protection of permanent grassland (Mecklenburg-Vorpommern and Schleswig-Holstein), as the ratio of permanent grassland to total UAA registered in IACS has decreased by 5% or more since 2005.

Table 1a Development of nitrogen inputs and outputs (nitrogen surface balance) in Germany 1990-1999 in kg ha^{-1} of utilise*d agricultural area per year (Keppner* and *Ambros, 2008, Table 3.4, page 32).*

Year	1990[1]	1991	1992	1993	1994	1995	1996	1997	1998	1999
Inputs										
Mineral fertiliser	121	110	101	99	93	103	102	101	103	111
Secondary raw material fertiliser	3	3	3	3	3	3	3	3	3	3
Livestock manure	98	90	88	86	85	84	84	83	82	81
Other N inputs	40	39	38	38	38	38	38	38	38	38
Atmospheric deposition	23	23	23	23	23	23	23	23	23	23
Biological N Fixation	16	15	14	14	14	14	14	14	14	14
Seeds/planting materials	1	1	1	1	1	1	1	1	1	1
Total N inputs	262	242	230	226	219	228	227	225	226	233
Total N outputs	115	118	110	117	113	116	118	124	126	126
Gross N balance	147	124	120	109	106	112	109	101	100	107
Gaseous N losses	49	46	45	42	40	42	42	42	42	45
Livestock manure	23	21	21	20	20	20	20	20	20	20
Mineral fertiliser[2]	18	17	17	16	14	16	15	15	15	16
Other N losses[2, 3]	8	8	7	6	6	6	7	7	6	8
Net N balance	98	78	75	67	66	70	67	59	58	62

[1] 1990 data base for new Länder in parts uncertain.

[2] Figures calculated after Dämmgen (2007).

[3] Figures calculated after Körschens et al. (2004).

Set-aside of arable land without productive use for non-food crops amounted to an area between 0.7 and 1.4 million hectares in the years from 1990 to 2005. The area was subject to yearly decisions on the share of obligatory set-aside as eligibility condition for the receipt of CAP crop payments. In 2003, about 8% of arable land or 5.5% of UAA were set-aside managed as fallow without non-food crops. Between 2003 and 2007, this area was reduced by 290,000 hectares, and between 2007 and 2008 by another 300,000 hectares. Together with grassland losses, there were land use changes on about 4% of total UAA, constituting potential ‘hot-spots’ of N loads. For the federal state Lower Saxony, it has been calculated that amelioration and land use change can induce substantial additional N losses of 30% of the yearly N surplus from fertilisation, with high regional variations (Osterburg and Schmidt, 2008). Thus, amelioration and land use change merit more attention when monitoring potential N losses from agricultural land use. However, for a detailed assessment of these sources an improved data base on soil hydrology and drainage as well as GIS based land use information are needed, which are not available at national level.

Table 1b Development of nitrogen inputs and outputs (nitrogen surface balance) in Germany 2000-2006 in kg ha^{-1} of UAA utilis*ed agricultural area per year (Keppner* and *Ambros, 2008, Table 3.4, page 32).*

Year	2000	2001	2002	2003	2004	2005	2006[4)]
Inputs							
Mineral fertiliser	118	108	106	105	107	104	105
Secondary raw material fertiliser	3	3	3	3	3	3	3
Livestock manure	81	81	79	78	77	76	76
Other N inputs	37	38	37	37	37	37	37
Atmospheric deposition	23	23	23	23	23	23	23
Biological N fixation	13	14	13	13	13	13	13
Seeds/planting materials	1	1	1	1	1	1	1
Total N inputs	239	230	225	223	224	220	221
Total N outputs	128	132	125	106	136	132	124
Gross N balance	111	98	100	117	88	88	97
Gaseous N losses	45	44	44	45	44	43	43
Livestock manure	19	19	19	19	19	19	19
Mineral fertiliser [2]	17	18	17	17	17	16	16
Other N losses [2, 3]	8	8	8	9	8	8	8
Net N balance	66	54	56	72	44	45	54

[1], [2], and [3] see footnotes Table 1a.

[4] 2006 preliminary figures.

1.5 Overview of trends in water quality

Groundwater

The positive trend of decreasing nitrate concentrations in groundwater continued in the latest monitoring period 2004-2006. Figures 5 and 6 show the frequency distributions of changes in nitrate concentrations, calculated by subtraction, between the latest monitoring period (2004-2006) and the 2000-2002 and 1992-1994 monitoring periods respectively. To allow for a comparison between the 2004-2006 period and the first monitoring period, the class limits had to be adapted accordingly.

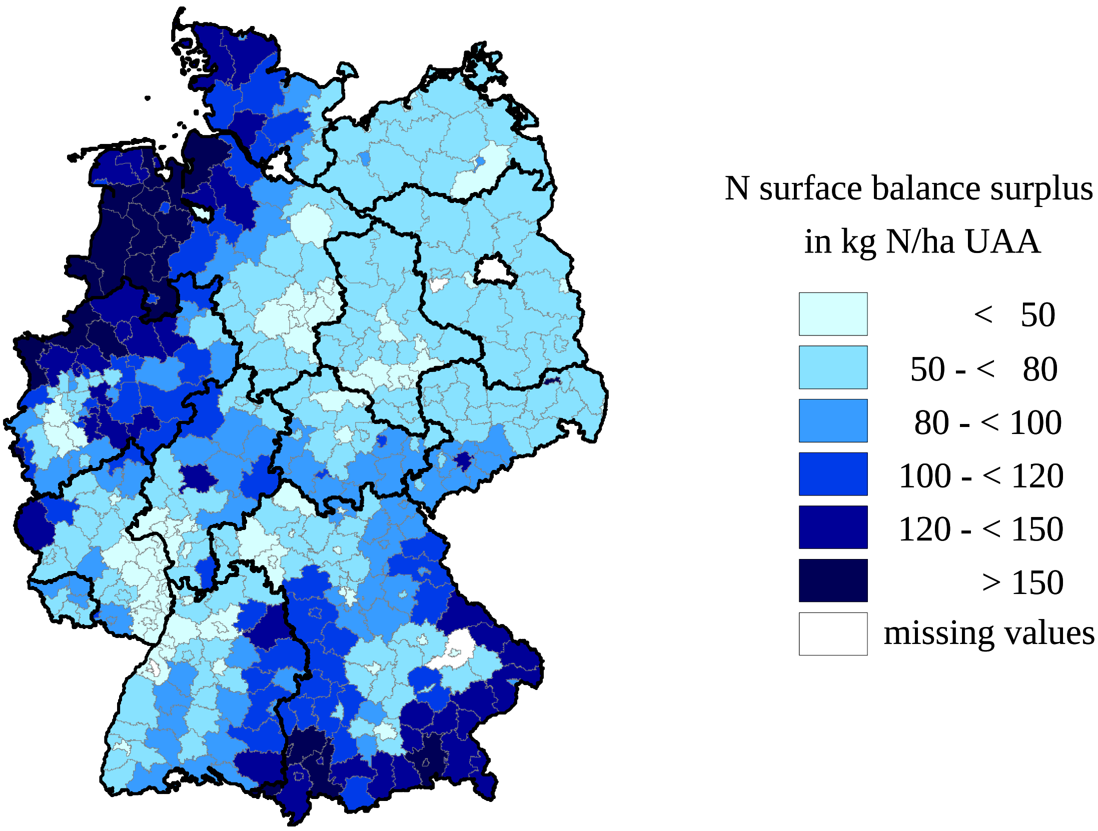


Figure 4 N surplus (net N balance) in Germany at county level (NUTS 3) in 2003. According to an estimate of the surface balance (without deduction of gaseous emissions, N deposition, and N in secondary raw material fertiliser) (Source: Osterburg, 2008).

Almost one third of the monitoring stations show a strong downward trend (33.5% and 28.8% respectively for the 2000-2002 and the 1992-1994 reference periods). This can be regarded as a positive development. At 23.5% and 27.1% of monitoring stations respectively, nitrate concentrations show at least a weak reduction. However, compared to the 2000-2002 period there is evidence of an increasing trend (weak or strong increase) at about a third of the monitoring stations, while compared to the first monitoring period about a quarter of the monitoring stations show an increase in nitrate concentrations.

The number of monitoring stations showing a decreasing trend (weak reduction or strong reduction) predominates in both comparisons, compared to the number of monitoring stations showing an increasing trend (strong increase or weak increase). In Figure 3 the ratio between monitoring stations with decreasing versus increasing nitrate concentrations is somewhat wider at 3:2 (91:58 monitoring stations). The assessment of the comparison between the latest monitoring period and the first monitoring period (Figure 5) is even more positive, with a ratio of 2:1 (99:42 monitoring stations).

Figure 7 shows the spatial distribution of mean nitrate concentrations in the 2004-2006 period and the changes compared to the 2000-2002 means at the 170 monitoring stations.

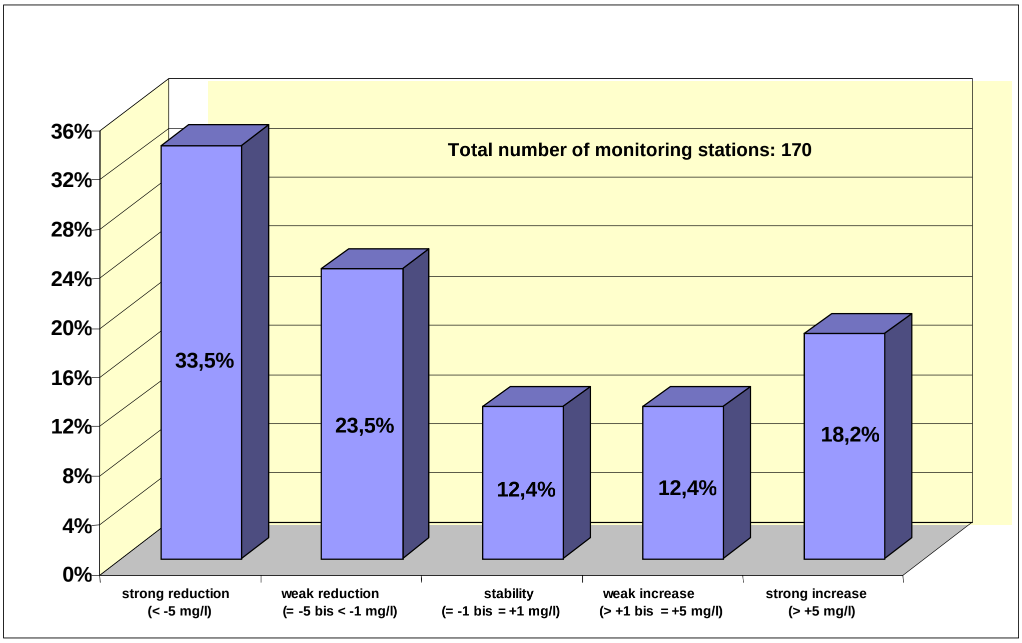


Figure 5 Frequency distribution of changes in mean nitrate concentrations in groundwater in Germany between the 2000-2002 reporting period and the 2004-2006 reporting period.

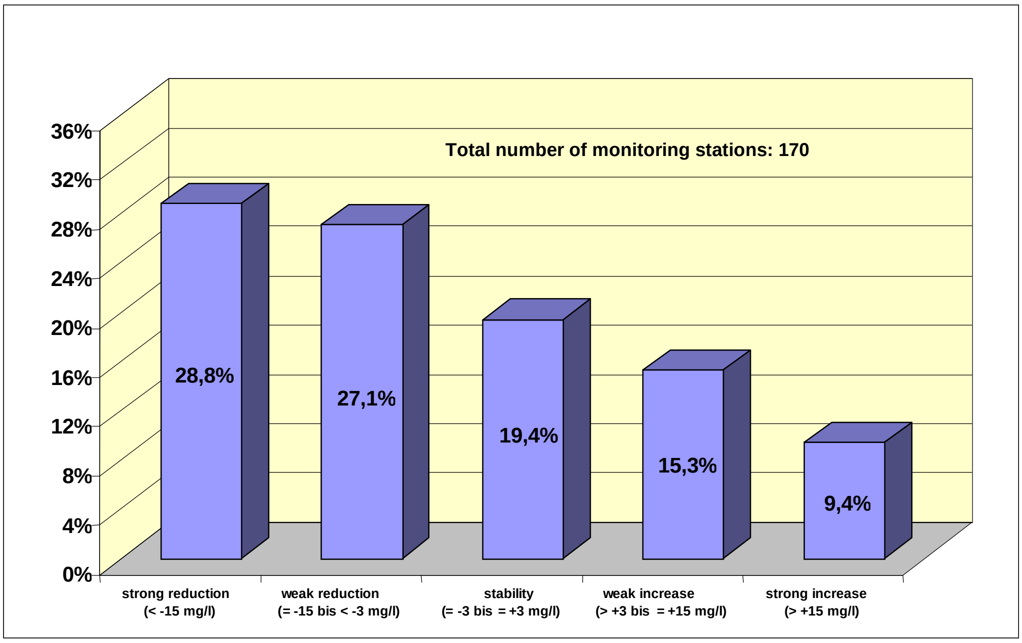


Figure 6 Frequency distribution of changes in mean nitrate concentrations in groundwater in Germany between the first reporting period (1992-1994) and the last reporting period (2004-2006).

Monitoring stations at which the first nitrate sampling data were gathered in 1995 are included in the 1992-1994 monitoring period.

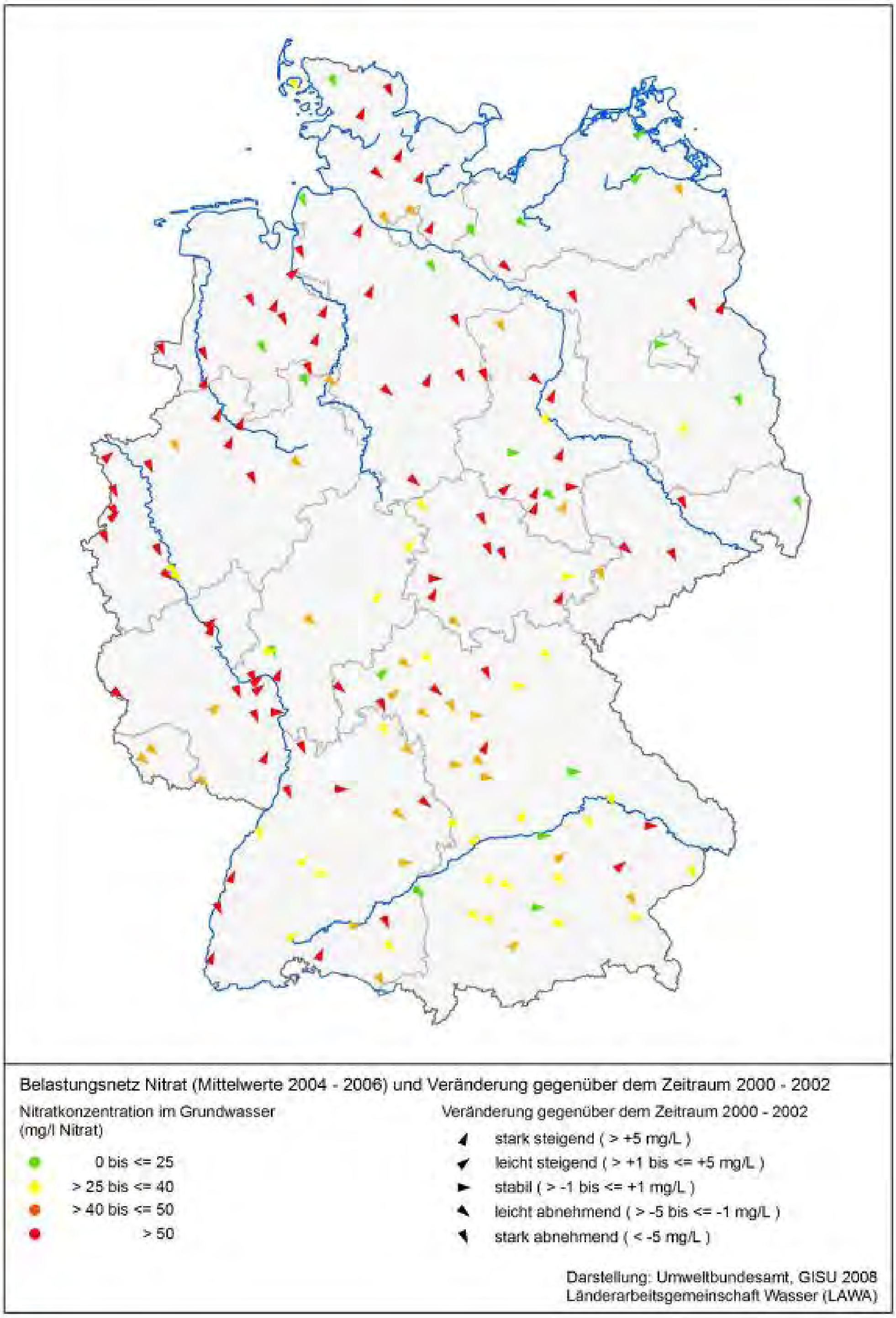


Figure 7 Operative groundwater monitoring network for nitrates (mean values for 2004-2006) and changes compared to the 2000-2002 period at 170 common groundwater monitoring stations.

Surface waters

Nitrate pollution of inland surface waters is subject to regular measuring at monitoring stations as part of the Länder network of monitoring stations. Representative summary data provided by the Länder were used for the evaluation. This does not preclude the possibility that regionally, and especially in smaller surface waters, loads may differ substantially and might require more far-reaching measures. However, this does not call the overall development into question. The representative selection of these monitoring stations based on uniform nationwide criteria includes 153 monitoring stations; Länder-Arbeitsgemeinschaft-Wasser (LAWA) network of monitoring stations. At these monitoring stations, sampling is carried out at least 12 times per year and in most instances 26 times per year.

In the Federal Republic of Germany, the assessment of the chemo-physical quality of waters uses a seven-level classification system to describe water quality. The chemical water quality classification (LAWA, 1998) uses the rating for nitrates as given in Table 2.

Table 2 German classification system for surface water quality with respect to nitrate concentration as NO_3 and NO_3-N[1] in mg l^{-1}.

Name of substance	Substance-related chemical water quality class						
	I	I - II	II	II - III	III	III - IV	IV
Nitrate-N (mg N l^{-1})	≤ 1	≤ 1.5	≤ 2.5	≤ 5	≤ 10	≤ 20	> 20
Nitrate (mg NO_3 l^{-1})	≤ 4.4	≤ 6.6	≤ 11.1	≤ 22.1	≤ 44.3	≤ 88.6	> 88.6

[1] For surface waters it is necessary to convert to N in order to allow for the comparison of the different nitrogen components which are subject to transformation in the ecosystem, primarily nitrate, nitrite (NO_2), ammonium (NH_4) and organic nitrogen.

The water quality map for nitrate (Figure 8) gives an overview of the development of nitrate pollution of watercourses between 1997 and 2006. It shows the quality classes as established at the monitoring stations of the LAWA network. Annual characteristic values are used to assign the stations to classes; the control value is the 90^{th}-percentile, which means, 90% of the readings taken in a year are lower than this value.

Figure 9 shows that in 2006 16% of the surface water monitoring stations had a 90^{th}-percentile value for nitrate-N below 2.5 mg N l^{-1}, 44% had values between 2.5 and 5 mg N l^{-1}, 39% had values between 5 and 10 mg N l^{-1}, and 2 stations had values between 10 and 20 mg N l^{-1}. Since 1994 none of the monitoring stations had 90th-percentile values of more than 20 mg N l^{-1}. The number of stations showing very high (IV) to elevated (III) levels of contamination has declined significantly since the mid-1990s. In contrast, the number of stations exhibiting moderately elevated (II-III) levels of contamination has increased significantly. The number of stations exhibiting moderate (II) to very low (I) levels of contamination has remained steady.

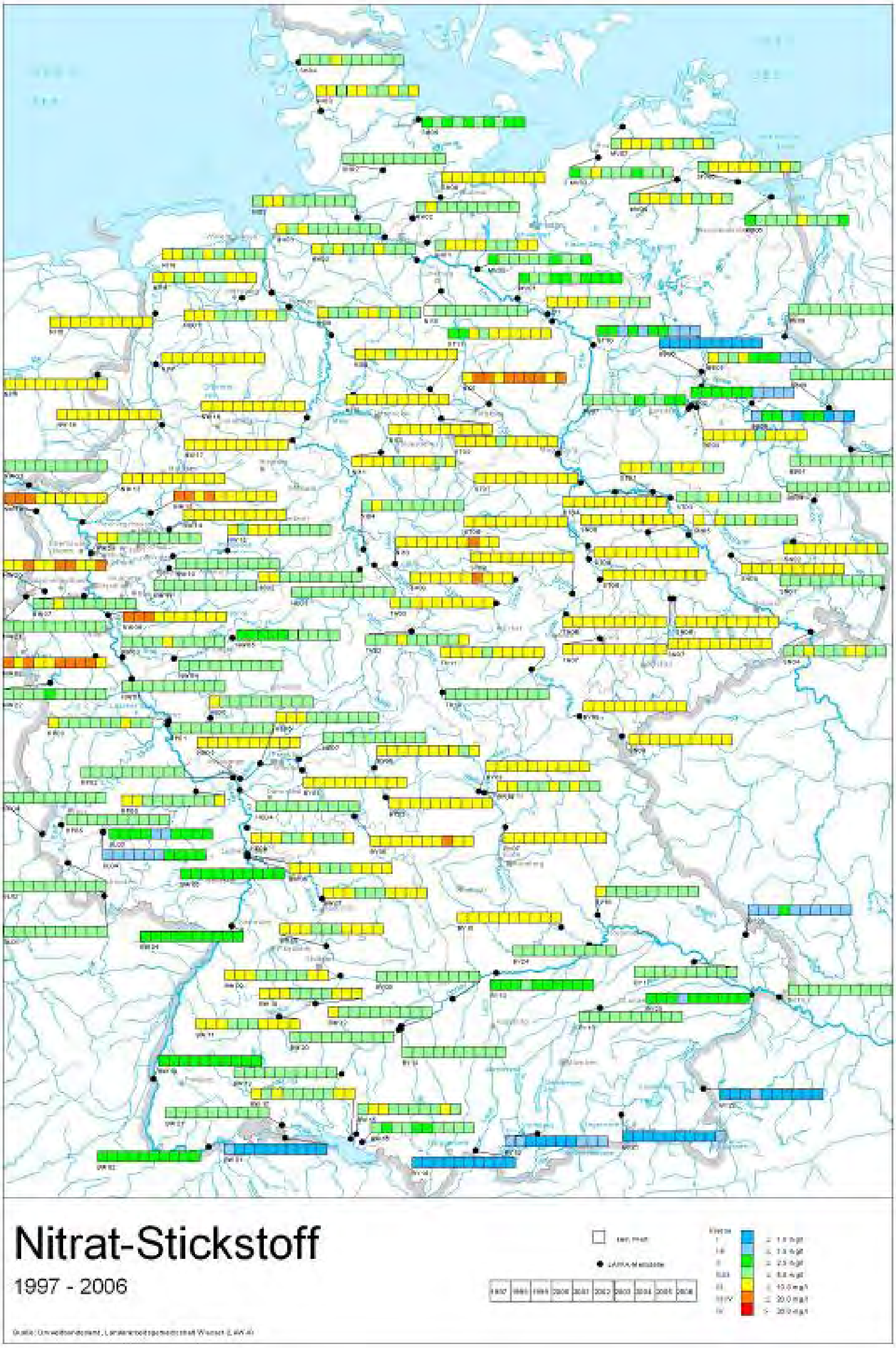


Figure 8 Water quality map for nitrate in surface waters in Germany for 1997-2006.

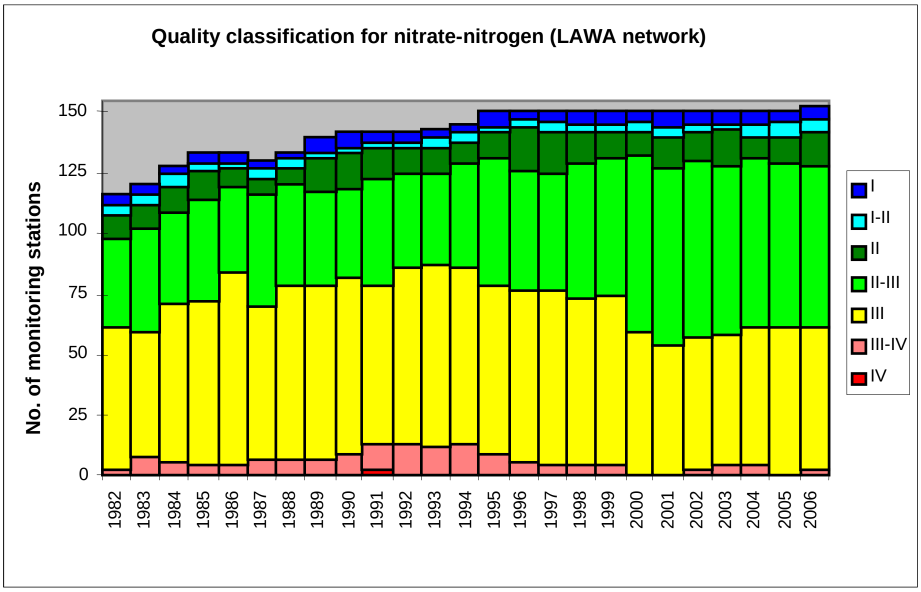


Figure 9 Distribution of nitrate concentrations in surface water monitoring stations in Germany by quality classes in the period 1982-2006.

The Nitrates Directive's quality objective of 50 mg NO_3 l^{-1} was met during the 2003-2006 reporting period at all monitoring stations shown. The annual mean was used as the control value.

Trend estimate
A trend estimate for the 153 monitoring stations is also made based on the 90th-percentiles. Under the climatic and hydrological conditions in Germany, higher nitrate concentrations occur during winter. Therefore, this approach is consistent with the proposal in the development guide to use winter averages.

In order to minimise the influence of fluctuations of nitrate concentrations due to run-off, the 90th-percentiles of the years 1991-1994 and 2003-2006 respectively were averaged. The averages in the two reporting periods were compared and the results grouped by percentage deviation from the 1991-1994 reporting period.

Figure 10 shows a slight or clear reduction of contamination at the majority of monitoring stations. Approximately 85% of monitoring stations of the LAWA network show a downward trend while at approximately 10% of monitoring stations the nitrate load has remained steady and at 5% of the stations there has been a greater or lesser increase.

The causes of the reduction in contamination have already been explored in detail in the notification submitted at the end of the First Action Programme (BMU, 2000, section 2.1.3 and Appendix I). Analyses of both pollution loads (same report, Appendix I, Part A1) and emissions (same report, Appendix I, Part A2) showed independently of each other that the reductions are predominantly due to measures implementing Council Directive 91/271/EEC concerning urban wastewater treatment. Newer emission analyses also confirm this result for the current reporting.

The increases at some sampling stations are likely due to the expansion of biological treatment in sewage treatment plants. Previously insufficiently treated wastewater contained higher levels of ammonium, which are now discharged as nitrates or to a lesser extent denitrified to gaseous nitrogen.

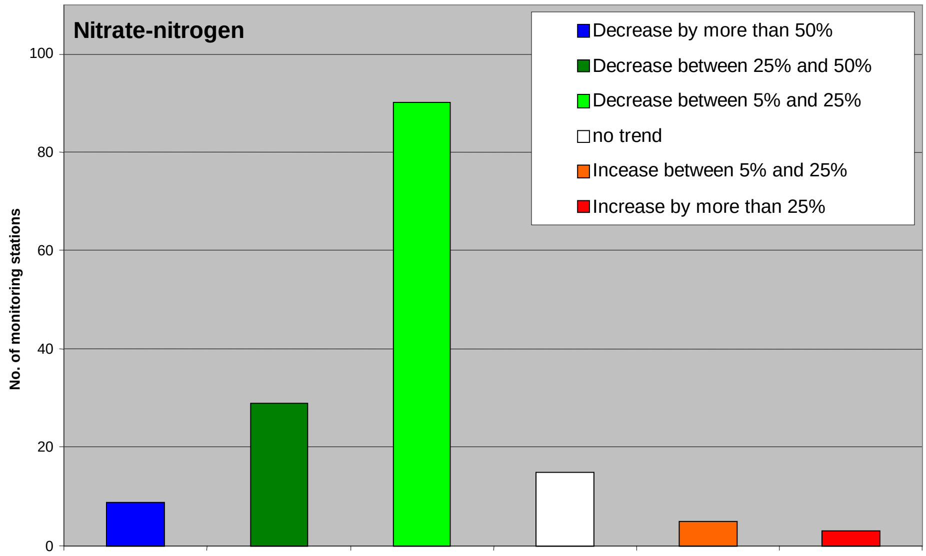


Figure 10 Changes in nitrate concentrations in surface waters in Germany 2003-2006 compared to 1991-1994.
Basis: LAWA network of monitoring stations; averages of 90th-percentiles of the years.

North Sea
An evaluation of the data based on the reference and orientation values derived for the WFD shows that nitrate orientation values at North Sea stations were in most cases clearly exceeded during the 2003-2006 reporting period (Figure 11). The readings from the Buoy 15 station in the Northern Friesian Wadden Sea (Nordfriesisches Wattenmeer Eider, Tonne 15; BLMP N3.2) are particularly striking, with winter values for 2006 exceeding the orientation value fourfold.

Nitrate concentrations decline with increasing distance from the coastline as inputs are derived mainly from land areas and become progressively more diluted in a seaward direction.

Assessment of eutrophication in the German Bight
The national report on the eutrophication status of the German coastal region prepared in the context of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) has identified the entire inner German Bight (Deutsche Bucht, Figure 11) as a problem area with regard to eutrophication. Apart from nutrient and oxygen concentrations this comprehensive assessment for the 2001-2005 period primarily considered biological parameters.

Similarly, the quality assessment report for the Wadden Sea (Essink et al., 2005) concludes that the Wadden Sea must continue to be classified as a problem area with regard to eutrophication. The nutrient contents assessed for the Wadden Sea were three to five times higher than the background values (Essink et al., 2005). The results of the eutrophication assessment for the German Bight including the Wadden Sea are also mirrored in the results of the inventory carried out in accordance with Article 5 of the WFD which show that the majority of German North Sea coastal waters are not expected to attain ‘good ecological status’ by 2015 as they are eutrophied. It has become evident that, apart from the biological quality elements of the WFD, the quality element ‘nutrient conditions’ is of key importance to German transitional and coastal waters, for example, with regard to determining nutrient reduction measures.

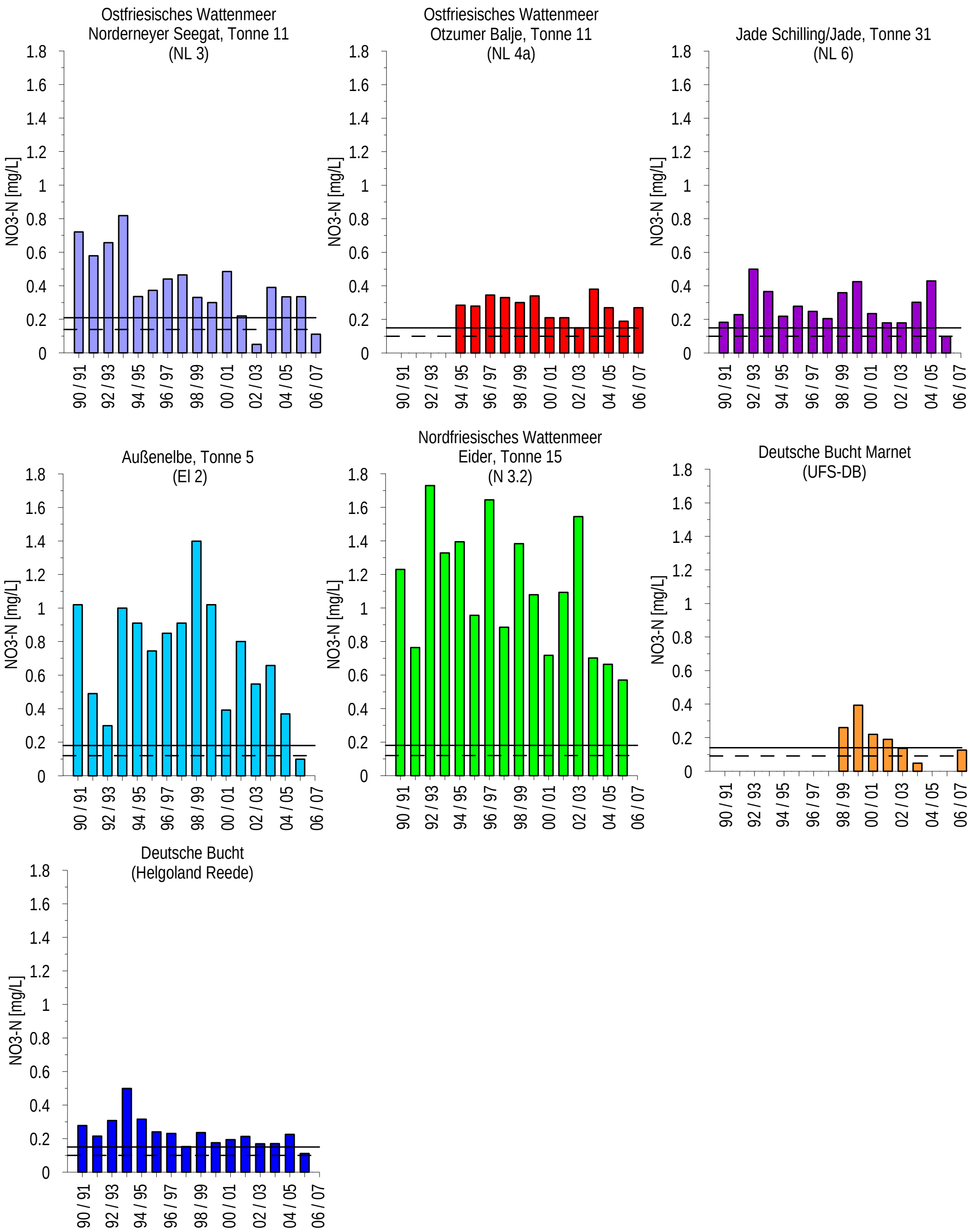


Figure 11 Nitrate-N winter values (mg N l^{-1}) monitoring stations at the North Sea coast taken at a depth of mostly 0.5-1.0 m in 1991 to 2006.

Samples taken across the turn of the year from 1 November to 28 February; January and February values are assigned to the previous year. Background values and orientation values refer to the relevant classification of coastal waters in accordance with the Water Framework Directive.

Baltic Sea
As would be expected, nitrate concentrations at the Baltic Sea monitoring stations (Figure 12) are much lower compared to the North Sea (Figure 11). The assessment of nitrate concentrations in accordance with the WFD shows that in the years 2003-2006 nitrate orientation values at the 'Flensburg Inner Förde' (OM225019) and 'Pomeranian Bay' (OMOB4) stations were often exceeded. However, at the 'Kiel Outer Förde' (OM225059) and 'Mecklenburg Bay' (OMO5) stations, nitrate concentrations have consistently been below the orientation value in the past four years. WFD implementation does not require the assessment of waters at the offshore stations 'Kiel Bay' (OMBMPN3), 'Lübeck Bay' (OM714)', 'Mecklenburg Bay' (OMO5) and 'Pomeranian Bay' (OMOB4) as these are located outside of the 1 NM zone; only the chemical condition needs to be assessed based on concentrations of priority substances. As they correspond best to water types B3/B4, the background and orientation values for these types were used. Figure 12 shows that the orientation values for these three stations were only exceeded in the 1990s. A weakness of this pragmatic approach can be seen in that the readings taken over the past few years were in part below the background values. However, if one considers that at the selected Baltic stations nitrogen is also being fixed by way of phytoplankton biomass production during the winter, the nitrogen concentrations measured would theoretically need to be increased. To this end, the chlorophyll concentrations measured during the winter could be converted into nitrogen equivalents and added to the nitrate concentrations. In such test calculations for the selected Baltic Sea stations background and orientation values for nitrates were exceeded throughout.

Assessment of eutrophication at the German Baltic Sea coast
A thematic assessment of eutrophication in the Baltic Sea is currently being carried out under the Helsinki Convention. The joint assessment method (HELCOM Eutrophication Assessment Tool; HEAT) closely follows the OSPAR method. It can reasonably be assumed that the bulk of the German Baltic Sea inner coastal waters will be found to be eutrophied.

Comparison of nitrate concentrations in the periods 1991-1994 and 2003-2006
At the majority of marine and coastal water stations nitrate concentrations show a slight decrease or have remained stable. A comprehensive assessment of monitoring results with a view to trend estimates is constrained by low sampling frequencies for the entire 1991-2006 period.

As nitrates are mostly derived from diffuse sources, the nitrate concentrations are closely correlated with annual rainfall patterns and the associated discharge. A potential reduction at source is therefore not clearly traceable and in turn it is difficult to identify a general trend. Nevertheless, between the first reporting period (1991-1994) and the current reporting period (2003-2006) a decline in nitrate concentrations could be detected in German coastal waters and thus a slight approximation to orientation and background values.

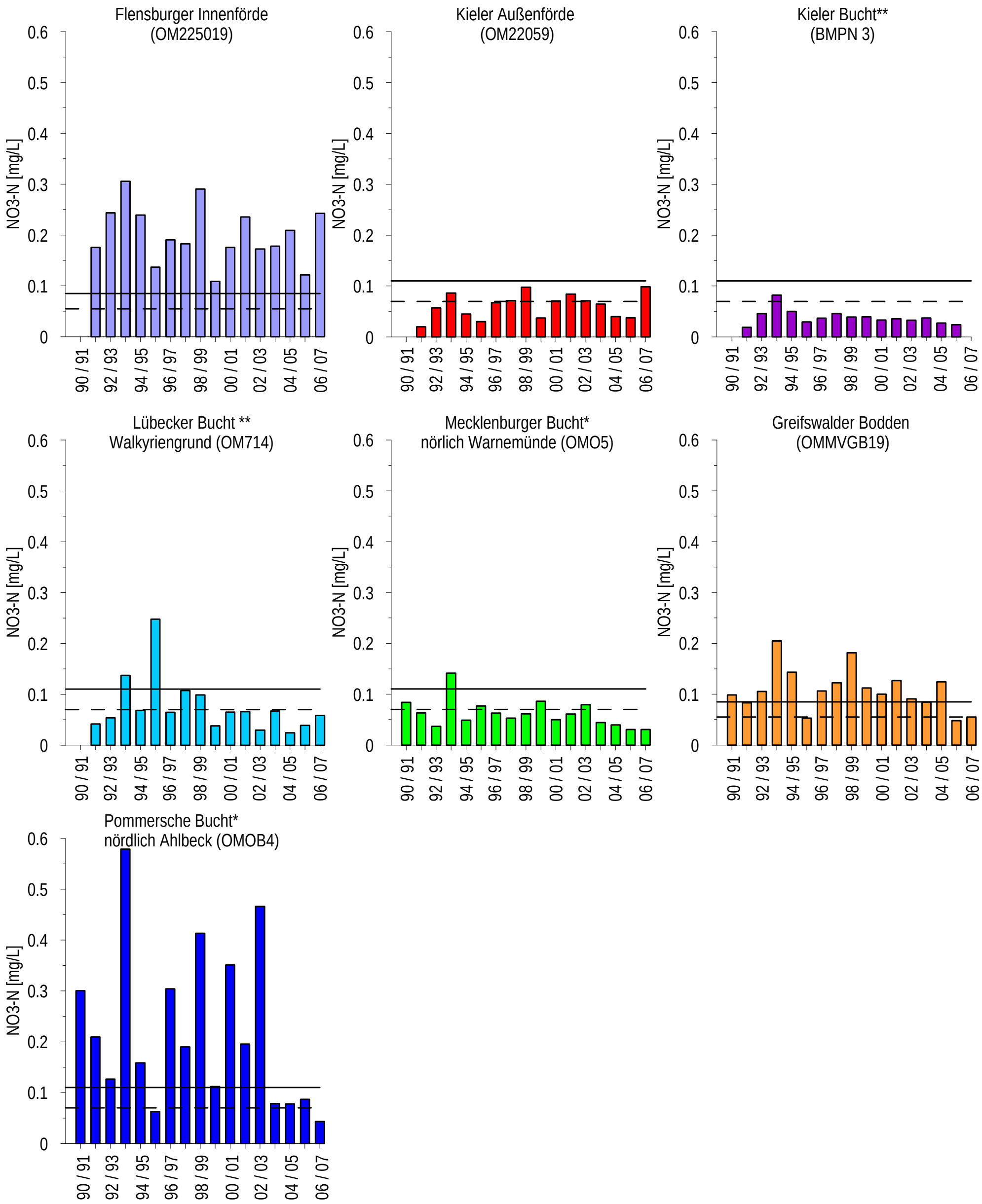


Figure 12 Nitrate-N winter values (mg N l[-1]) for monitoring stations at the Baltic Sea Coast taken at a depth of 0.5-1.0 m in 1991 to 2006 (1 November to 28 February).

Background values and orientation values refer to the relevant classification of coastal waters in accordance with the Water Framework Directive. For the 'Flensburg Förde' and 'Greifswald Bodden' stations the respective higher background and orientation values are shown.

*, ** Chemical assessment only in accordance with WFD, correspond most closely to water types B3* and B4**.

At the monitoring stations located in German North Sea coastal waters with estuarine influence a decline of > 30% in nitrate concentrations compared to the first reporting period was reported at the 'Norderney Tidal Channel, Buoy 11', 'Outer Elbe, Buoy 5', 'Eider, Buoy 15' and 'Helgoland Roadstead' stations. However, at the 'Otzum Tidal Creek, Buoy 11' and 'Jade Estuary Schillig, Buoy 31' stations nitrate concentrations have remained merely stable in the current reporting period compared to the first reporting period.

For Baltic Sea coastal waters in Schleswig-Holstein the nitrate-N winter concentrations at the 'Flensburg Inner Förde' and 'Lübeck Bay' stations were considerably lower (> 25%) in the current reporting period (2003-2006) than in the early to mid-1990s. At the 'Kiel Outer Förde' and 'Kiel Bay' stations, outside of the 1 NM zone, slight increases and decreases of nitrate-N concentrations below the orientation values were observed. At the coast of Mecklenburg-Western Pomerania considerable decreases of nitrate-N readings (between 36% and 66%) have also been observed.

1.6 Overview of monitoring networks

Monitoring network for surface water

As Germany applies the Action Programmes across its entire territory, there are no monitoring programmes for the identification of nitrate vulnerable zones (NVZs).

Nitrate pollution of inland surface waters is subject to regular measuring at monitoring stations as part of the Länder network of monitoring stations. Representative summary data provided by the Länder were used for the evaluation. This does not preclude the possibility that regionally, and especially in smaller surface waters, loads may differ substantially and might require more far-reaching measures. However, this does not call the overall development into question. The representative selection of these monitoring stations on the basis of uniform nationwide criteria includes 153 monitoring stations (LAWA network of monitoring stations, see Figure 8). At these monitoring stations sampling is carried out at least 12 times per year and in most instances 26 times per year. In Germany nitrate concentrations are classified according to a system consisting of seven quality classes (see Table 2). Class II with an upper limit of 2.5 mg N l^{-1} is the target value. For classification the 90th-percentile values of all analyses within a year are used.

Monitoring network for coastal waters
The competent federal German authorities and the Länder jointly carry out monitoring programmes in estuaries, coastal waters and offshore areas (Joint Federal/Länder North Sea Monitoring Programme, Joint Federal/Länder Baltic Sea Monitoring Programme). These programmes are undertaken in fulfilment of commitments the Federal Republic of Germany has taken on in the context of international marine environmental protection conventions (OSPARCOM, HELCOM) including reporting obligations under relevant EU Directives, for example, Nitrates Directive (EC, 1991).

The monitoring stations selected for the Joint Federal/Länder Monitoring Programme cover the estuaries of the major and minor rivers (Weser, Elbe, Eider, Jade) including the Wadden Sea, the inner German Bight (Helgoland-Reede station) and the outer coastal areas of the North Sea. In the German Baltic Sea area both coastal and marine areas are represented (see Figures 13 and 14).

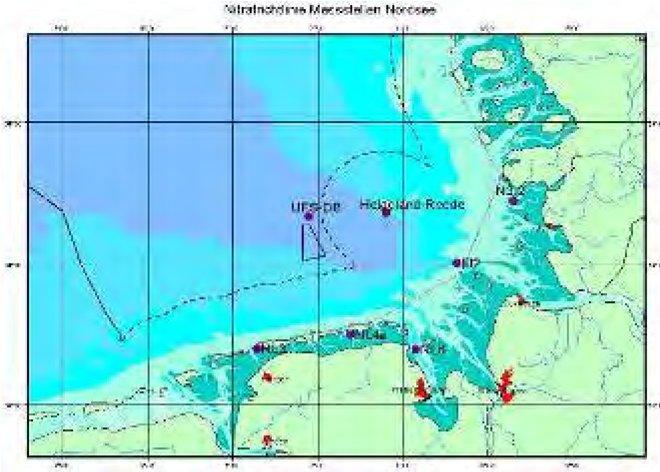


Figure 13 Nitrate monitoring stations in German coastal waters of the North Sea.

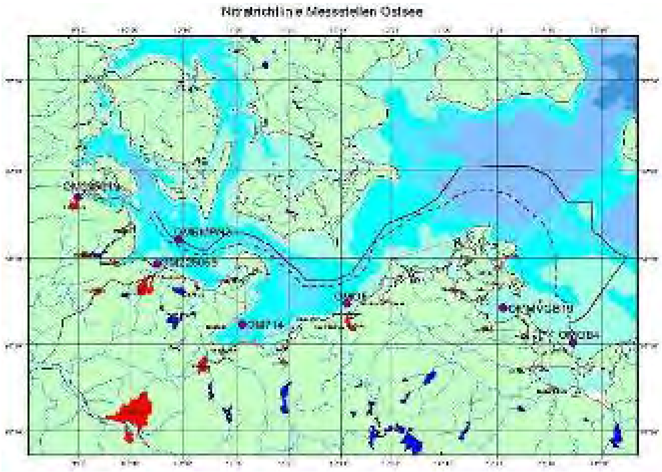


Figure 14 Nitrate monitoring stations in German coastal waters of the Baltic Sea.

Monitoring networks for groundwater

For the first German nitrate report (BMU, 2000) the so-called 'EU nitrate network' was established. It consisted of about 180 sampling sites, located in areas with high nitrate concentrations in groundwater. Due to losses of sites there are currently 170 operational sites. The sites were selected and are operated by the Federal States. The criteria for the selection of sites were:

- site must be located in the upper aquifer, and
- contamination by nitrate must come from agriculture.

The EU-nitrate network (see Figure 15, blue dots) is not representative of the nitrate dis-tribution in German groundwater. It can be characterised as an operational network according to the classification of the Water Framework Directive. Sampling frequency is not uniform all over Germany. In the 2004 to 2006 period about 13% of the sites were analysed once per year, about 60% twice a year and about 11% every two months.

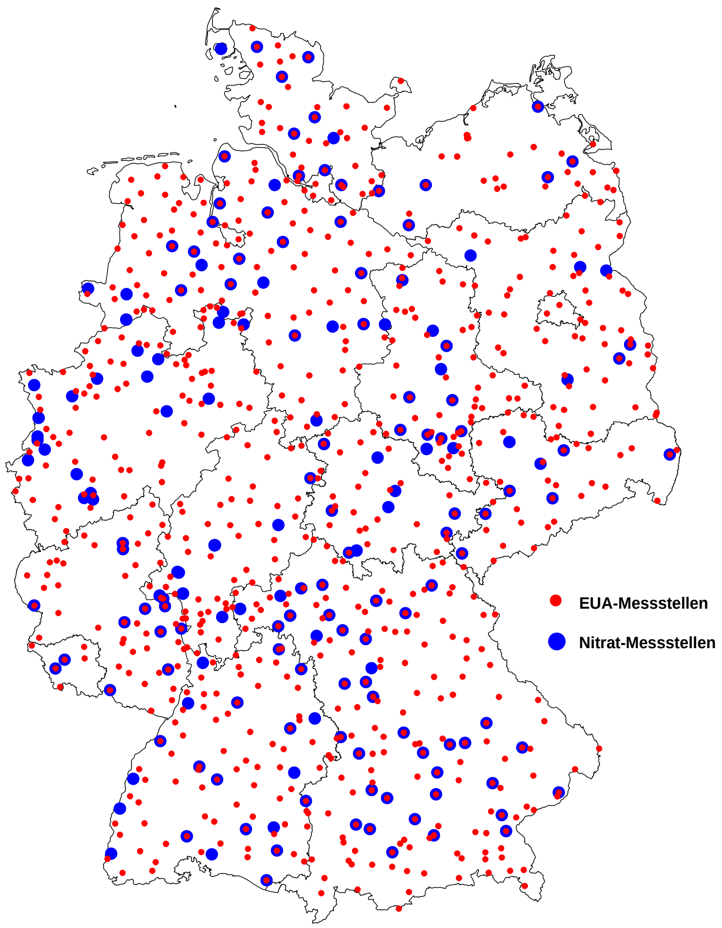


Figure 15 Sampling sites of the Groundwater Monitoring Network (EEA-Network = red) and the Nitrate Network (blue).

The European Commission stated the need for a representative overview of nitrate concentration in groundwater. In the 1990s in Germany a representative groundwater monitoring network was installed to fulfil existing obligations for reporting to the European Environment Agency (EEA). It is referred to as the 'EEA network' (see Figure 15, red dots) (Wolter and Mohaupt, 2005). Of major interest are the impacts of diffuse (non-point source) anthropogenic inputs of contaminants, for example, nitrates, pesticides, acidifying components and other pollutants, on groundwater quality (Wolter et al., 2000).

The EEA network consists of about 800 sampling sites distributed more or less evenly over the 16 Federal States. The number of sampling sites in each state depends on its size. At present there is an average of one sampling site per 450 km^2. In close co-operation with the German Federal States, the Federal Environment Agency (UBA) defined the set of data necessary to characterise the sampling site and its catchment area.

Important parameters are location and type of sampling site, petrographic composition of the aquifer, and predominant land use in the catchment area. In addition to temperature, conductivity and acidity, parameters characterising groundwater quality include all major anions and cations, selected heavy metals, metalloids, some organic components and selected pesticides (Table 3).

Table 3 Important parameters to characterise the sampling site and catchment and the groundwater status.

Sampling site:
Code number and location of sampling site
Altitude of site and well screen position
Type of sampling site (well, spring, etc.)
Land use
Hydrogeology (stratigraphy, petrography)
Type of aquifer (unconsolidated rock, fractured rock, karst)
River basin

Important parameters analysed:
Groundwater specific data
Temperature; pH; electrical conductivity. O_2; NH_4; NO_2; NO_3; o-PO_4; Cl; SO_4; B; DOC K; Na; Ca; Mg
Heavy metals/metals/metalloids Al; As; Pb; Cd; Cr; Fe; Cu; Mn; Ni; Zn
Aliphatic halogenated hydrocarbons
Pesticides

In general, sampling at the sites of the EEA network should be conducted at least twice a year. The data have to be reported to the Federal Environment Agency once a year. The network is designed to give a representative picture of groundwater quality in Germany (Figure 16).

Under the Water Framework Directive Member States had to establish monitoring networks for groundwater and surface waters. Table 4 shows the number of sites selected in Germany for these different networks.

Table 4 Monitoring networks for surface waters and groundwater according to Article 8 of EU WFD. (Source: www.wasserblick.net)

Surface waters	Type of monitoring sites		
	Surveillance network	Operational network	Investigative monitoring network
Rivers	259	5,562	373
Lakes	68	585	0
Transitional waters	7	7	0
Coastal waters	34	70	0
Total	369	6,390	373
Groundwater	**Type of monitoring sites**		
	Surveillance network	Operational network	Quantitative network
All groundwater sites	5,682	3,979	8,960

In addition to these networks, the German Federal States have independent groundwater monitoring networks. Many of them are sub-networks to identify natural background levels as well as diffuse and point source pollution. Several Federal States have sub-networks to determine the impact of agriculture on groundwater quality. The number of sampling sites in these networks differs significantly from state to state. Further information on these networks can be obtained from the environment or water resources management reports of the Federal States.

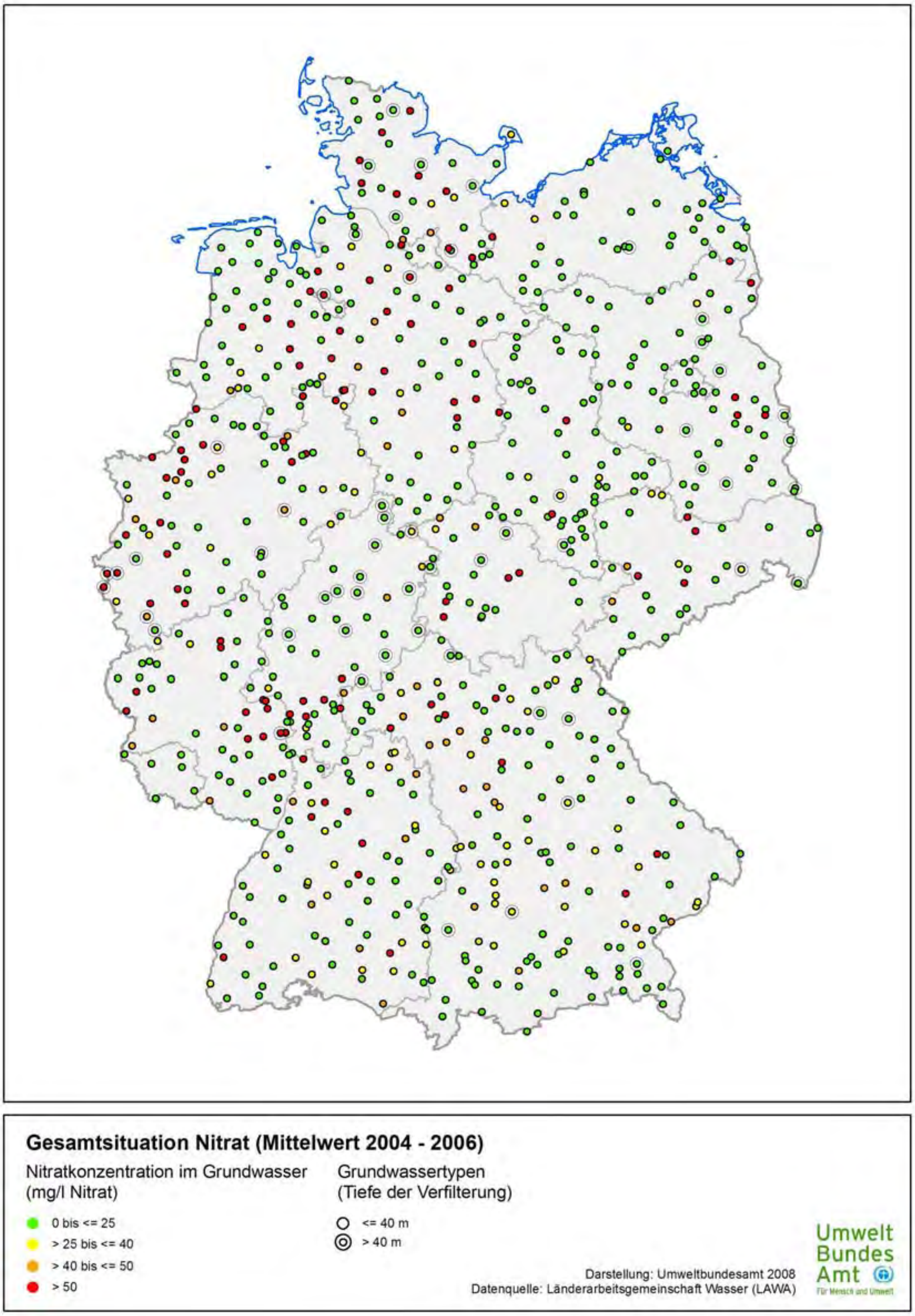


Figure 16 Distribution of nitrate in German groundwater.
Average values for the sampling sites of the EEA groundwater monitoring network.

Monitoring of compliance with the codes of GFP

In accordance with the logic of the Nitrates Directive, the focus of monitoring in the agricultural sector is on compliance with the codes of Good Farming Practice. There are two types of controls: According to the Council Regulation establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers (Reg. (EC) 1782/2003), regular 'Cross Compliance' checks regarding selected EU legislation have to be performed. Selected rules defined in the Fertilisation Ordinance, which are based on Nitrates Directive and are feasible for systematic on-the spot control, are part of these systematic checks. Further, the Länder authorities perform on-the-spot controls in case of suspicion or in response to information received (so-called Anlasskontrollen). These controls are focussed more on cases of expected non-compliance. In Table 5, control items are listed and the relevance for administrative or Cross Compliance controls indicated. Systematic Cross Compliance checks do not cover all codes of GFP, and focus on formal checks, for example, the mere existence of fertiliser records, without referring to the quality of the record or the resulting surplus. The maximum N and P surplus is controlled neither through administrative inspections by specialised authorities nor through Cross Compliance checks.

Table 5 Control items related to the Federal Fertilisation Ordinance (DüV) and their relevance for fines and Cross Compliance.
Based on Landwirtschaftskammer Niedersachsen, 2006.

Infringement	Relevant for administrative controls and fines	Relevant for Cross Compliance controls and sanctions
No soil testing (P)	Yes	No
No Nmin tests	Yes	Yes
No values/no accounting for manure N	Yes	Yes
Fertiliser record missing	Yes	Yes
Incomplete or wrong fertiliser record	Yes	No
No keeping of fertiliser record and calculation data for fertilisation planning	Yes	No
Exceeding the max. N surplus	No	No
Exceeding the max. P surplus	No	No
Missing records on use of meat/bone meal	Yes	No
Spreading of fertilisers/manure on saturated or frozen soils	Yes	Yes
Leakage of N and P fertilisers into surface water	Yes	Yes
No respect of restriction on sloped arable land	Yes	No
Use of unauthorised technology (by 2010 onwards)	Yes	Still unclear
No immediate incorporation of manure into soil on uncultivated arable land	Yes	No
Exceeding the 170 kg N threshold	Yes	Yes
Spreading fertiliser/manure during the time in which this is prohibited	Yes	Yes
Exceeding the maximum N amount in autumn	No	Yes
Use of fertilisers not in keeping with the requirements of the Fertilisers Ordinance (DüMV)	Yes	No
Failure to respect ban on application of meat/bone meal, *Kieselgur*	Yes	No

In contrast to fines, Cross Compliance sanctions are calculated on the basis of direct payments, and payment reductions can be implemented without further legal procedures after an infringement has been detected. The procedure for Cross Compliance controls in Germany is described in the following.

Statutory Management Requirements: Control Points for the Nitrates Directive (Cross Compliance standards and controls according to Reg. (EC) 1782/2003, Annex III) (after Nitsch, 2006).

Control reports specifying the control criteria have been developed by the Working Group on Cross Compliance in Germany in order to ensure a uniform execution of inspections (the full details of the requirements are specified in the Länder brochures on cross compliance). A distinction is drawn between standards that are controlled systematically and others that are brought to the attention of the Competent Control Authority in other ways, for example, specialised authorities controlling national legislation independently through on-the-spot checks are obliged to report non-compliances which are relevant for cross compliance. These so called 'cross checks' are an integral part of the German system of implementing cross compliance (Bund-/Länder-AG, 2006).

The control reports for 2007 defined systematic control standards for cross compliance with respect to the Nitrates Directive. However, the Nitrates Directive is only applicable if N fertiliser within the meaning of the Federal Fertilisation Ordinance is applied or slurry or manure is stored on the farm. The systematic control standards are:

- The content of mineral N (Nmin) in the soil has to be determined and documented annually through soil analyses for all plots with similar conditions and crops or on the basis of published test results from comparable locations or recommended procedures for calculation and estimation of N content (not necessary for permanent pasture and if farmer is not obliged to produce an N balance).
- The content of total nitrogen in organic or organic-mineral fertilisers or other substrates, and additionally of NH_4 (ammonium nitrogen) in case of slurry and other liquid organic fertilisers, has to be determined and documented before application on the basis of labelling, laboratory analyses, or on the basis of the calculation and estimation procedures recommended by the competent authority or approximate values. This is not necessary if farmer is not obliged to produce an N balance.
- An N balance has to be produced every year. Exceptions are, for example, for holdings that only have areas with ornamental plants, tree nurseries and orchards, or areas that are only grazed with a maximum N input of 100 kg N ha^{-1} and no additional fertilising or holdings, where each field is not fertilised with more than 50 kg N ha^{-1} per year, or on farms with less than 10 ha agriculturally used land, or on farms with less than 10 ha agriculturally used land - already excluding the above named areas - with a maximum of 1 ha vegetable, hops and strawberries and producing not more than 500 kg N from manure.
- Maximum limits for the application of fertilisers containing N: 170 kg N ha^{-1} on farm level per year from livestock manure (application of up to 230 kg N ha^{-1} per year on grassland and forage crops under certain conditions has to be authorized).
- Sufficient storage capacity for liquid organic fertiliser of animal origin must be present.

Control in case of suspicion or in the framework of additional specialised administrative controls:

- Prescribed distances to watercourses when applying N fertiliser have to be complied with.
- Prescribed distances to watercourses when applying N fertiliser on steep slopes have to be complied with.
- N fertiliser may only be applied to absorptive soil.
- Fertilisation with liquid manure, poultry excrements or other nitrogen-containing liquid fertilisers (all with more than 1.5% N kg^{-1} dry matter) after harvesting is only permitted on field grass, undersown crops, autumn sowings including intercropping and for straw fertilisation .
- After harvesting of the main crop only 40 kg NH_4-N ha^{-1} or 80 kg total N ha^{-1} may be applied to arable land with liquid manure, poultry excrements or nitrogen-containing liquid secondary raw material fertiliser.
- The ban on applying fertilisers with more than 1.5% N kg^{-1} dry matter during a certain period in winter must be complied with. This does not apply to farmyard manure other than dried poultry manure.
- Structures for storing liquid manure must be stable and leak-proof. No liquid must seep into ground- or surface water or into the sewerage system.
- Liquid manure must not run off or overflow. It must not seep into groundwater or surface water or into the sewerage system.
- Stationary structures for storing solid manure are to be provided with a close and water-impermeable base plate.
- At stationary structures for storing solid manure, liquids have to be properly collected.

The results of Cross Compliance and other inspections are shown in Table 6. In some areas the infringement rates as a percentage of total number of controls are around 5% and higher, namely for spreading on saturated or frozen soils, soils testing, and record keeping. Also, the rules for manure storage capacities show an elevated rate of non-compliance. The responsible Länder report that compliance has improved over time (Keppner and Ambros, 2008), which can be explained through advisory and education efforts, incentives for agri-environmental schemes related to water protection, and the increased threat of sanctions due to Cross Compliance.

Compared to the monitoring of N concentrations in surface water and groundwater, the monitoring of the performance of the Action Programme remains rather weak, as controls are focused on formal GFP indicators and are fairly disconnected from the real environmental performance of the farms, for example, in terms of their N surplus. Only few Länder have reported results derived from fertiliser records, for example, decreasing N surplus. For the derogation for animal manure per hectare, the federal state of North Rhine-Westphalia plans to integrate monitoring data on N surplus and N concentration in leachate and groundwater. In some Länder, similar efforts are undertaken, aimed at demonstrating the effectiveness of measures taken in water protection areas.

Table 6 Monitoring measures regarding fertiliser *legislation in the 2004-2006 period.*
Source: Keppner and Ambros (2008, Table 3.4, page 39), including cross compliance (CC) inspections.

Monitoring of compliance with the Fertilisation Ordinance	Total Inspections[1] - No. -	Out of that CC inspections - No. -	Total Infringe-ments[2] - No. -	Total Fines im-posed[3,4] - No. -	Infringe-ments in % of controls	Fines in % of controls
1. Avoidance of direct deposition and no prevention of run-off of fertiliser into surface waters	6,645	744	109	47	1.64%	0.71%
2. Land spreading of nitrogen-containing fertilisers with disregard for absorptive capacity of soils	6,754	744	336	201	4.97%	2.98%
3. Immediate incorporation into the soil of slurry, liquid manure, poultry manure and nitrogen-containing secondary raw material fertiliser on unploughed arable land	9,450	28,020	431	266	1.54%	0.95%
4. Exceeding the total allowable nitrogen quantity when land-spreading slurry, liquid manure, poultry manure or nitrogen-containing secondary raw material fertiliser in the autumn	5,338	744	44	20	0.82%	0.37%
5. Unlicensed landspreading of slurry, liquid manure, poultry manure or nitrogen-containing secondary raw material fertiliser during the period in which applications are prohibited	6,939	744	131	73	1.89%	1.05%
6. Limited application of livestock farm waste on soils with very high phosphorus (P) or potassium (K) contents	10,579		17	8	0.16%	0.08%
7. Limit to the total amount of nitrogen derived from livestock farm waste which may be applied to land on the holding on average	15,467	2,249	369	203	2.39%	1.31%

Monitoring of compliance with the Fertilisation Ordinance	Total Inspections[1] - No. -	Out of that CC inspections - No. -	Total Infringe-ments[2] - No. -	Total Fines im-posed[3,4] - No. -	Infringe-ments in % of controls	Fines in % of controls
8. Regular and correct (as per regulation) determination of available nitrogen/content of P, K and Ca in the soils.	24,613	29,808	4,464	2,013	14.98%	6.75%
9. Correct (as per regulation) determination of N, P and K contents of farm wastes to be land-spread	15,129	2,096	189	40	1.25%	0.26%
10. Record keeping for the purposes of determining the amount of fertiliser required and for nutrient input/output budgeting	22,901	29,464	1,659	829	5.63%	2.81%
11. Compliance with retention period for records	19,083	5,207	334	148	1.75%	0.78%
12. Compliance with provisions regarding construction and capacity of storage facilities for livestock manure	5,959	2,108	178	14	2.99%	0.23%

1 Number of cases investigated by the competent authority. Includes cases where Anlasskontrollen (that means, inspections in cases where there are reasons to think that irregularities have been committed) were carried out to follow up on non-compliance cases discovered during IACS inspections. The number of IACS inspections are given in brackets. Data regarding IACS inspections were only available for six Länder (Bavaria, Hesse, Mecklenburg-Western Pomerania, Lower Saxony, North-Rhine Westphalia, Saxony-Anhalt).

2 Number of infringements, independent of the nature of proceedings taken (caution, cautionary fine, order, administrative fine).

3 Evaluation of completed and legally effective fines imposed during the reporting period.

4 326 fine proceedings instituted in the federal state Hesse can not be assigned to individual infringements and are therefore not included in the table.

Against the background of the implementation of the Water Framework Directive, several Länder are considering to use data from farm records for monitoring. This would mean that control data is used for monitoring issues, which poses problems regarding the authorisation of data use as well as regarding data interpretation because the data would come from risk-based farm samples, which are not representative but represent farms with an elevated risk of non-compliance. In most control systems there is also a random sample group, representing farms without elevated risk. This latter group of farms could be used for monitoring purposes. However, there is still no comprehensive approach based on empirical data for complementing immission monitoring with evidence of agricultural emissions. As time lags between emissions and immissions in groundwater are large, often going far beyond the

WFD target year 2015, the monitoring of emissions is the only way to document improvement of trends before immission levels respond.

2 Effect monitoring

2.1 Use of models in Effect Monitoring and data interpretation

In Germany, many current Research and Development (R&D) projects deal with the further development of integrated model approaches for large scales, focusing on the regional, federal state (Länder) and national scale. Selected projects and their benefits for effect monitoring are discussed below. The foci of current R&D are in particular:

- to identify sub-areas within groundwater bodies at risk, where high N inputs into the groundwater occur,
- to define priority areas for agricultural management measures,
- to check and to optimise the network of operative monitoring stations which have been installed during the monitoring phase of the EU WFD,
- to calculate residence times in soil, the unsaturated zone and groundwater, and
- to calculate current and future (for example, for 2015) N surpluses from agriculture and N concentrations in leachate to enable trend overviews for all of Germany.

In the following, examples are given of current R&D projects in Germany dealing with the tasks mentioned above. With regard to assessments on the national scale the German Federal Environment Agency initiated a research project which has been carried out since 2008 by the Research Centre in Jülich and the Technical University in Brandenburg (Kuhr et al., 2009). The aim of the project is to develop a methodology to assess the status of groundwater bodies as well as the effectiveness of programmes of measures to reduce nitrate inputs to groundwater. The study was carried out in two test areas in the federal states Lower Saxony and Hesse.

The starting point and key element of the methodology are conceptual models as outlined by Littlejohn et al. (2002) in the CIS WG 2.7 Monitoring Guidance. Such conceptual models are adjusted to the individual situation of each groundwater body examined. In general, conceptual models have to show and explain the relationship between (potential) inputs and the occurrence (concentration and trend) of substances in groundwater (output) in a simple way. The relation between input and output may depend on different factors and processes (Figure 17).

Therefore, the first step of the project is to identify the most relevant parameters and processes determining nitrate transport in soil, subsoil, the unsaturated zone, and groundwater. In a stepwise approach relevant information and data sets describing the most relevant parameters are identified. Then it is determined which parameters explain elevated nitrate concentrations at individual monitoring sites. The parameters found to be most relevant for explaining the occurrence of elevated nitrate concentrations in the upper aquifer are land use (agriculture), hydrodynamics (flow direction), groundwater level, and nitrate concentration in the leachate. Using a GIS it was demonstrated for the test area ‘Große Aue’ that combinations of these parameters explain the origin and spatial distribution of elevated nitrate concentrations at 19 out of 20 sampling sites. At the same time it was possible to identify those parts of the groundwater body with a notable risk of groundwater contamination by nitrates. Applying these (conceptual) models highly vulnerable sub-areas could be identified. In one of the test areas, highly vulnerable areas cover only 25% of the groundwater body. Measures to reduce the input of nitrogen should be carried out primarily in these sub-areas where they are believed to be most effective.

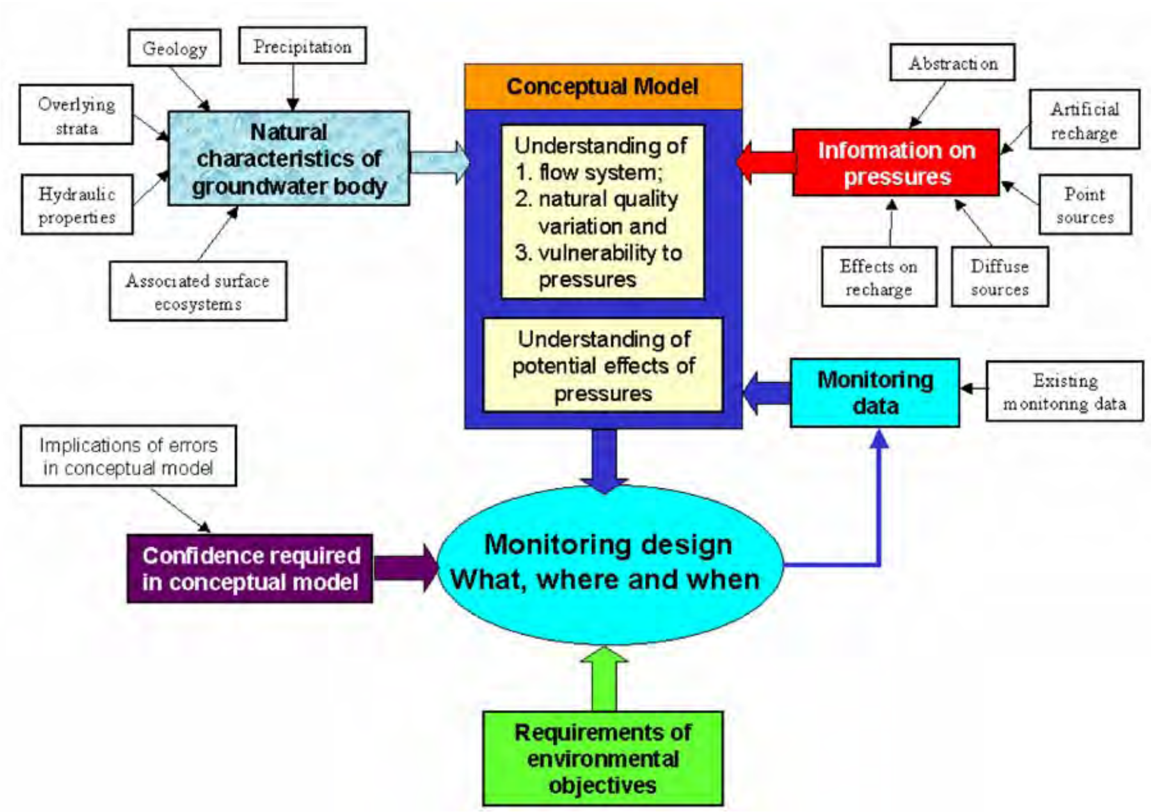


Figure 17 The conceptual model representing the current understanding of the groundwater system based on knowledge of its natural characteristics, perceived pressures and knowledge of impacts (Littlejohn et al., 2002).

A separate task in the project is the assessment of the effectiveness of measures planned to restore good status. Taking current nitrate concentrations in leachate, the general hydrogeological situation and land use into account, the necessary reduction in nitrogen input (allowable nitrogen surplus) is modelled for those sub-areas where nitrate concentrations exceed 37.5 mg l^{-1} (this corresponds to 75% of 50 mg l^{-1}). This is compared with the (potential) reduction achievable by different measures such as extensification, inter-tillage or land use change. Potential reductions are compared to the reduction needed to guarantee nitrate concentrations lower than 50 mg l^{-1} in groundwater. Using this approach, it can be assessed if the planned measures are appropriate to reach good groundwater chemical status.

The assessment of the status of a groundwater body is based on monitoring data from the various sampling sites. Assessments of the effectiveness of programmes of measures are also based on these data. Even if the concentration of nitrates exceeds 50 mg l^{-1} in 2015, that means, at the end of the first programme of measures, the WFD may have been implemented properly. This is due to the fact that the residence time of subsurface waters is longer than six years. It may take years or decades until the effects of measures to reduce nitrate inputs are detectable at monitoring wells. To account for this, the flow time has been modelled and taken into account when assessing the effectiveness of measures. To estimate flow time, the residence time in the root zone, in overlaying strata and in the aquifer have to be calculated using the models DENUZ and WeKu (Kunkel & Wendland, 1997). The overall travel time sums up to 15 years in the test area ‘Große Aue’ (Lower Saxony) and to 12 years in the test area ‘Schwalm’ (Hesse).

If these steps are carried out systematically, a good overview is obtained of priority areas where measures should be carried out, whether the measures planned are sufficient to reach the nitrate reduction required to achieve good status and how long it takes until the effects of measures are detectable at groundwater monitoring wells. This information is of key importance when assessing the effectiveness of measures and deciding whether there is a need to extend the time limit for reaching good groundwater status. The combined use of these models leads to the need to apply more sophisticated models and calculations, as the practical application of the ‘Methodology for assessing the effectiveness of WFD programmes of measures’ developed in Germany has shown. This means that conceptual models are the starting point for the assessment of both measures and management plans and will need to be continuously refined.

Just how effect monitoring on the local scale and trend analysis on the supra-regional scale are combined, was demonstrated successfully by the EU Life project WAgriCo (Water Resources Management in Cooperation with Agriculture, 2005-2008). It emphasised the integration of knowledge at farm, regional and state level, the co-operation between water management and agriculture as well as the intensive participation of farmers to enhance the realisation of agri-environmental measures. More than 50 farms participated in the project. The basic idea is to use experiences from drinking water protection areas about nitrate mitigation measures and their quantified effects on nitrate concentrations in soil, leachate and groundwater.

The starting point is the calculation of nitrate balances at the farm level. Nitrate inputs exceeding 60 kg ha^{-1} per year have to be lowered through consultancy, technical, and management measures. The measures selected were taken from long-existing management programmes in drinking water protection areas. For these areas, broad knowledge exists about the effects of such measures on groundwater quality and data are available from long-term measurements in the root zone (mineral N in autumn), the unsaturated zone, and the aquifer. Highly effective and therefore acceptable measures were selected and costs assigned (Table 7). Then, the raster-oriented model tools GROWA (Kunkel and Wendland, 2002) and DENUZ (Kunkel and Wendland, 1997) were used to quantify the nitrate concentration in leachate and to predict the effects of measures. This has been done for pilot areas in the federal state Lower Saxony (groups of groundwater bodies Lager Hase, Große Aue and Ilmenau/Jeetzel) with more than 300,000 ha agricultural land in total. This work forms the basis for upscaling the local information about the delineation of priority areas, groundwater quality and effects of measures at the regional and state levels not only for the current but also for future states, for example, the year 2015 (Kunkel et al., 2008). To underpin the model results, regional sampling and analysis of soil and groundwater is being continued in the drinking water protection areas. Regarding effect monitoring WAgriCo contains several new aspects:

- Further sampling stations are employed, beyond the groundwater sampling stations of existing networks for Nitrates Directive implementation.
- Data from detailed annual measurements in soil, leachate and groundwater to assess the effects of measures can be integrated without additional costs, since monitoring in drinking water protection areas has to be performed in any case.
- By combining measurements and modelling, model results especially about effects of measures are calibrated at the local scale. Based on this, the models can be upscaled to large areas, for example, states, for sites with similar conditions.
- Costs for realizing measures can be calculated at the regional, state and national level.

Table 7 Benefits and ecological impact of mitigation measures tested in EU Live project WAgriCo.

Selected measures	Annual reduction of nitrate surplus which is liable to leaching per hectare by approximation	Annual costs per kg reduction in nitrogen
(Winter-hardy) catch crops	30 kg	€ 3.00 to € 4.50
Fallow land, multiyear greening	55 kg	€ 2.20
Reduced soil cultivation after maize	8 kg	€ 3.75
Non-application of slurry in the autumn	15 kg	€ 1.35
Exact slurry application techniques	13 kg	€ 2.50
Turnips as catch crop before winter grain	20 kg	€ 2.00
Self-sown rape	15 kg	€ 3.20
Organic farming	45 kg	€ 4.25

Overall, the cross-scale project structure and the emphasis on stakeholder participation enhance the transferability of the WAgriCo findings and tools to other (EU Member) states with similar natural conditions and agricultural structure. The WAgriCo project has been prolonged in the federal state Lower Saxony up to the year 2010 in order to maintain the participation structures already developed and to further prove the effectiveness of measures. From 2010 onwards the proposed mitigation measures, which are highly accepted and cost-efficient, will be included in Lower Saxony's agri-environmental programmes.

In Germany most states prefer their own methodologies for the analysis of nitrogen inputs into groundwater and surface waters. This hampers the comparability of results as well as the implementation of the WFD for entire river basin districts. Large river basins running through several states, for example, the river Weser, are affected in particular. Therefore, an urgent need exists for tools for supra-regional analyses of nitrogen inputs and the evaluation of agricultural measures to assist in the established process of programmes of measures. The large-scale application of an integrated modelling tool comprising a nutrient balance model (RAUMIS), a water balance model (GROWA), a hydrogeological model (WeKu) and a nitrogen model (DENUZ) has been demonstrated successfully for the Weser River Basin (about 49,000 km²). This has been done in the AGRUM project (Analysis of agricultural and environmental measures in the field of water protection with regards to the EU WFD, 2005-2008). AGRUM was initiated by the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) and the Weser River Basin Commission (FGG Weser). Project partners were the initiating authorities, the federal states North Rhine-Westphalia, Lower Saxony, Bremen, Hesse, Thuringia, Saxony-Anhalt and Bavaria, the Research Centre Jülich (FZJ), the Federal Research Institute for Rural Areas, Forestry and Fisheries (vTI), the Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB) and the company Infoterra (Kreins et al., 2009; Kuhn et al., 2008).

The overall aim was to develop an integrated model tool to quantify the nitrogen input to groundwater and surface waters from diffuse and point sources. Special emphasis was put on area-differentiated modelling of diffuse nitrate inputs to the aquatic system from agricultural sources employing the models GROWA, DENUZ and WeKu, developed at the Research Centre Jülich. The integrated modelling tool developed was used to analyse the nitrate inputs for the status quo 2003 und for 2015 as baseline scenario, comprising all impacts on nitrogen fertiliser inputs evolving from further implementation of the EU Nitrates Directive in Germany. Following the baseline scenario, the demand for further nitrate reduction was derived for those sub-areas where nitrate concentrations in leachate exceed 50 mg l^{-1}. Combinations of mitigation measures (Table 7) were proposed, depending on local conditions. The effects of such (combinations of) measures were quantified for the Weser River Basin district, taking into account all relevant agricultural, geo-hydrological and also socio-economic aspects and their inter-dependencies.

Aspects which may be of benefit for effect monitoring under the Nitrates Directive are:

- The integrated modelling tool developed allows sub-areas to be identified where high nitrate surpluses occur or where nitrate concentrations in leachate exceed the drinking water limit of 50 mg l^{-1}.
- This makes it possible to define priority areas for implementation of agricultural management measures.
- The integrated modelling tool allows the calculation of residence times in soil, unsaturated zone and groundwater and to forecast the duration of effects in groundwater.
- The integrated modelling tool allows the calculation of costs for realizing agricultural measures.
- This methodology can be employed for trend overviews at the state as well as the national scale for user-defined time steps, at low costs and without further extending monitoring networks.

2.2 Tools for calculation of nutrient inputs

The nitrate model DENUZ, the hydrological model GROWA and the hydrogeological model WeKu are combined with a nutrient surplus model (RAUMIS) to account for the interactions between soil properties, temperature, precipitation, geological conditions, et cetera, when nitrate concentrations in leachate and groundwater are quantified. For a basic understanding of the interactions between these aspects an integrated hydrological/hydrogeological conceptual model (Figure 18) was developed. The model consists of three main features similar to the basic outline of conceptual models as described in Figure 18, namely assessment of natural characteristics, assessment of anthropogenic impact using monitoring data, and model tools providing a linkage between the first two parts. Based on the conceptual model the interactions between agricultural practice, nitrogen surpluses, nitrogen concentration in leachate and in groundwater are analysed. In the same way nitrogen intakes into surface waters are modelled and, finally, groundwater quality is characterised.

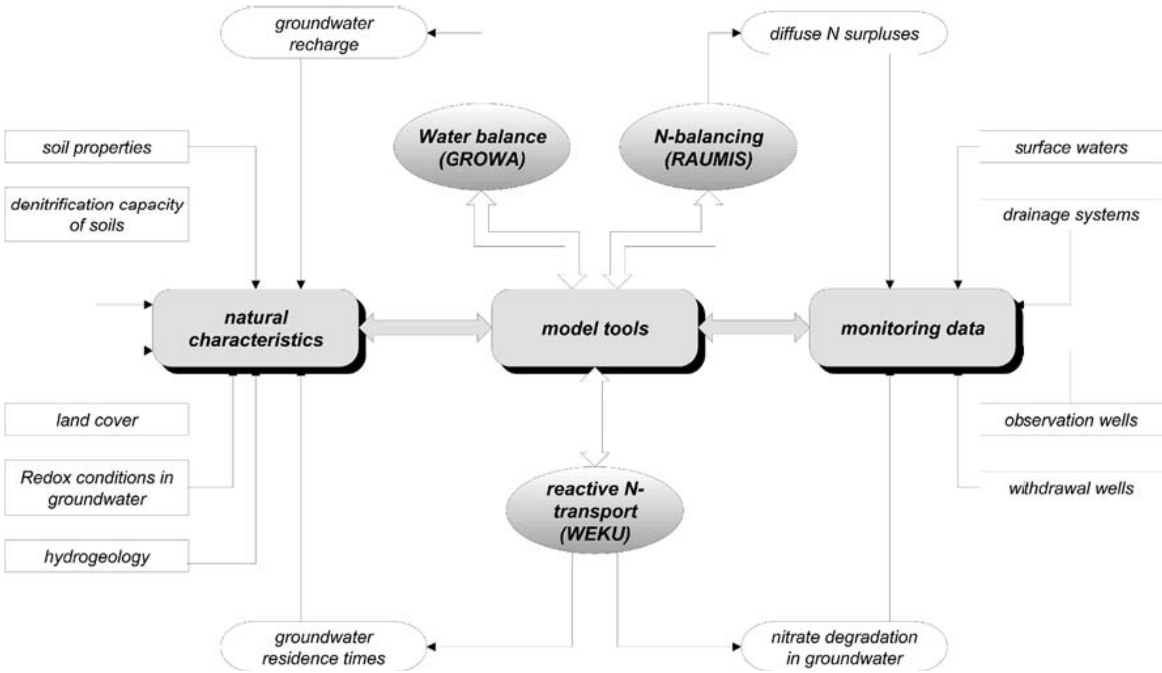


Figure 18 Example of an integrated hydrological/hydrogeological conceptual model for determination and ranking of target areas to plan and implement nitrogen reduction measures (Kunkel et al., 2008).

For example, in the WAgriCo project described above, the natural site conditions represent an important basis for understanding the groundwater status. In a first step, a hydrogeological characterisation was done using a number of different data sets available at federal state level, for example, from geological maps, geological/hydrogeological profiles and the distribution of clay covers above the aquifers. A hydrochemical/hydrodynamic characterisation of groundwater was performed using data on the hydraulic conductivities and the groundwater pressure heads of the upper aquifers as well as groundwater quality data related to the redox and salinization status of the aquifers. From the data (Table 8) characterizing natural site conditions available for the Federal State of Lower Saxony a number of data sets of particular importance for the assessment of areas sensitive to nitrate leaching were selected. These data often also represent input parameters for modelling tools, for example, for water balance or reactive subsurface nutrient transport modelling.

Table 8 Natural site characteristics/input data for modelling.
Models GROWA, DNEUZ and WeKu.

Parameter	Data set	Scale
Land cover	Landcover categories	1:25,000
Agricultural production	Agrarian statistical data on animals, cultivation, harvest, mineral fertiliser	County level
Climate	Summer precipitation levels, Winter precipitation levels, Potential evaporation	Interpolated point data
Topography	Slope, Exposure	50 x 50 m² raster
Soil parameters	Plant-available water, Denitrification capacity of soils, Groundwater influence	1:50,000
Hydrogeology	Hydrogeological units, Geological profiles, Hydraulic conductivity	1:200,000
Hydrodynamics	Depth to groundwater, Run-off in rivers, River network, drainage systems	1:200,000 or point data
Hydrochemistry	Groundwater monitoring data	Point data

In the conceptual model the linkage between natural characteristics, land use and status of groundwater and surface waters is provided by model tools. At present, three different tools are included in the model, considering N balancing, water balance and reactive N transport through the soil and groundwater into surface waters. As all of the applied modelling tools are described in detail in the literature (Kunkel and Wendland, 2002; Kunkel and Wendland, 1997) only a brief description is given here. An agricultural sector model, for example, RAUMIS, is used to link agricultural practice and N surpluses in soil. Agricultural statistics, for example, on crop yields, livestock farming and land use, were taken to determine nitrogen supplies and extractions for the agricultural area. The long-term nitrogen balance averaged over several vegetation periods is calculated using information on organic nitrogen fertilisation, mineral nitrogen fertilisation, symbiotic N fixation, atmospheric N inputs and N extractions with the crop substance. As a rule, the difference between nitrogen supplies, primarily by mineral fertilisers and farm manure, and nitrogen extractions, primarily by field crops, leads to a positive N balance. The displacement of N surpluses from soil to groundwater and surface waters is coupled to run-off components, which were quantified area-differentiated using the GROWA model. Against the background of a long-term application, run-off was distinguished into the relevant run-off components for nitrate emissions to surface run-off, namely direct run-off (the sum of surface run-off, natural interflow, drainage run-off) and groundwater run-off. Whereas direct run-off reaches surface waters within short time periods (within about a week), groundwater run-off needs much more time (years to decades) to percolate into surface waters. The groundwater recharge level and the ratio between groundwater recharge and total run-off are important model based parameters for assessing the extent to which diffuse nitrogen surpluses are displaced from soil to groundwater. In areas where groundwater recharge is the dominant run-off component, nitrate leached out of the soil will reach the groundwater almost completely. In flood-plains along rivers groundwater recharge is reduced due to rapid movement of percolating water and groundwater into surface waters. The reduction of groundwater recharge is particularly large under drained land. A significant part of the nitrate washed out of the soils will reach surface waters via direct or drainage run-off without leaching into groundwater. During transport through the soil and the groundwater, nitrogen surpluses may be denitrified to molecular nitrogen. Denitrification losses in the soil occur mainly in the root zone in case of low oxygen and high water contents as well as high contents of organic substances. In a Michaelis–Menten kinetics approach these denitrification conditions were combined with the calculated nitrogen surpluses and the residence times of the percolation water in the root zone calculated as a function of average field capacity and the percolation run-off level. The potential nitrate concentration in recharged groundwater is a modelled parameter which combines nitrogen surpluses from agriculture, water balance and denitrification in the soil.

Reactive nitrate transport in groundwater was modelled using the stochastical WEKU model on the basis of a first order reaction depending on nitrogen inputs into the aquifer, denitrification conditions in groundwater and groundwater residence times. These parameters allow an assessment of the time-lags between the implementation of certain mitigation measures and their effect on groundwater or surface water quality. The observed nitrate concentration in groundwater is usually much lower than the nitrate concentration in the leachate. This is due to denitrification processes in the aquifer. However, although denitrification in groundwater is relatively effective – extensive field studies indicate a halving of the nitrate load in groundwater after a residence time of between 1.2 and 4 years – the process irreversibly consumes pyrite and/or organic carbon reservoirs in the aquifer. In contrast to nitrate reduction in soil, denitrification in groundwater cannot be regarded as being inexhaustible.

2.3 Empirical monitoring of the effectiveness of agri-environmental measures

As explained in the section ‘Monitoring of compliance with the codes of GFP’, there is no comprehensive empirical monitoring of the effectiveness of the Action Programme and of additional agri-environmental measures focused on emissions from agriculture in Germany. The calculated sectoral farm gate or surface balances provide a quite rough picture only. On this basis, changes due to policy intervention can hardly be detected. At regional level, missing data both for mineral fertiliser input and manure imports and exports are obstacles to a more precise depiction of the real N surplus (Osterburg and Schmidt, 2008). However, for the preparation of the next Nitrates Directive Action Programme beyond 2013 more monitoring and evaluation efforts are envisaged for.

At farm level, although there are far-reaching documentation duties, no broader monitoring effort is made to gather and interpret fertiliser records and nutrient balances. Information from inspections is in most cases limited to the control items (‘control points’), and data on the results of nutrient balances are in most cases not systematically collected. Another problem is the verification of balance data, which might cause high additional administrative effort. Farm accounting data containing information on mineral N inputs have been used to forecast the effects of the German Action Programme (Osterburg, 2007). However, the effects will depend mainly on the administrative implementation of the maximum N and P surplus in the future, so that a timely monitoring and evaluation of trends in N balances have been recommended.

In contrast to the situation for farm balances, autumn mineral N contents in soils (Nmin) are monitored more systematically in many Länder, both as a baseline for advice, and for monitoring the effects of additional measures in designated drinking water areas. Autumn Nmin as target indicator (the N fraction prone to be leached over winter time) is not strongly correlated to N surplus, but is driven also by N content in soils, soil management and weather conditions. The two 'philosophies' of N and water protection related indicators, Nmin and N balance, are still not consistently combined in effect modelling (which is normally based on N surplus). However, both indicators depict important aspects of N losses to water.

In a project for the Working Group of the Federal States on Water (LAWA) impacts of voluntary measures for water protection have been evaluated (Osterburg et al., 2007). In most cases effects had to be estimated based on expert judgements, because data from on-farm monitoring to assess the effects of agri-environmental measures are in most cases missing. In order to provide more evidence of the real-world effects of such water protection measures, monitoring data would have to be analysed in a more systematic manner using statistical methods. An example of an effect assessment based on 8,600 data sets on Nmin was presented by Schmidt et al. (2007). This work is continued in the framework of the WAgriCo-II project using an even broader data base. One conclusion is that assessments of the effectiveness of measures continue to require attention. The focus should be on using existing monitoring data for statistical analysis and on improving the monitoring data base in case other sources do not exist (as in the case of farm N balances). These data and analyses would allow a better insight into trends of nutrient surplus and relevant drivers, and helps to derive criteria for efficient policy design taking cost-effectiveness into account.

2.4 Forecast for nitrate in groundwater

Based on the results presented here from the 170 common monitoring stations of the Nitrate Network, a forecast of the possible future development of groundwater quality is given for the first time. Due to the special importance of the year 2015 with regard to the EU Water Framework Directive the forecast also includes the period from 2012-2015.

The estimated future development of nitrate concentrations in groundwater at the 170 common monitoring stations of this operational monitoring network is based on changes in frequency distributions of the concentration classes. The method used is linear regression. The calculated trend line was tested for statistical significance. A probability of 90% (α = 0.05, two-tailed test) was chosen as significance level.

The regression was carried out with concentrations of 50 mg l^{-1}, 40 mg l^{-1} and 25 mg l^{-1}, which delimit the four predefined concentration classes. Table 9 shows the baseline data and the forecast based thereon for the 50 mg l^{-1} concentration limit, which is of principal interest and also corresponds to the quality standard for nitrates in groundwater pursuant to the EU Water Framework Directive. For the first reporting period, the share of common monitoring stations showing nitrate concentrations ≤ 50 mg l^{-1} is comprised of the sum of the shares of the three lower concentration classes (5.3% + 20.6% + 14.1%), amounting to 40.0%. The same process was used for the following three reporting periods.

The four value pairs in Table 9 already demonstrate that the percentage share of common monitoring stations with an average nitrate concentration at or below the quality standard of 50 mg l^{-1} increases continuously. The slope of the calculated regression line shows an increase of 3.42% per reporting period. The regression line slope shows a significant trend, indicating an increase of the share to 53.4% and 55.8% respectively for the fifth and sixth reporting periods. Consequently, the share of monitoring stations in the concentration class > 50 mg l^{-1} will therefore decrease (see Figure 19).

Table 9 Forecast of the development of the share of common monitoring stations with a nitrate concentration below the quantification limit of ≤ 50 mg l^{-1}.

Monitoring periods	1992-1994[1)]	1996-1998	2000-2002	2004-2006	2008-2011	2012-2015
EU Nitrate Reports (x-axis)	1	2	3	4	5	6
Share of common monitoring stations with ≤ 50 mg l^{-1} [as %]	40.0	40.5	44.7	50.0	---	---
Regression line: y = f(x) = 3.42 x + 35.3						
Linear regression [as%]	38.7	42.1	45.5	48.9	---	---
Forecast [as%]:					52.4	55.8

1) Monitoring stations at which the first nitrate sampling data were gathered in 1995 are included in the 1992-1994 monitoring period.

The same procedure was used for the calculations for the concentration limits of 40 mg l^{-1} and 25 mg l^{-1}. In the case of the 40 mg l^{-1} data set, the calculated regression is not representative and could not be extrapolated to provide a forecast.

Figure 19 summarises the results of these calculations. The decrease in the > 50 mg l^{-1} concentration class is clearly evident, starting at 60% and dropping to a forecast 44.2%. The increase in the percentage share of common monitoring stations with an average nitrate concentration at or below 25 mg l^{-1} is similarly prominent, starting at 5.3% and rising to an expected 16% by 2015. Due to the non-significant trend for the 40 mg l^{-1} concentration limit the two medium concentration classes of > 25 to ≤ 40 mg/l and > 40 to ≤ 50 mg l^{-1} can not be differentiated further. Their joint share increases slightly from 34.7% at the outset to a forecast 39.8% by 2015.

It can be established that generally a lower degree of contamination of groundwater with nitrates compared to the initial reporting period is discernible. Provided current conditions remain unaltered or are slightly enhanced by optimised measures (for example, Action Programme), it can reasonably be expected that the trend in groundwater quality will continue.

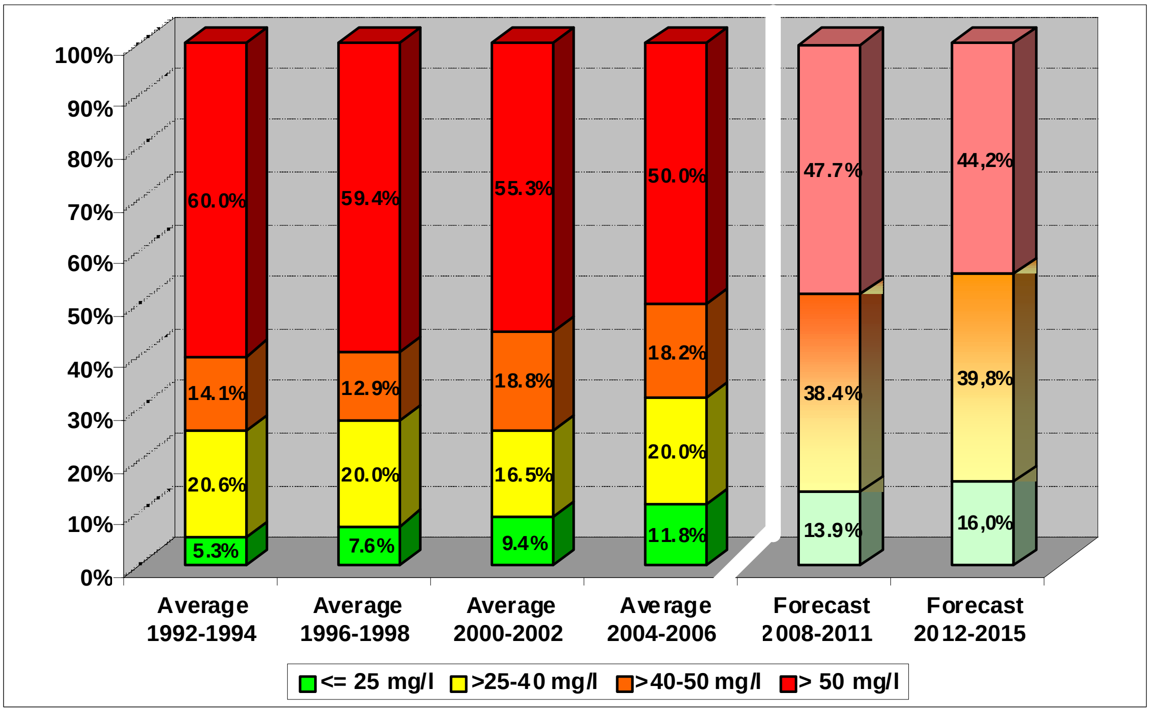


Figure 19 Forecast for the development of nitrate concentrations, based on frequency distributions of the average nitrate concentrations at the 170 common monitoring stations of the EU operational monitoring network in the four completed reporting periods.

Monitoring stations at which the first nitrate sampling data were gathered in 1995 are included in the 1992-1994 monitoring period.

3 Discussion

The effectiveness of measures to reduce nitrate concentrations in water bodies and, in particular, in groundwater is monitored mainly through a national network referred to as the EU Nitrate Network. This network is operated by the various German Federal States. Data evaluation takes place at four-year intervals in connection with reporting on the implementation of the Nitrates Directive. The results from all investigation periods show a decrease in nitrate levels at the majority of measuring sites of the national EU Nitrate Network.

The Water Framework Directive requires assessment of the chemical status of all groundwater bodies in Germany. Although Germany has not designated any nitrate vulnerable zones (NVZs) in the implementation of the Nitrates Directive, there are also some regions in Germany in which groundwater pollution by nitrate is found particularly often. The WFD requires achievement of good groundwater chemical status by 2015. This increases the pressure on Member States to quickly carry out suitable, effective measures in heavily polluted regions. The European Commission can be expected to request information about the causes for non-achievement at least for groundwater bodies which will not achieve good chemical status by 2015. This means that the effectiveness of programmes of measures will need to be assessed at least for some of the groundwater bodies and the results reported to the European Commission.

The Nitrates Directive and the Water Framework Directive therefore complement each other and thus help to clearly improve the protection of groundwater in terms of a reduction of excessive nitrate inputs.

4 References

BMU (2000) Bericht der Bundesrepublik Deutschland gemäß Artikel 10 der Richtlinie 91/676/EWG des Rates vom 12. Dezember 1991 zum Schutz der Gewässer vor Verunreinigungen durch Nitrat aus landwirtschaftlichen Quellen. Mitteilung der Regierung der Bundesrepublik Deutschland vom November 2000, 2. Bericht gemäß Artikel 10 der Richtlinie 91/676/EWG des Rates vom 12. Dezember 1991 zum Schutz der Gewässer vor Verunreinigungen durch Nitrat aus landwirtschaftlichen Quellen. (Bundesumweltministerium, unpublished).

Bund-/Länder-AG (2006) Informationsbroschüre für die Empfänger von Direktzahlungen über die anderweitigen Verpflichtungen (Cross Compliance). Vorlage für Info-Broschüren der Länder, Ausgabe 2006 (blueprint for info brochure of the Länder, 2006 edition), unpublished manuscript (in German).

Dämmgen U (Ed.) (2007) Emissionen aus der deutschen Landwirtschaft - Nationaler Inventarbericht (NIR) 2007 für 2005, Tabellen, Landbauforschung Völkenrode, Sonderheft 304 A.

EC (1991) Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Communities, L375, 31/12/1991, 1-8.

Essink, K., Dettmann, C., Farke, H., Laursen, K., Lüerßen, G. L., Marencic, H., Wiersinga, W. (Eds.) (2005) Wadden Sea Quality Status Report 2004. Wadden Sea Ecosystem No. 19.

Keppner, L. and Ambros, W. (2008) Nitrates Report 2008. Joint report by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Ministry of Food, Agriculture and Consumer Protection. Bonn, Germany, [www.bmu.de; www.bmelv.de].

Körschens, M., Rogasik, J., Schulz, E., Bönig, H., Eich, D., Ellerbrock, R., Franko, U., Hülsbergen, K.-J., Köppen, D., Kolbe, H., Leithold, G., Merbach, I., Peschke, H., Prystav, W., Reinhold, J. and Zimmer, J. (2004) Humusbilanzierung – Methode zur Beurteilung und Bemessung der Humusversorgung von Ackerland, VDLUFA-Standpunkt. (http://www.vdlufa.de/joomla/Dokumente/Standpunkte/08-humusbilanzierung.pdf).

Kreins, P., Behrendt, H., Gömann, H., Hirt, U., Kunkel, R., Seidel, K., Tetzlaff, B. and Wendland, F. (2009) Analyse von Agrar- und Umweltmaßnahmen im Bereich des landwirtschaftlichen Gewässerschutzes vor dem Hintergrund der EG-Wasserrahmenrichtlinie in der Flussgebietsgemeinschaft – AGRUM-Weser. – Endbericht zum Forschungsprojekt, Hildesheim.

Kuhn, U., Henneberg, S., Gömann, H., Kreins, P., Seidel, K., Tetzlaff, B., Wendland, F., Hirt, U. and Behrendt, H. (2008) Reducing diffuse nutrient inputs from agricultural areas in the Weser river basin unit (in German). Wasser und Abfall, 10:20-23.

Kuhr, P., Baron, U., Kunkel, R., Voigt, H.-J. and Wendland, F. (2009) Assessment and Optimization of programmes of measures for groundwater protection according to EU Water Framework Directive (in German). Project Research Centre Jülich, Brandenburg Technical University and Federal Environmental Agency. Final Report, Jülich.

Kunkel, R. and Wendland, F. (1997) WEKU; a GIS-supported stochastic model of groundwater residence times in upper aquifers for the supraregional groundwater management. Environmental Geology, 30:1-9.

Kunkel, R. and Wendland, F. (2002) The GROWA98 model for water balance analysis in alrge river basins – the river Elbe case study. J. Hydrol., 259, 152-162.

Kunkel, R., Eisele, M., Schäfer, W., Tetzlaff, B. and Wendland, F. (2008) Planning and implementation of nitrogen reduction measures in catchment areas based on a determination and ranking of target areas. Desalination, 226, 1-12.

Littlejohn, C., Nixon, S., Casazza, G., Fabiani, C., Premazzi, G., Heinonen, P., Ferguson, A. and Pollard, P. (2002) Guidance on Monitoring for the Water Framework Directive, Water Framework Directive, Common Implementation Strategy, Working Group 2.7 Monitoring, Final Draft 15, October 2002.

Landwirtschaftskammer Niedersachsen (2006) Einhaltung von Cross Compliance Kriterien als Bestandteil der Umsetzung der Ziele der EG-Wasserrahmenrichtlinie. Text by Jelko Djuren, Hermann Geerken, Nora Matthäus, Caroline Schmidt. Leaflet supported by the LIFE-project WAgriCo. Oldenburg.

LAWA (1998) Beurteilung der Wasserbeschaffenheit von Fließgewässern in der BRD – Chemische Gewässerklassifikation. Berlin, August 1998.

Nitsch, H. (2006) National Report on Germany for EU Cross Compliance evaluation (Evaluation of the application of cross compliance as foreseen under Regulation 1782/2003), vTI, unpublished manuscript (in English).

Nitsch, H., Osterburg, B., Von Buttlar, C. and Von Buttlar, H.-B. (2008) Aspekte des Gewässerschutzes und der Gewässernutzung beim Anbau von Energiepflanzen : Ergebnisse eines Forschungsvorhabens im Auftrag des Umweltbundesamtes. Braunschweig: vTI, 128p, Arbeitsber. vTI-Agrarökonomie, 2008/03.

Osterburg, B., Rühling, I., Runge, T., Schmidt, T.G., Seidel, K., Antony, F., Gödecke, B. and Witt-Altfelder, P. (2007) Kosteneffiziente Maßnahmenkombinationen nach Wasserrahmenrichtlinie zur Nitratreduktion in der Landwirtschaft : Bericht im Auftrag der Bund/Länder-Arbeitsgemeinschaft Wasser (LAWA) im Rahmen des Länderfinanzierungsprogramms 'Wasser, Boden und Abfall' 2006 (Projekt-Nummer AR 1.05 FAL). Landbauforsch Völkenrode SH, 307:3-156.

Osterburg, B. (2007) Analysen zur Düngeverordnungs-Novelle vom Januar 2006. Landbauforsch Völkenrode SH, 307:267-302.

Osterburg, B. (2008) Bestandsaufnahme der N-Bilanzüberschüsse - Status quo, Entwicklungen und 'hot spots'. Agrarspectrum, 41:61-73.

Osterburg, B. and Schmidt, T.G. (2008) Weiterentwicklung der Berechnung regionaler Stickstoffbilanzen am Beispiel Niedersachsen. Landbauforsch, 58(1-2):45-58.

Schmidt, T. G., Gödecke, B. and Antony, F. (2007) Wasserschutzwirkungen von Agrarumweltmaßnahmen – Statistische Auswertung von Herbst-Nmin-Werten aus niedersächsischen Wassergewinnungsgebieten. Landbauforsch Völkenrode SH 307, pp. 229-252.

Wolter, R. and Mohaupt, V. (2005) Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by Germany. In: Monitoring effectiveness of the EU Nitrates Directive Action Programmes (ed. by B. Fraters, K. Kovar, W.J. Willems, J. Stockmarr and R. Grant) (Results of the international MonNO3 workshop in the Netherlands, 11-12 June 2003, pp. 139-158, Bilthoven, RIVM report 500003007.

Wolter, R., Rosenbaum, S. and Hannappel, S. (2000) The German groundwater monitoring network. In: Monitoring Tailor-Made III (ed. by J.G. Timmerman, W.P. Cofino, R. E. Enderlein, W. Jülich, P. Literathy, J. M. Martin, P. Ross, N. Thyssen, R. K. Turner, R. C. Ward) (Proc. Int. Workshop, 25 – 28 September 2000, Nunspeet, The Netherlands), 277-282, Springer-Verlag Heidelberg.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Republic of Ireland

D. Daly[1] and P. Torpey[2]

[1] *Hydrometric and Groundwater Section, Environmental Protection Agency, Richview, Clonskeagh, Dublin 14, Ireland*
e-mail: d.daly@epa.ie

[2] *Department of Agriculture, Fisheries and Food, Government Buildings, Convent Road, Roscommon, Ireland*
e-mail: patricia.torpey@agriculture.gov.ie

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the Republic of Ireland and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). Ireland has implemented the Nitrates Directive by designating the whole national territory as a nitrate vulnerable zone. Ireland was granted a derogation in 2007 to apply amounts of up to 250 kg N ha^{-1} $year^{-1}$ from livestock manure on agricultural land. Monitoring requirements arising from the derogation decision included a comprehensive monitoring and evaluation programme in agricultural mini-catchments, which has commenced, and reinforced water monitoring in catchments located in proximity to most vulnerable lakes and particularly vulnerable aquifers. Implementation of the Water Framework Directive (WFD) (EC, 2000) enabled a re-evaluation of the national rivers, lakes and groundwater monitoring networks and, in the case of the groundwater network in particular, upgrading by installation of new monitoring points. The groundwater monitoring approach is oriented towards providing a network that is representative of both the pressures and hydrogeological settings present in Ireland. The monitoring results show that nitrate concentrations in rivers have remained relatively stable, while there was a slight increase in nitrates in groundwater. Highest concentrations in rivers and groundwater are present in the south and south-east, where the pressure from agricultural activities is highest. As phosphate is a major cause of eutrophication in Ireland, the role of groundwater in transporting phosphate to rivers has been evaluated for WFD classification purposes. Over 13% of the land area was classified as 'poor' status due to elevated concentrations in groundwater – this area is located in the vulnerable karstified limestone areas of the west of Ireland. The reduction of livestock numbers and applications of chemical fertilisers since 2000 and the improved regulation of agricultural activities is expected to decrease the leaching of nutrients into water.

1 Introduction

1.1 Environmental goals and measures

In 2003, Ireland adopted a whole territory approach in implementing the Nitrates Directive (EC, 1991) (S.I. No. 213 of 2003). A National Action Programme was finalised following stakeholder consultation in July 2005 and this applies across the whole national territory. The primary aims of the National Action Programme are to reduce water pollution/eutrophication caused or induced by nitrates and phosphates from agricultural sources and to prevent further such pollution/eutrophication. In addition, a specific objective is to increase the efficiency of nitrogen use in agriculture using 2006 as a base year (DEHLG/DAF, 2005). Furthermore, it is expected that the full implementation of the Action Programme will assist in achieving the Water Framework Directive (WFD) target of at least ‘good status’ in all waters or such higher status as is required in relation to protected areas (DEHLG/DAF, 2005).

The Good Agricultural Practice (GAP) Regulations (S.I. No. 788 of 2005), which give statutory effect to certain elements of the National Action Programme, were enacted in December 2005. These were later replaced by S.I. No. 378 of 2006, while S.I. No. 526 of 2007 provided for increased penalties and for prosecution on indictment of offences. More recently, S.I. No. 101 of 2009 has provided for strengthened enforcement provisions and for better farmyard management in order to comply with a judgement of the European Court of Justice in relation to the Dangerous Substances Directive. These latest regulations also provide the legal basis for the operation of a derogation under the Nitrates Directive granted to Ireland by the European Commission in 2007 (EC, 2007). Under this derogation Ireland has approval to apply amounts of up to 250 kg N ha^{-1} $year^{-1}$ from livestock manure on agricultural land.

For the purposes of the National Action Programme, the national territory of Ireland has been sub-divided into three zones on the basis of the length of the growing season, the weather, soil types, et cetera, in each zone (Figure 1). These zones govern the application of the GAP Regulations, the main elements of which are:

– Periods when the land application of fertilisers is prohibited (Table 1).
– Sufficient capacity of storage facilities for livestock manure (Table 1).
– The amount of livestock manure to be applied is limited to 170 kg N ha^{-1} $year^{-1}$ and the total amount of fertilisers to be applied is limited to the foreseeable N and P requirements of crops.
– Requirements as to the manner of application of fertilisers. It is not permitted to apply fertilisers when land is waterlogged, flooded, frozen or when heavy rain is forecast within 48 hours; within specified buffer zones adjacent to surface waters and abstraction points; or by using an upward facing splash plate or sludge irrigator.
– The availability of nitrogen and phosphorus in chemical and organic fertilisers is specified in the GAP Regulations (for example, nitrogen and phosphorus in chemical fertilisers and phosphorus in organic fertilisers is deemed to be 100% available).
– Winter green coverage of soils must be established within specified timescales.
– Certain records must be kept.

Approval of Ireland's derogation request (to apply up to 250 kg N ha^{-1} $year^{-1}$ from livestock manure) by the European Commission was granted on the basis that it would apply to farms with at least 80% grassland. This potentially encompasses a maximum of 10,000 cattle holdings in Ireland, representing 8% of total holdings, 8% of total utilised agricultural area and 20% of total livestock units (EC, 2007).

Table 1 Prohibited application periods in three Irish national zones and a sub-zone (see Figure 1).

Zones	Storage capacity required	Type of fertiliser		
		Chemical fertilisers	Organic fertilisers	Farmyard manure
A	16 weeks	15 Sept - 12 Jan	15 Oct - 12 Jan	1 Nov - 12 Jan
B	18 weeks	15 Sept - 15 Jan	15 Oct - 15 Jan	1 Nov - 15 Jan
C (Donegal and Leitrim)	20 weeks	15 Sept - 31 Jan	15 Oct - 31 Jan	1 Nov - 31 Jan
C* (Cavan and Monaghan)	22 weeks	15 Sept - 31 Jan	15 Oct - 31 Jan	1 Nov - 31 Jan

Local Authority personnel are responsible for farm inspections in relation to the GAP regulations while the Department of Agriculture, Fisheries and Food carry out inspections in the context of cross-compliance for the purposes of the Single Payment Scheme.

Ireland has to date made two reports to the European Commission as required under Article 10 of the Nitrates Directive. The first of these was submitted in 2004 by the Department of the Environment, Heritage and Local Government and related to the 2000-2003 reporting period; the second was submitted in 2008 by the Environmental Protection Agency (EPA, 2008) and related to the 2004-2007 reporting period.

1.2 Overview of trends in nitrogen and phosphorus loads and surpluses

A summary of agricultural activity in Ireland during the period 2004-2007 is presented in Table 2 together with figures for the previous reporting period, where available. Grass is the dominant crop in Ireland: an average of 3,889,500 ha was devoted to grass production in the 2004-2007 period, which comprised 90% of the agricultural land area. Livestock numbers fell during the 2004-2007 period thereby impacting on organic N production. Cattle numbers fell by 4.4% between June 2004 and June 2007. Sheep and pig numbers fell by 18.5% and 4.0% respectively during this period. This resulted in a reduction of 20,800 tonnes of nitrogen from livestock manure being applied on land. Chemical N use fell from 362,500 tonnes in 2004 to 321,600 tonnes in 2007. Chemical P use fell by 10,200 tonnes (24%) during this period.

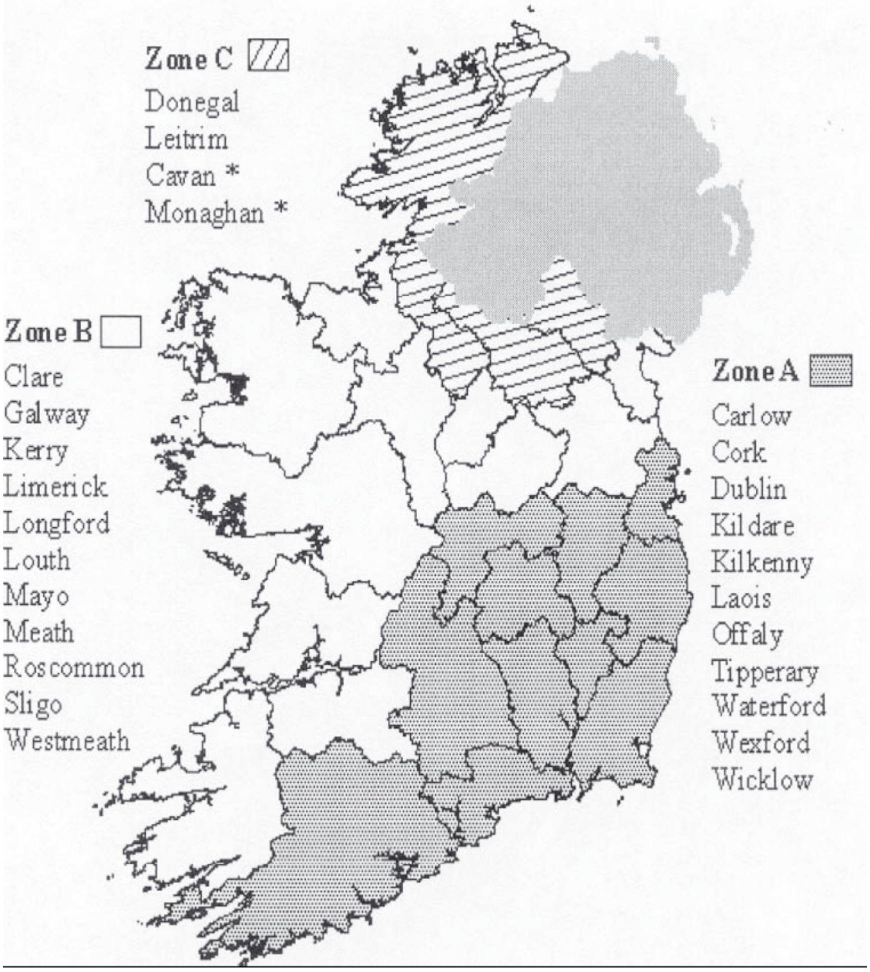


Figure 1 Three zones governing the application of GAP regulations in Ireland.

Table 2 Agricultural statistics for Ireland
Table adapted from EPA, 2008.

	Reporting Period		
	Previous period 2000-2003	Current period 2004-2007	
Total land area (km²) [1]	68,900		68,900
Agricultural land (km²) [1]	44,148	2004	43,050
		2005	43,020
		2006	42,605
		2007	42,759
Agricultural land available for application of manure (km²) [1,2]	39,366	2004	38,514
		2005	38,305
		2006	37,895
		2007	38,211

	Reporting Period			
	Previous period 2000-2003		Current period 2004-2007	
Grassland area (km^2) [1]	40,419 (revised)		2004	38,810
			2005	39,008
			2006	38,795
			2007	38,965
Annual use of organic N from livestock manures (thousand tonnes) [3]	2000 (revised)	462.9	2004	453.9
	2001	458.4	2005	451.9
	2002	453.9	2006	448.2
	2003	453.7	2007	433.1
Annual use of mineral N (thousand tonnes N) [4]	2000	407.6	2004	362.5
	2001	368.7	2005	352.2
	2002	363.5	2006	345.2
	2003	388.1	2007	321.6
Number of farmers [1]	141,257		2004	NA
	2003	135,600	2005	132,700
Cattle (million heads, in June) [1]	2000	7.0374	2004	7.0156
	2001	7.0497	2005	6.9826
	2002	6.9922	2006	6.9159
	2003	6.9995	2007	6.7041
Sheep (million heads, in June) [1]	2000	7.5550	2004	6.7772
	2001	7.3303	2005	6.3922
	2002	7.2096	2006	5.9732
	2003	6.8489	2007	5.5216
Pigs (million heads, in June) [1]	2000	1.7221	2004	1.6531
	2001	1.7430	2005	1.6877
	2002	1.7845	2006	1.6432
	2003	1.7262	2007	1.5878
Poultry (million heads, in June) [1]	2000	13.9608	2004	NA
	2001	12.6026	2005	11.8170
	2002	12.7086	2006	NA
	2003	12.7378	2007	NA

[1] Central Statistics Office (CSO), Ireland.
[2] Estimated from the area allocated to grassland and crop production, but excludes rough grazing.
[3] Department of Agriculture, Fisheries and Food estimate (using CSO June livestock numbers). Includes N deposited on land by grazing livestock.
[4] Department of Agriculture, Fisheries and Food.
NA = not available

As a result of the changes in livestock numbers, chemical fertiliser usage and other factors, the OECD agricultural nitrogen balance showed a reduction for Ireland from +83 kg ha^{-1} of total agricultural area in 2000 to +82 kg ha^{-1} in

2004. The figures for phosphorus were +8 kg ha^{-1} in 2000 and +6 kg ha^{-1} in 2004. It is expected that these figures will show significant further reductions when the figures are calculated for 2005, 2006 and 2007.

1.3 Overview of monitoring networks

Groundwater

The implementation of the Water Framework Directive (WFD) required that a comprehensive groundwater quality monitoring programme should be operational by 22 December 2006. This requirement necessitated the review of the existing networks, followed by the establishment of carefully selected new networks. In early 2009, the water quality network consisted of 275 wells (a density of 1/250 km^2), with sampling taking place every three months. The network consisted of 275 WFD surveillance monitoring points, of which 114 are WFD operational monitoring points.
The average nitrate concentrations for 2007 at the national EPA groundwater quality monitoring stations are shown in Figure 2. Generally the eastern and south-eastern portion of the country has the greatest proportion of monitoring stations with elevated nitrate concentrations. This is attributed largely to the impact of diffuse agricultural sources.

Phosphate is a major source of concern for surface waters because small amounts may lead to eutrophication of lakes and rivers. Historically, phosphate was not considered to be a significant problem in groundwater because it is not very mobile in soils or sediments and should therefore be retained in the soil zone. However, in extremely vulnerable areas, where the soil and subsoil are shallow and where phosphate enters groundwater in appreciable quantities, groundwater may act as an additional nutrient enrichment pathway for receptors such as lakes, rivers and wetlands.

While the maximum admissible concentration (MAC) for phosphorus in drinking water is 5 mg l^{-1} as P_2O_5, equivalent to 2.2 mg l^{-1} P (S.I. No. 81 of 1988), the environmental quality standard for good status river water bodies in Ireland for molybdate reactive phosphorus (MRP or orthophosphate) is 0.035 mg P l^{-1} as a mean concentration. As there are areas of the country where groundwater contributes significantly to flows in rivers, for example, where 60-80% of the surface water flow comes from groundwater, elevated phosphate concentrations in groundwater in these areas may be contributing to eutrophication in rivers and lakes. The mean phosphate concentrations in groundwater in the period 2004-2006 are shown in Figure 3. Elevated phosphate concentrations in groundwater are noticeable in the west of Ireland, particularly at monitoring locations in karstified limestone areas. This reflects the vulnerable nature of these aquifers and the relative ease of transport of pollutants within the conduit karst underground flow regime.

Rivers

The details on the rivers monitoring network are given in Table 3. River monitoring for the Nitrates Directive is undertaken as part of the main WFD Monitoring Programme. The Surveillance Monitoring network comprises 180 sites at which a full suite of biological quality elements, priority substances and supporting physico-chemical quality elements are monitored (including nitrate).

This Surveillance Network provides the information for reporting under Article 10 of the Nitrates Directive. Sampling to monitor the physico-chemical determinants is undertaken every three months.

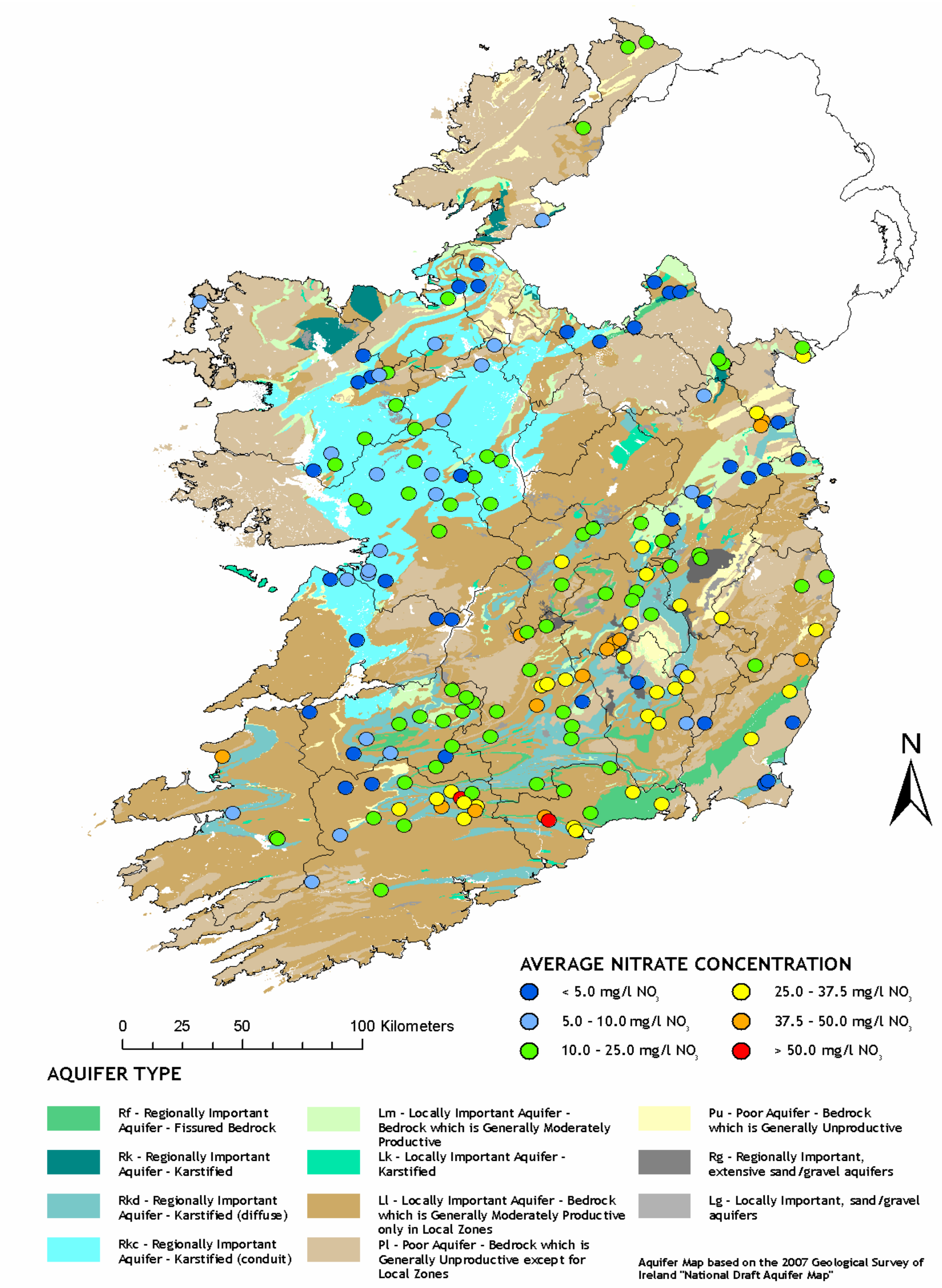


Figure 2 Mean nitrate concentrations in groundwater in Ireland 2004-2006.

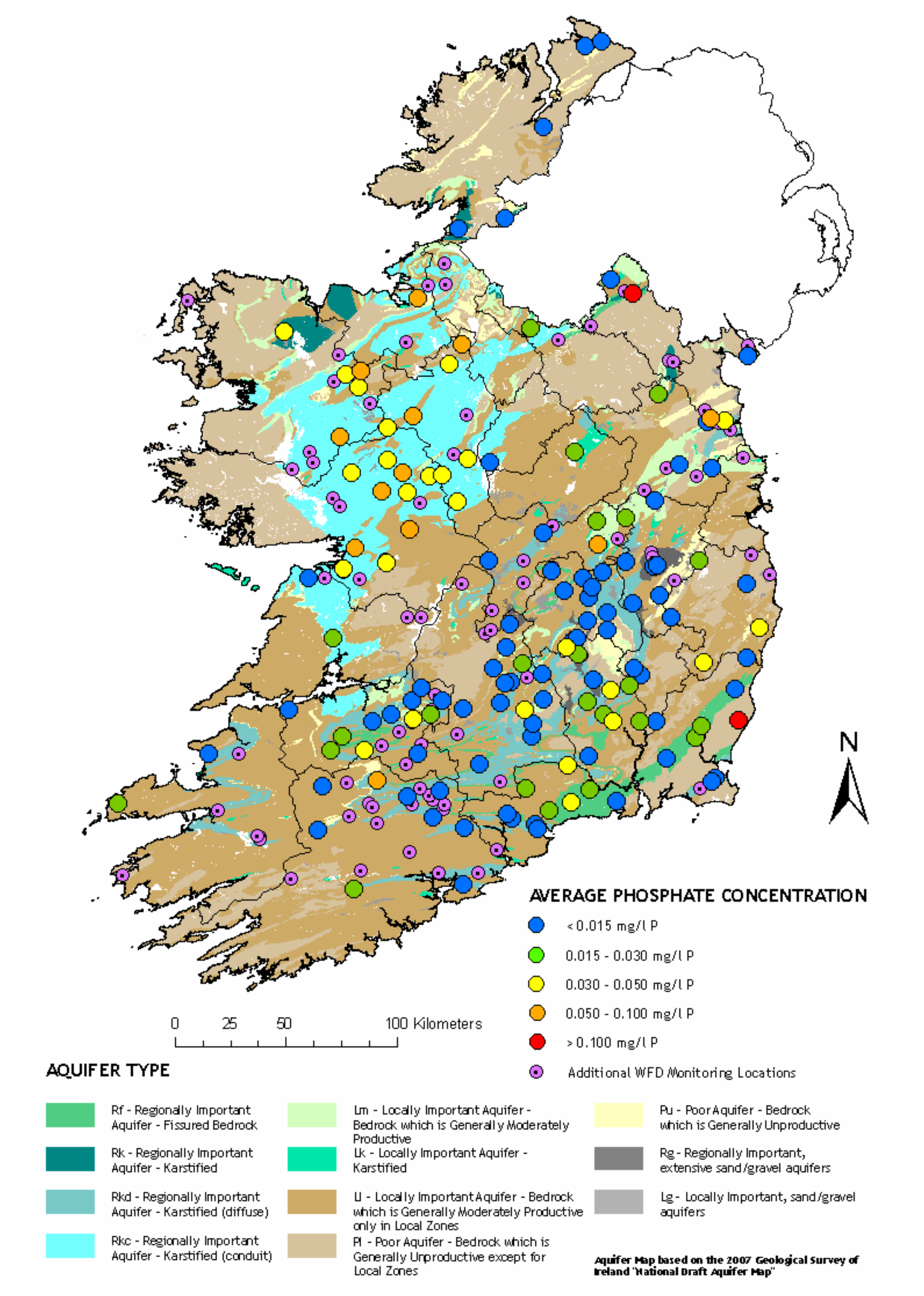


Figure 3 Mean phosphate concentrations in groundwater in Ireland 2004-2006.

Table 3 Details on the river monitoring network in Ireland.

Monitoring Network	No. sites	No. sites
WFD Surveillance Monitoring	180	
WFD Operational Monitoring	2,551	
Total Number of river monitoring sites	2,731	
Number of sites for water chemistry		1,389
Number of sites for biological quality elements		2,302
(Note – not all sites have both biology and chemistry)		

1.4 Overview of trends in nitrate, nitrogen and phosphorus

Groundwater

The average nitrate concentrations for 2007 can be compared with the three-year averages for the period 1995 to 2006 in Table 4. This shows an increase in the proportion of wells with nitrates in the range 25-37.5 NO_3 mg l^{-1}.

Table 4 Average nitrate concentration (mg NO_3 l^{-1}) in groundwater in Ireland, as percentage of monitoring locations within each concentration range.

Period	Nitrate concentration range (mg NO_3 l^{-1}) < 5	5 - 10	10 - 25	25 - 37.5	37.5 - 50	> 50
1995-1997	13.3	18.3	50.0	11.7	6.7	0.0
1998-2000	20.7	15.9	45.1	11.0	4.9	2.4
2001-2003	16.2	18.0	44.1	11.8	8.1	1.8
2004-2006	14.6	11.7	46.7	17.5	7.3	2.2
2007	21.3	13.8	39.1	17.2	7.5	1.1

Rivers

The average river concentrations for nitrate at the available national monitoring stations are shown in Table 5. The number of river sites for which data were available was 1,179 sites in 1995-1997; 1,617 in the period 1998-2000, 2,615 in the period 2004-2006 and 1,996 in 2007; data were not included for the 2001-2003 period due to a data quality issue. The results show that nitrate concentrations in rivers have remained relatively stable apart from an apparent increase in the 1998-2000 period. The highest nitrate concentrations in rivers occur in regions dominated by tillage and in karst limestone areas in the south and south-east of the country.

Lakes

Arising from the WFD monitoring programme, data were available for a total of 208 lakes for 2007 (Table 6). The average nitrate concentrations ranged from 0.016 to 57.02 mg l^{-1} NO_3 with an overall average of 1.87 mg l^{-1} NO_3 (208 lakes).

Table 5 Average nitrate concentration (mg l^{-1} NO_3) in rivers in Ireland, as percentage of monitoring locations within each concentration range.

Period	Nitrate concentration range (mg NO_3 l^{-1}) < 5	5 - 10	10 – 25	25 - 37.5	37.5 - 50	> 50
1995-1997	33	25	39	3	0	0
1998-2000	23	19	39	13	3	3
2004-2006	31	25	40	5	1	0
2007	32	23	39	6	0	0

Table 6 Average nitrate concentration (mg l^{-1} NO_3) in lakes in Ireland, as percentage of monitoring locations within each concentration range.

Period	Nitrate concentration range (mg NO_3 l^{-1}) < 5	5 - 10	10 – 25	25 - 37.5	37.5 - 50	> 50
2007	92.6	3.70	3.2	0	0	0.5

2 Effect monitoring

2.1 Strategy for effect monitoring

Monitoring the effectiveness of the measures introduced in Ireland's National Action Programme, including the derogation, involves:

- the use of national indicators and statistics;
- a comprehensive monitoring and evaluation programme in agricultural mini-catchments; and c) on-going monitoring of groundwater and surface water.

National indicators

The Fertiliser Use Survey (FUS)
This survey is conducted by Teagasc (Irish Agriculture and Food Development Authority) and includes information on farm management, that means, farming system, soil suitability class, county, utilisable agricultural area, forage area, arable area; it also includes data on the quantities and types of chemical fertiliser used by farmers for different crops together with data on crop area and livestock numbers generated by the Irish National Farm Survey.

The Farm Facilities Survey (FFS)
Baseline data on farm facilities and managements relating to manure, dirty water and fodder systems were established by the initial Farm Facilities Survey in 2003, which was conducted by Teagasc. This survey covered all animal types but was concentrated on bovine grazing livestock as they account for the major proportion of manure production. Farms selected for analysis were categorised in accordance with standard protocols regarding type and size to ensure that the farm sample selected was statistically representative of the national situation. Future surveys will provide data that will be used to monitor and evaluate changes in relation to the baseline levels.

Agricultural mini-catchments

Teagasc is contracted by the Department of Agriculture, Fisheries and Food to conduct a four-year Agricultural Mini-Catchment Monitoring Programme in order to provide the basis for a scientific review of the National Action Programme (and subsequently WFD) measures (S.I. 101 of 2009) with a view to adopting modifications where necessary. A number of intensively farmed mini-catchments on a range of contrasting physical settings, such as soil types, have been established in partnership with stakeholders. The effect of changes in farm management practices on the transfer of nutrients from source to water and their impact on water quality will be evaluated. Measurements, modelling and socio-economic studies will be used to evaluate the efficacy, cost-effectiveness and economic impact of the measures. Modifications to measures will be identified where evidence indicates that water quality targets may not be achieved.

The three main objectives of the Agricultural Mini-Catchments Monitoring Programme are:

– to establish a group of intensively farmed mini-catchments, where productive agriculture is practiced and water quality targets are or may be compromised;
– to generate the knowledge to ascertain the efficacy and cost-effectiveness of the National Action Programme measures against a background of profitable farming;
– to disseminate this knowledge to a wide audience.

The programme was established in 2008 and will run to 2012. A programme manager and a team of scientists, including a principal scientist, technicians and farm advisors are in place. Quality assurance on the scientific aspects of the programme is provided by an Expert Steering Group, which includes national and international experts in catchment management. A forum for national stakeholder consultation is provided while Teagasc also undertakes consultation with local stakeholder groups.

2.2 Monitoring networks

General

Both the groundwater and surface water networks are subdivided into surveillance and operational monitoring networks for WFD purposes. The operational networks focus on water bodies that are considered to be ‘at risk’ and where measures are needed to maintain or improve the status of the water bodies.

Groundwater

The groundwater monitoring network for surveillance and operational monitoring utilises relatively large groundwater abstraction points in the bedrock aquifers and in overlying sand/gravel aquifers. These monitoring points are considered to give representative samples as they are not usually affected significantly by nearby point pollution sources. Most of these monitoring points are either wells or springs tapping conduits and fractures in limestones, or wells located in geological fault zones where the permeability is enhanced. The remainder of the monitoring points are in unconfined volcanic aquifers, confined bedrock aquifers (usually sandstone) and in sand/gravel aquifers.

Bedrock aquifers underlie 100% of the country; 30% are productive, while 70% are ‘poor aquifers’. The productive aquifers consist of Carboniferous limestones, Carboniferous and Devonian sandstones, and Ordovician volcanics. All bedrock aquifers have a fissure permeability only; this is in contrast to most if not all other EU countries, where many of the main aquifers have either an intergranular permeability or dual permeability – both fissure and intergranular. In addition, most of our productive aquifers are karstified limestones (the limestone is dissolved and a high proportion of flow is in conduits). In the poorly productive aquifers, high yielding wells are located in zones of high transmissivity along geological faults.

Representativity analyses have been undertaken to ensure that the monitoring points in combination represent both the variation in hydrogeological settings and the pressures. This is an innovative approach, which relies on a smaller network than in other countries, but one which is focused and is therefore effective both in terms of cost and data collection.

Samples are taken every three months; in total 275 groundwater locations are sampled each time, 139 are wells that are already used for drinking water or industrial supplies, 71 are spring overflows and 65 are specially installed piezometers. A majority of the operational points were chosen to monitor diffuse pollution, in particular nitrates and phosphates in groundwater.

Surface waters

The precise quality elements monitored at any given river site under operational monitoring will depend on the particular programmes of measures (PoMs) and what quality elements are most sensitive to the pressure being assessed for PoMs. Operational Monitoring plus surveillance monitoring sites in combination provide data for Effect Monitoring in the present context – especially for assessing the effect of the Nitrates Directive derogation approved for certain Irish farms. This is done by statistically comparing water quality and ecological status in river water bodies in relation to the number of derogation farms in the upstream catchments.

2.3 Detailed technical description of network used for effect monitoring

Monitoring responsibilities

In rivers and lakes, monitoring of phytoplankton, benthic algae, macro-invertebrates, relevant pollutants and priority substances is the responsibility of the Environment Protection Agency (EPA). Fish monitoring is the responsibility of the Central Fisheries Board and physico-chemical monitoring is a joint local authority/EPA responsibility. The EPA undertakes the assessment and reporting of groundwater monitoring data, while maintenance of the monitoring points is a joint local authority/EPA responsibility. The Minister for Agriculture, Fisheries and Food is responsible for monitoring and evaluation programmes in relation to farm practices as may be necessary to determine the effectiveness of measures being taken in accordance with the GAP Regulations, including the derogation.

Fertiliser Use Survey and Farm Facilities Survey

Farm management data from the Teagasc National Farm Survey (NFS) are used as the basis for these surveys. Farms are randomly selected to represent the major farm systems and sizes using information from the CSO Census of Agriculture. The classification of farms into six main farm systems is based on the EU farm typology as set out in Commission Decision 78/463. These are dairying, dairying with other enterprises, cattle rearing, cattle with other systems, mainly sheep and tillage systems. These systems refer to the dominant enterprise in each group.

Agricultural Mini-Catchment Monitoring Programme

This programme is still in its establishment phase. However, Teagasc has put in place an integrated research and advisory team including a soil scientist, a hydrogeologist, hydrogeochemist, a socio-economist, farm advisors, technicians and an overall data manager. A principal scientist provides scientific leadership and management and a programme manager is responsible for the overall management of the programme and delivery of its outputs.

A network of up to eight mini-catchments is planned under this programme and these are identified following a significant and systematic selection process using Multi-Criteria Decision Analysis. This approach is based on EU Guidelines on the monitoring required under Article 7 of the Nitrates Directive. These guidelines suggest that monitoring should be focused on areas *'… of intensive crop and livestock production … with elevated nitrate concentrations … adjacent to existing or projected eutrophication areas … with similar land use, soil type or agricultural practice'*.

Six mini-catchments have been finalised to date and monitoring programmes are being established. Four of these are situated in grassland areas, one of which has a high N loss risk while the other three are predominantly at risk of P loss with varying levels of N loss risk. Two catchments have a high proportion of tillage, one in which the greatest risk is N loss through leaching from free-draining soils, while in the other P loss through overland flow is more likely due to the predominance of heavy soils. These six mini-catchments are situated to the east, south-east and south of the country.

It is intended to select a suitable mini-catchment location(s) on pure limestone geology where groundwater nutrient pathways dominate, that means, karstified areas. The final mini-catchment(s) will likely be west of the River Shannon and situated in the extensive karst landscape of counties Galway and Mayo. Groundwater in these areas is currently classified as 'poor status' under the WFD status classification system.

In terms of linking cause and effect with parameters of nutrient hydrochemistry, that means, N and P, in water draining each catchment, a base conceptual model, as follows, has been applied to develop an experimental design protocol for each catchment:

- sources (inputs and net soil accumulation);
- mobilisation (potential for release; desorption/erosion/leaching);
- pathways (overland flow, subsoil flow, weathered/upper fractured bedrock, deep bedrock flow);
- transfers (stream network and final flux leaving catchment).

Groundwater monitoring

Springs are an important feature in Ireland, particularly in karstified limestone areas. Over 70 springs are now included in the groundwater quality network; weirs or other flow measurement structures have been installed at 28 of these springs, thereby enabling a comprehensive assessment and understanding of pollutant movement in the underground environment.

Well monitoring points in the karst limestones, volcanics and in fault zones have the same general design. Typically well depths range from 30-100 m below ground level (bgl), although the majority are < 60 m deep. They are lined into bedrock, which is usually encountered 0-15 m bgl. In some instances, well screens are installed at the main water entry zones. In the remaining monitoring points, the wells are 'open hole', that means, due to the competent nature of the bedrock, a liner or screen is not needed.
Sand/gravel aquifers underlie 2% of the country. These aquifers are usually unconfined, are not overlain by clay subsoils and are generally relatively thin (5-15 m saturated thicknesses), with the sampling depth either opposite high permeability zones or towards the bottom of the holes. As the monitoring points are abstraction points, they are considered to give a representative sample of the groundwater.

The sampling depth is not considered to be a critical factor in monitoring the karst limestones, volcanics and the fault zones due to the particular hydrogeological settings present in Ireland. Relevant factors are as follows:

- Most of our bedrock aquifers are unconfined.
- All our bedrock aquifers have a fissure permeability (K) only. Consequently, groundwater velocities in most Irish bedrock aquifers are relatively fast (a few metres per day) and mixing of groundwater in the top about 60 m readily occurs. In our karst aquifers, the velocities can be considerably higher (up to 100 m $hour^{-1}$). Consequently, travel times through the groundwater system are normally in the order of days, weeks and months, rather than decades and centuries.
- In the monitoring points in these aquifers, water can usually be drawn from all bedrock fractures in the well, that means, from the total bedrock length. Therefore, the water sample is generally a composite of water from all fractures and/or conduits through out the total length of bedrock in the borehole (on average, from 40-50 m saturated bedrock). In view of the velocities of groundwater flow and the hydraulic interconnection throughout the depth of the wells due to the presence of fractures, sampling at different depths is not usually considered appropriate or necessary.

Since 2006, a high priority has been given to understanding and monitoring poorly productive aquifers, which underlie 70% of the country. Up until then, emphasis was on the productive aquifers, which are the main source of groundwater for water supply (groundwater supplies cover approximately 25% of drinking water in Ireland). In the poorly productive bedrock aquifers, groundwater flow is considered to flow in three pathways: in fault zones; in fractured and weathered zones at the top of the bedrock; and at depth in widely dispersed, poorly interconnected fissures (see Figures 4 and 5). Meeting representativity requirements is not readily achievable in these aquifers. Relatively high yielding wells, located in fault zones, are included in the monitoring network. Sixty multi-level piezometers (wells) have been installed in six hydrogeologically-different 'type' settings – Galway granite, Pre-Cambrian rocks of north Mayo, Pre-Cambrian rocks in a cross-border groundwater body in Donegal, Lower Palaeozoic rocks in Louth, Old Red Sandstone in Cork, and impure limestones in Meath. A stream catchment has been associated with each geological setting. Monitoring well clusters were installed at three locations along a transect, starting near the stream and moving up-gradient towards the groundwater divide. At each location, wells/piezometers were installed at three or four different depths to enable groundwater level and groundwater quality to be monitored. The depths varied depending on the local hydrogeological settings; however the shallow piezometers were generally located in the range 2-5 m deep; the intermediate 4-10 m; and the deep 10-50 m. This is illustrated schematically in Figure 6.

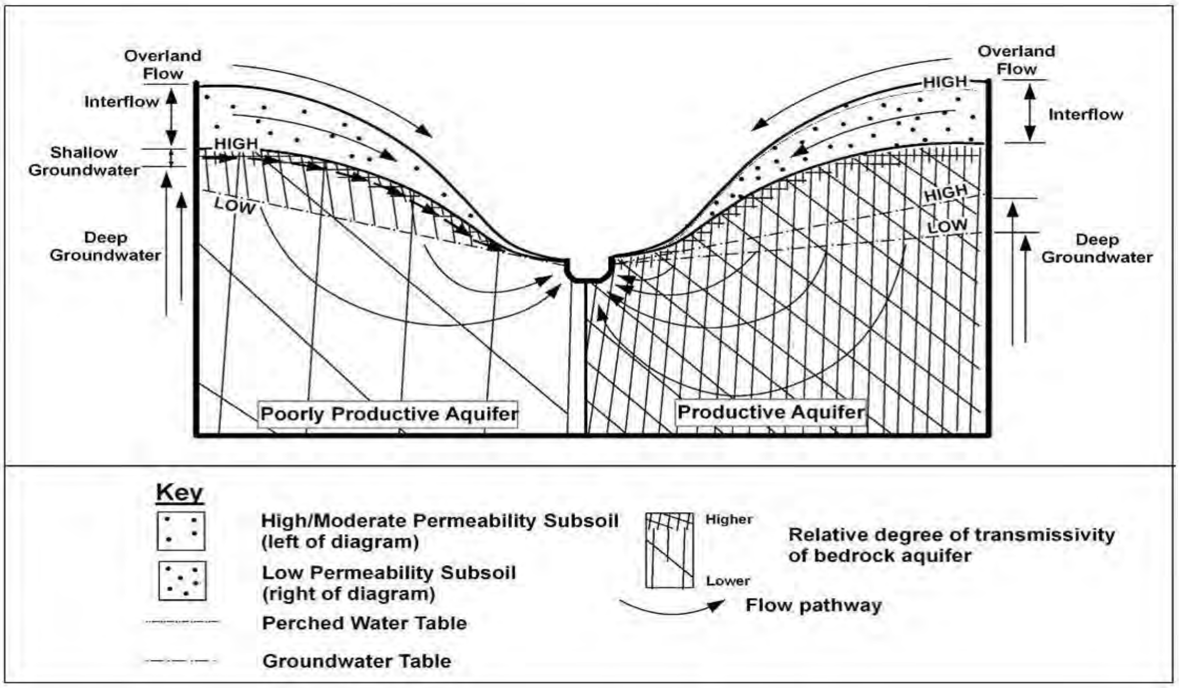


Figure 4 Components of surface water and groundwater flow in poorly productive (left) and productive (right) bedrock aquifer settings.

Data interpretation

The National Farm Survey, the Fertiliser Use Survey and the Farm Facilities Survey will provide information on national indicators.

The Agricultural Mini-Catchment Monitoring Programme will generate evidence of the farming community's compliance with the National Action Programme measures. The programme will generate a long term data set of field and farmyard nutrient sources, the transport in soil-water of the nutrients leaving the field/farm through the soil/subsoil system, their delivery to water bodies and their impact on water quality. The programme will elicit information on the impact of the measures on farm profitability and provide a greater insight to socio-economic barriers to their adoption. The data generated will be analysed and modelled to provide the evidence linking the water quality responses to the changes in agricultural practices arising from the implementation of the National Action Programme measures.

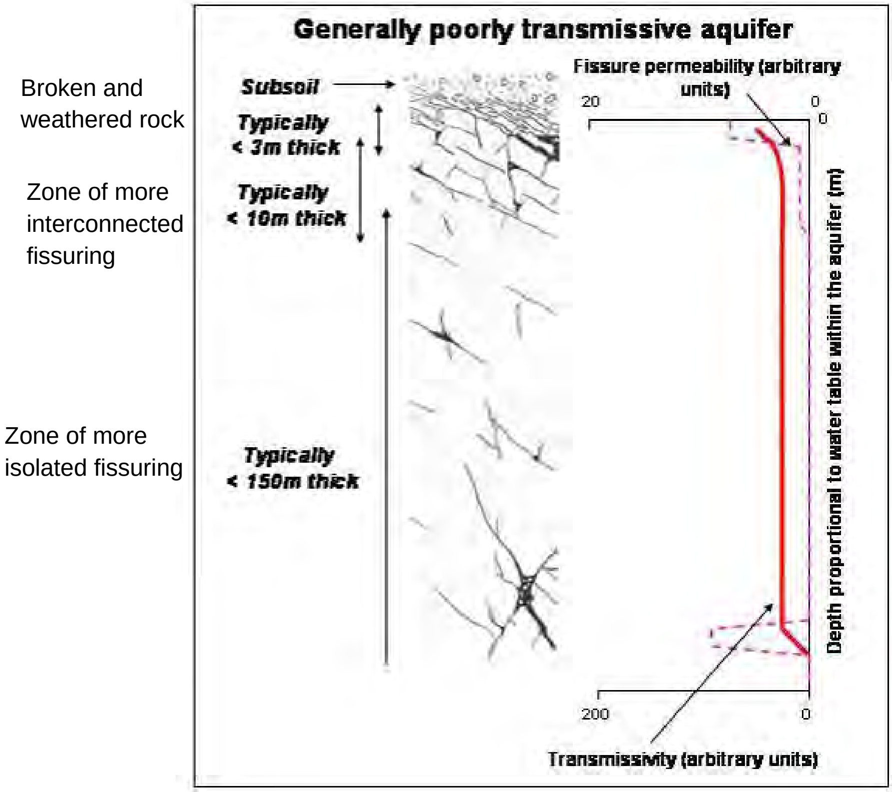


Figure 5 Conceptual variation of transmissivity and fissure permeability with depth through a generally poorly productive aquifer.
Amended from Geological Survey of Ireland, 2003. Shallow groundwater occurs in the upper part of the bedrock (typically < 3 m).

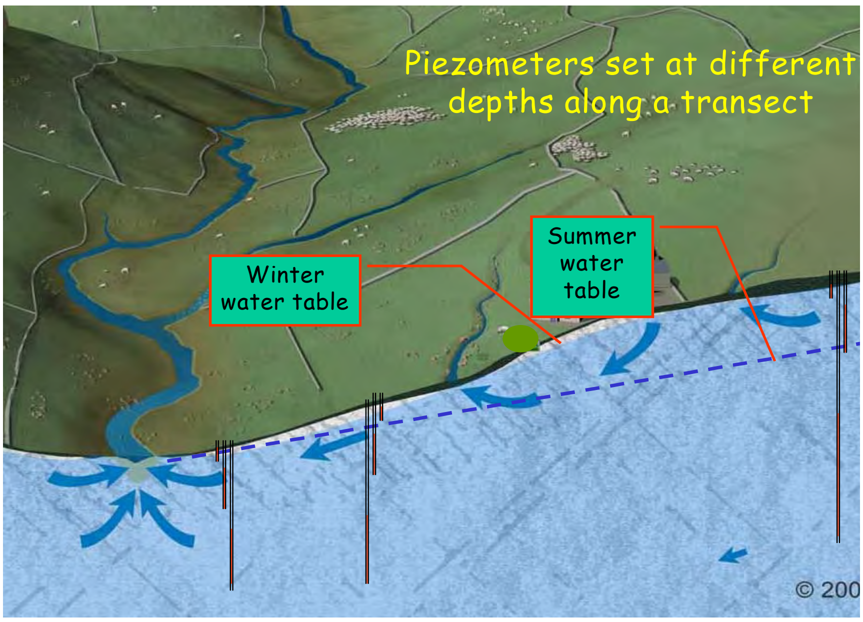


Figure 6 Schematic illustration of monitoring points along a transect in a poorly productive aquifer.

As a component of WFD groundwater body classification, trend assessments have been undertaken for nitrate at all groundwater monitoring points using appropriate statistical techniques, such as Sen's and Mann-Kendall. Significant upward trends were detected at two monitoring points, although a number of other monitoring points have elevated nitrate concentrations.

3 Discussion

Classification results for Water Framework Directive

The interim classification of groundwater bodies, as required for implementation of the WFD, was completed in December 2008. Two groundwater bodies (GWBs) were classed as 'poor' due to the presence of nitrates in the groundwater in the vicinity of drinking water sources (Daly and Craig, 2009). A further 101 GWBs (13.1% of area) were classed as 'poor' due to the presence of phosphates in groundwater in the karstic aquifers in the west of Ireland – see Figure 7. The objective will be to restore these GWBs to 'good' status.

Phosphates in groundwater

The restoration of GWBs in the west of Ireland classed as 'poor' status, due to high phosphate levels, to 'good' status, will be challenging; no other EU country is in a similar position. In the west of Ireland, pressures due to agricultural activities are low relative to the south and south-east of the country. The 'poor' status classification in the area is due to three factors:

a) the sensitivity of the surface water ecosystems to phosphate – the environmental quality standard (EQS) is 0.035 mg P l^{-1};
b) the vulnerability of the groundwater in the karstified aquifers (with bare rock, shallow soils and subsoils and sinking streams) where average phosphate concentrations in the five groups of GWBs in the area is 0.36 mg P l^{-1};
c) the groundwater contribution to surface water is usually more than 65% of stream flows.

As a consequence, a major focus for monitoring in Ireland will be on phosphates in the vulnerable, karstified aquifers; additional monitoring and assessments may be required to enable the 'critical source areas' to be located.

Nitrates in groundwater

Articles 3 and 4 of the Groundwater Directive (EC, 2006) (GWD), together with associated Annexes, lay down the criteria for assessing groundwater body chemical status. Groundwater quality standards are set in the GWD as 50 mg l^{-1} for nitrates. 'Threshold values' have been developed for Irish groundwater bodies by the EPA for substances that are leading to (or likely to lead to) chemical and/or ecological status failures. Threshold values (TVs) are annual average concentrations, rather than maximum admissible concentrations (MACs), and different TVs have been derived for the different chemical status tests, for example, for the surface water test the TV is the surface water EQS, whilst for use based status tests (drinking water and general chemical tests), the TV is 75% of the Drinking Water standard for appropriate determinants. In order to ensure that peak concentrations remained below the drinking water MAC, 75% of the MAC was taken to be the TV, because drinking water standards are MACs, and TVs are average values. These Member State defined quality standards are used as triggers for further investigation to determine whether or not the conditions for good chemical status are met, and do not by themselves define the actual boundary between good and poor status. Few EU countries have set TVs below 50 mg l^{-1}. The justification for other Member States taking 50 mg l^{-1} as a TV is unclear.

The main source of nitrates in rivers is usually diffuse agricultural sources leaching into groundwater, which in turn discharges into the rivers. Nitrates in rivers are regarded as posing a significant threat to transitional and coastal (TRAC) waters in the vicinity of estuaries. From an ecological perspective, the EU standard of 50 mg l-1 and the Irish TV of 37.5 mg NO_3 l^{-1} are high and are unlikely to prevent eutrophication impacts in the freshwater environment. The EPA has set a trigger action value (TAV) of 2.6 mg N l^{-1} (11.5 mg NO_3 l^{-1}) at the freshwater-saline interface. In undertaking the risk assessments required for WFD implementation, the EPA assessed the role of groundwater in contributing nitrates to TRAC waters; the 'at risk' groundwater bodies are shown in Figure 8. It is likely that during the period of the next WFD river basin management cycle (2009-2015) more detailed monitoring of groundwater and river flows may be needed to assess the nitrogen loading provided by groundwater to rivers and estuaries, and the ecological impact.

Nitrates Directive and Water Framework Directive

A coordinated approach is being taken to implementation of the Nitrates Directive and the WFD increasingly in Ireland, particularly in monitoring groundwater and surface water. This is resulting in a more integrated, holistic approach to river basin management.

Acknowledgements

The assistance of the following persons is gratefully acknowledged: Martin McGarrigle, EPA, who provided information on rivers; Matthew Craig, EPA, who assisted.

4 References

Daly, D. and Craig, M. (2009)). Chemical and quantitative status of groundwater bodies: a measure of the present, a signpost to the future. Proceedings of IAH (Irish Group) Seminar, Tullamore.

DEHLG/DAF (2005) Ireland: National Action Programme under the Nitrates Directive. Department of Environment, Heritage and Local Government/Department of Agriculture and Food.

EC (1991) Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Communities, L375, 31/12/1991, 1-8.

EC (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities, L 327, 22/12/2000, 1-72.

EC (2006) Directive 2006/118/EC, OJ L372 of 12.12.2006.

EC (2007) Commission Decision C(2007)/5095 of 22 October 2007 granting a derogation requested by Ireland pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources.

EPA (2008) Article 10 nitrates report 91/676/EEC. Nitrates report for Ireland 2004-2007. Environmental Protection Agency, Dublin, Ireland.

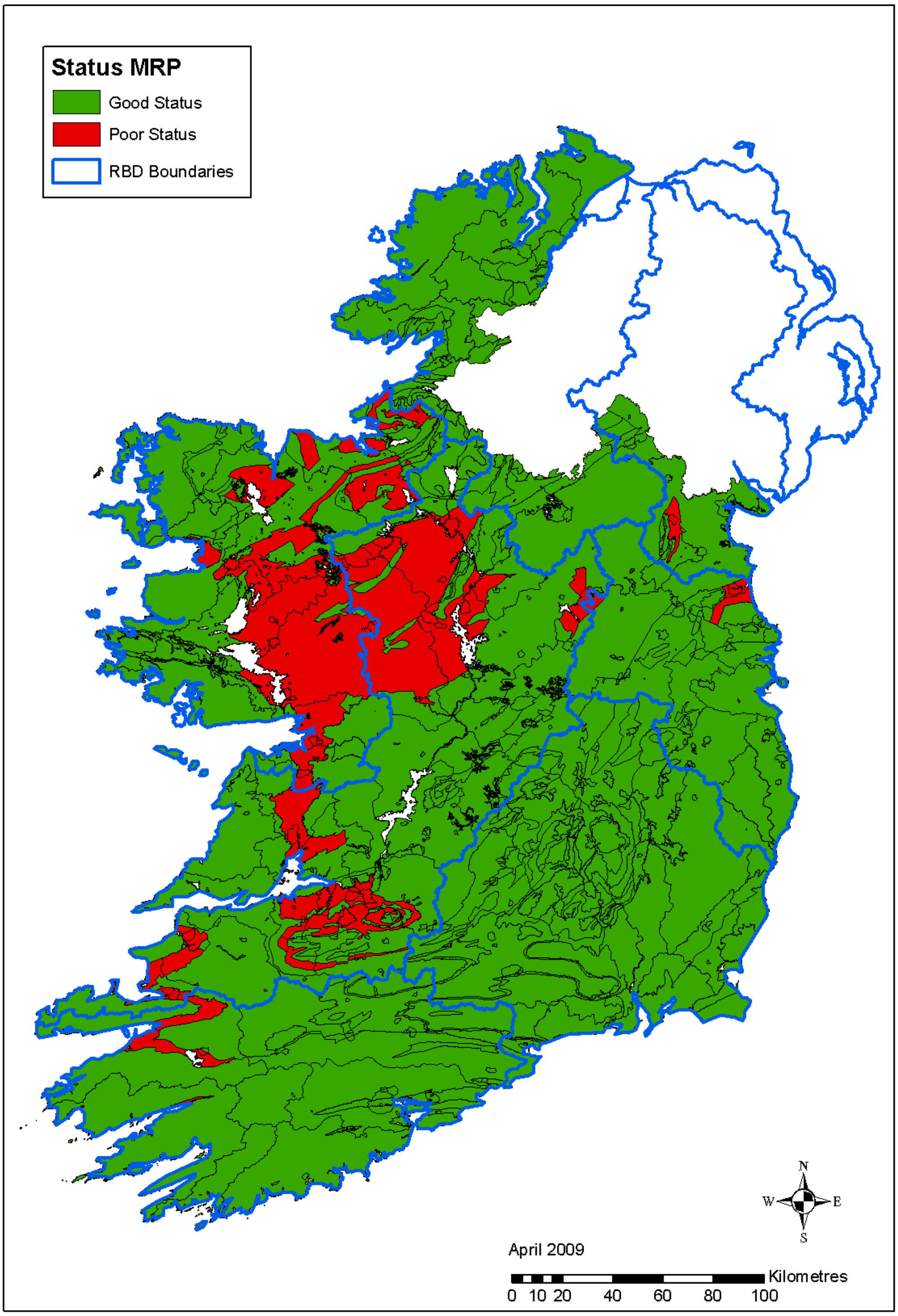


Figure 7 Chemical status of groundwater bodies based on an assessment of the orthophosphate (MRP) contribution to surface water ecosystems from groundwater.

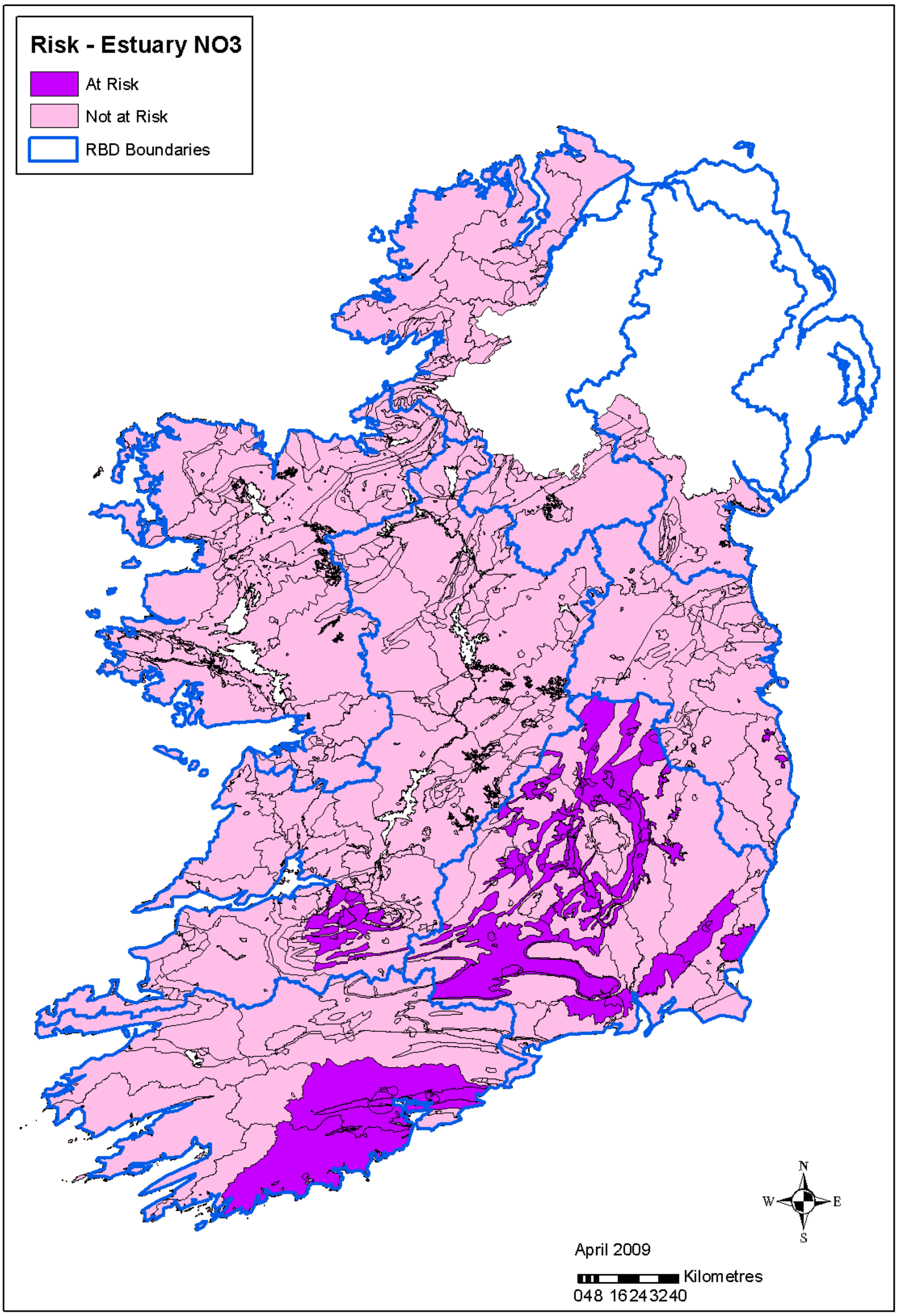


Figure 8 'At risk' groundwater bodies due to the contribution of nitrate in groundwater to transitional and coastal waters.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by Luxembourg

C. Neuberg

Administration de la Gestion de l'Eau, 51, rue de Merl, L-2146 Luxembourg, Luxembourg
e-mail: claude.neuberg@eau.etat.lu

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in Luxembourg and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). Luxembourg has established in 1994 a first action programme that was applied throughout its entire territory. The actual action programme has been established in 2000 and 2005 by the following regulation: 'règlement grand-ducal modifié du 24 novembre 2000 concernant l'utilisation de fertilisants azotés dans l'agriculture qui a transposé la directive CEE 91/676 du Conseil du 12 décembre 1991 concernant la protection des eaux contre la pollution par les nitrates à partir de sources agricole (Directive Nitrates)'. The specific situation in Luxembourg is outlined here with regard to the natural factors influencing nitrate occurrence, the driving forces for and the impact of nitrates on our freshwater resources, and finally, the details and strategy of Luxembourg's national programme for monitoring water quality. The development of nitrate concentrations is seen to be the key indicator for a following up of the progress of the Action Programmes. The results of Luxembourg's national monitoring programme form the main tool for monitoring and assessing effectiveness of Luxembourg's Nitrates Directive Action Programme.

1 Introduction

1.1 General

The main natural factors influencing nitrate occurrence in Luxembourg are climate, precipitation, hydrogeology and soil types. Other factors are of less importance.

Situated at the limit of two river basins, the basin of the river Rhine and the basin of the river Meuse (Maas), the Grand-Duchy of Luxembourg is characterised by rivers of low water (Figure 1). The surface waters are controlled regularly by the Water Agency (Administration de la Gestion de l'Eau).

The geology and the soil types are rather varied. In Luxembourg five main aquifers are distinguished (Figure 2). The lower Lias and the Trias are the most important groundwater bodies for water supply.

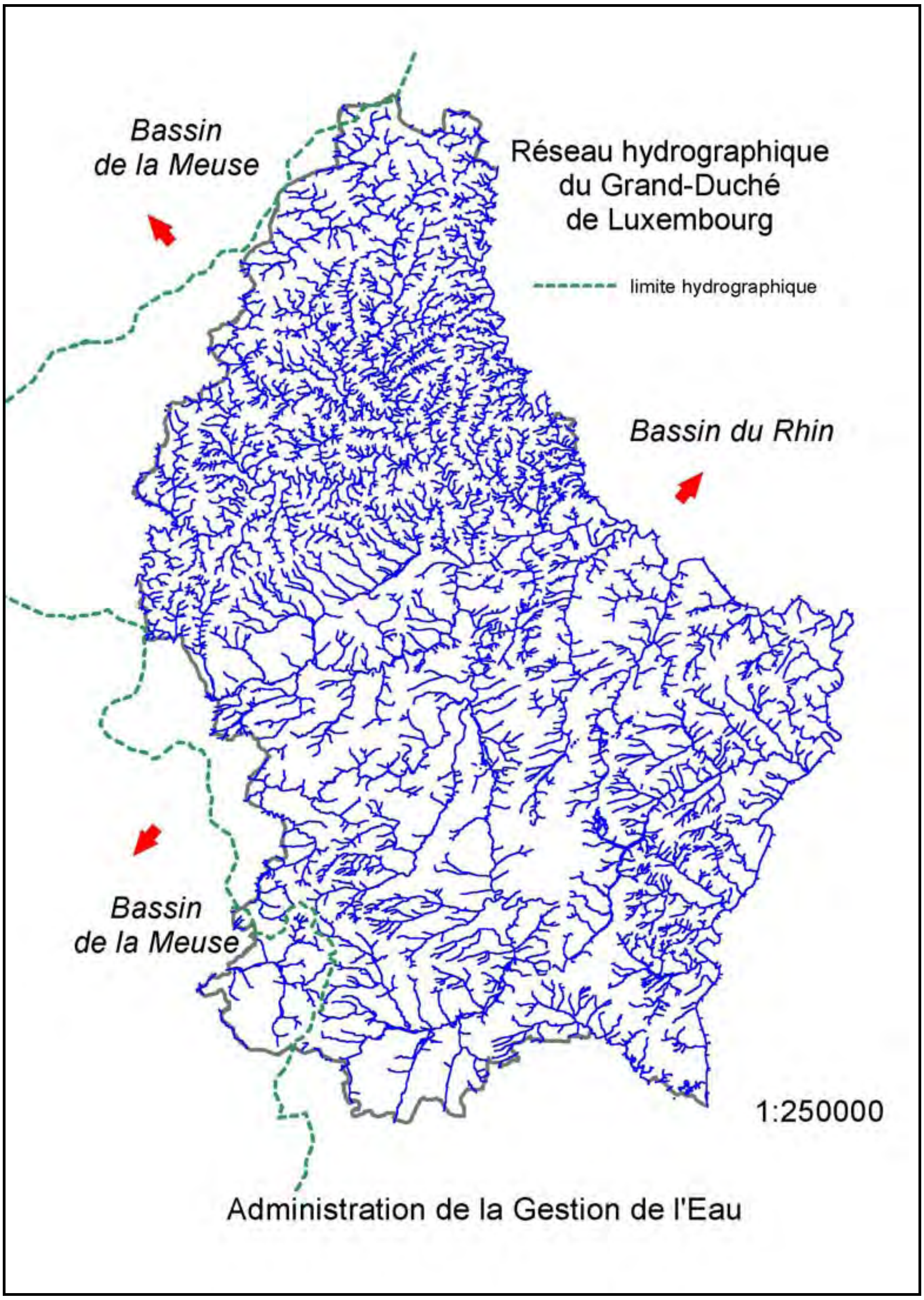


Figure 1 Two hydrographic basins of Luxembourg: Rhine and Meuse (Maas).

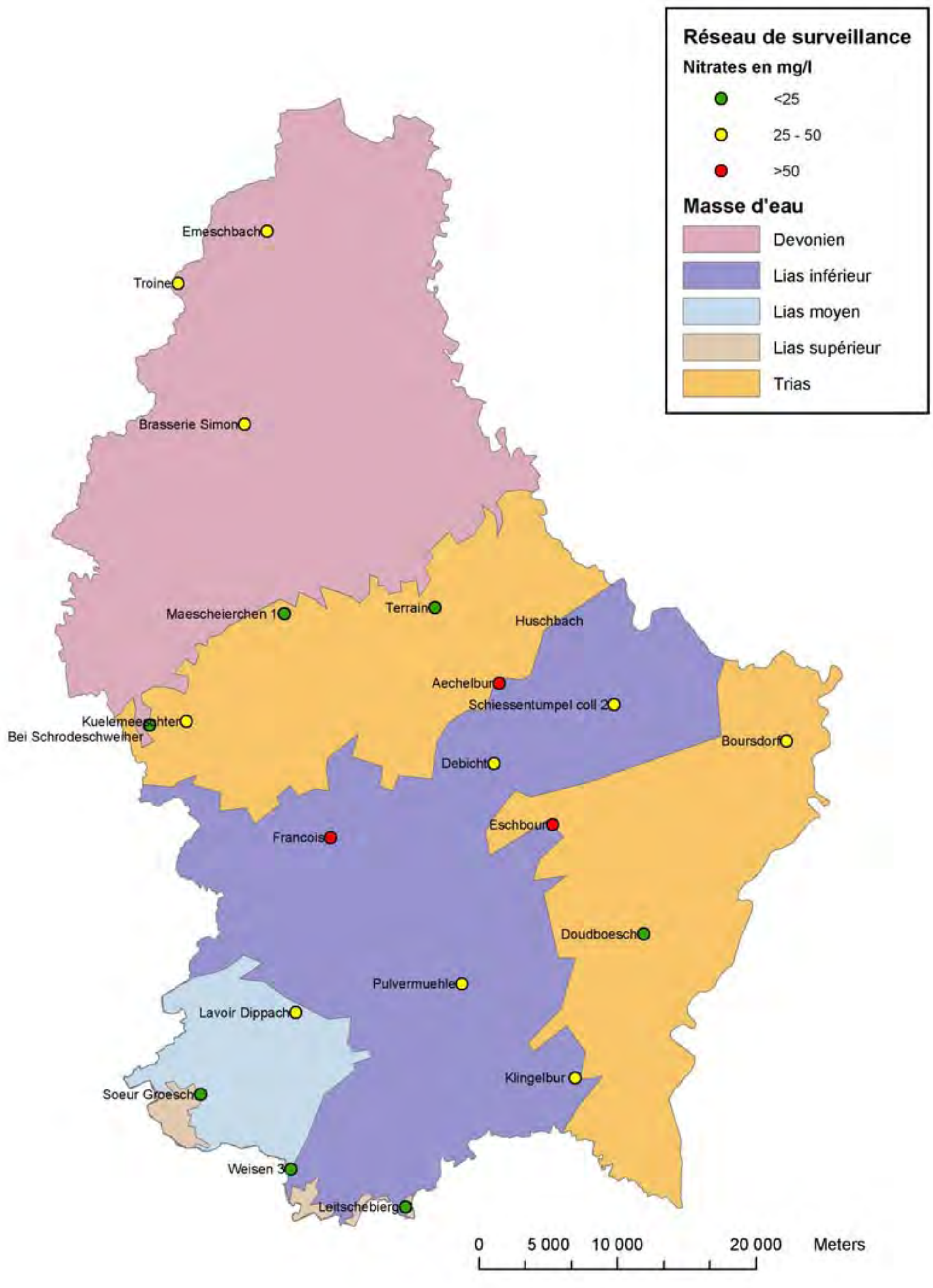


Figure 2 Localisation of the groundwater monitoring stations in Luxembourg.

1.2 Goals and Measures

The goals and targets are set by European and national legislation. For the Nitrates Directive (EC, 1991) Luxembourg is focusing on nitrate concentrations in surface waters and groundwater.

Luxembourg has established in 1994 a first action programme that was applied throughout its entire territory. The actual action programme has been established in 2000 and 2005 by the following regulation: 'règlement grand-ducal modifié du 24 novembre 2000 concernant l'utilisation de fertilisants azotés dans l'agriculture qui a transposé la directive CEE 91/676 du Conseil du 12 décembre 1991 concernant la protection des eaux contre la pollution par les nitrates à partir de sources agricole (Directive Nitrates)' (Service Central de Législation, 2000). This regulation was modified in 2005: 'règlement grand-ducal du 25 avril 2005 modifiant le règlement grand-ducal du 24 novembre 2000 concernant l'utilisation de fertilisants azotés dans l'agriculture' (Service Central de Législation, 2005).

Main measures in the Action Programme are application standards for manure and total N, storage of liquid manure, limitation in manure application in space and time.

1.3 Overview of trends in nitrogen and phosphorus loads and surpluses

The number of farms is steadily decreasing during the last two decades (Figure 3 and Table 1). More information has been published by the Ministère de l'Intérieur (2008).

Table 1 Evolution of the number of dairy farms in Luxembourg in the 2000-2007 period.

Year	2000	2001	2002	2003	2004	2005	2006	2007
Number of dairy farms	2,373	2,391	2,046	1,996	1,906	1,959	1,860	1,842

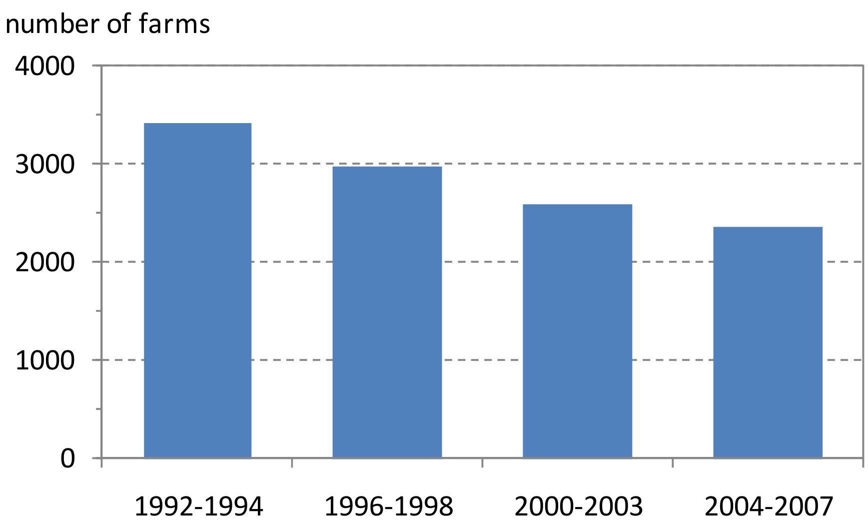


Figure 3 Evolution of the number of farms in Luxembourg (averages for each of the Nitrates Directive reporting periods).

The largest proportion (50.6%) of the agricultural land is permanent grassland, followed by arable land (46.6%) (year 2007).

Nitrogen balances calculated by several institutes (one example is shown in Table 1) show a decrease since the period 1996-1998. During the period 2004-2007 the nitrogen balances reached a level of 100 to 115 kg ha^{-1} depending on the institute that assessed these figures.

Table 2 Nitrogen balances for farms in Luxembourg.
Calculations by CONVIS, former FHL.

	Balances calculated for the years		
	1996-1998	2000-2002	2004-2006
Number of farms	223	200	181
Area of farms (ha)	21,532	22,160	21,829
Area per farm (ha)	96.6	110.8	120.95
N input (kg per ha)	183.0	174.3	172.67
Part of mineral N (kg per ha and %)	134 (73.2%)	126 (72.3%)	117.33 (68.0%)
N output (kg) per ha	45.0	47.3	57.0
Balance (input - output) (kg N per ha N)	137	127	115

These figures are confirmed by the decrease of the imports respectively the consumption of mineral fertilisers (Table 3). For the period 2000-2003 nearly 122 kg of mineral N fertilisers in average have been employed every year per hectare. This amount has gone down the following years to reach an amount of 116 kg per hectare in the period 2004-2006.

Because of the livestock decrease (6% between 1996-1999 and 2000-2003; 4% between 2000-2003 and 2004-2007), there is also decrease of manure production. Concerning the spreading of manure an increase can be observed of the employment of newer techniques.

1.4 Overview of trends in nitrate and phosphorus concentration

Surface waters

Average nitrate concentrations in surface waters in Luxembourg are between 7 and 32 mg NO_3 l^{-1} (Table 4). Six out of ten waters with long term monitoring show an increasing trend (Figure 4). Phosphorus concentration in surface water decreased between the 1996-1999 and 2004-2007 period (Table 5). Average concentrations ranged between 0.09 and 0.56 mg P l^{-1} for 2004-2007.

The level of eutrophication for most surface waters in Luxembourg is moderate, mainly due to phosphorus (Table 6).

Table 3 Consumption respectively imports of mineral fertilisers *in Luxembourg.*

	Average 1994-1999	2000	2001	2002	2003	2004	2005	2006
Total consumption (in tonnes)								
N fertilisers	17,920	18,130	15,410	15,949	12,905	16,355	14,230	14,034
P fertilisers	3,695	2,290	1,677	1,955	1,794	2,062	2,171	1,708
K fertilisers	4,889	2,730	1,865	2,027	1,884	2,267	2,388	1,876
Consumption per hectare cultivated (in kg)								
N fertilisers	141	142	120	124	101	128	110	109
P fertilisers	29	18	13	15	14	16	17	13
K fertilisers	38	21	15	16	15	18	18	15

Table 4 Nitrate concentrations and trends on surface waters (mg l^{-1}).

No	Name of the station	Average 1996/1999	Average 2000/2003	Trend 1996/1999 - 2000/2003	Average 2004/2007	Trend 2000/2003 - 2004/2007
1	Clerve – amont Clervaux	---	---	/	31.1	/
2	Wiltz - Kautenbach	21.8	23.0	weak increase	30.5	high increase
3	Sûre - Martelange	11.0	11.0	stable	17.6	high increase
4	Sûre – amont Esch/Sûre	---	---	/	21.4	/
5	Sûre - Wasserbillig	18.3	22.3	weak increase	25.8	weak increase
6	Alzette Esch/Alzette frontière	---	---	/	7.8	/
7	Alzette – Hesperange	---	---	/	26.8	/
8	Alzette – Steinsel	14.0	18.0	weak increase	16.5	weak reduction
9	Alzette – Ettelbruck	---	---	/	23.1	/
10	Ernz noire - Grundhof	24.0	22.0	weak reduction	20.1	weak reduction
11	Attert - Colmar-Berg	17.8	24.0	high increase	25.4	weak increase
12	Eisch – Steinfort	11.8	12.5	stable	19.3	high increase
13	Eisch – Mersch	19.3	19.5	stable	20.2	stable
14	Mamer – Mersch	21.5	22.5	stable	21.0	weak reduction
15	Syr – Mertert	19.3	20.0	stable	22.9	weak increase
16	Chiers - Rodange	---	---	/	10.9	/

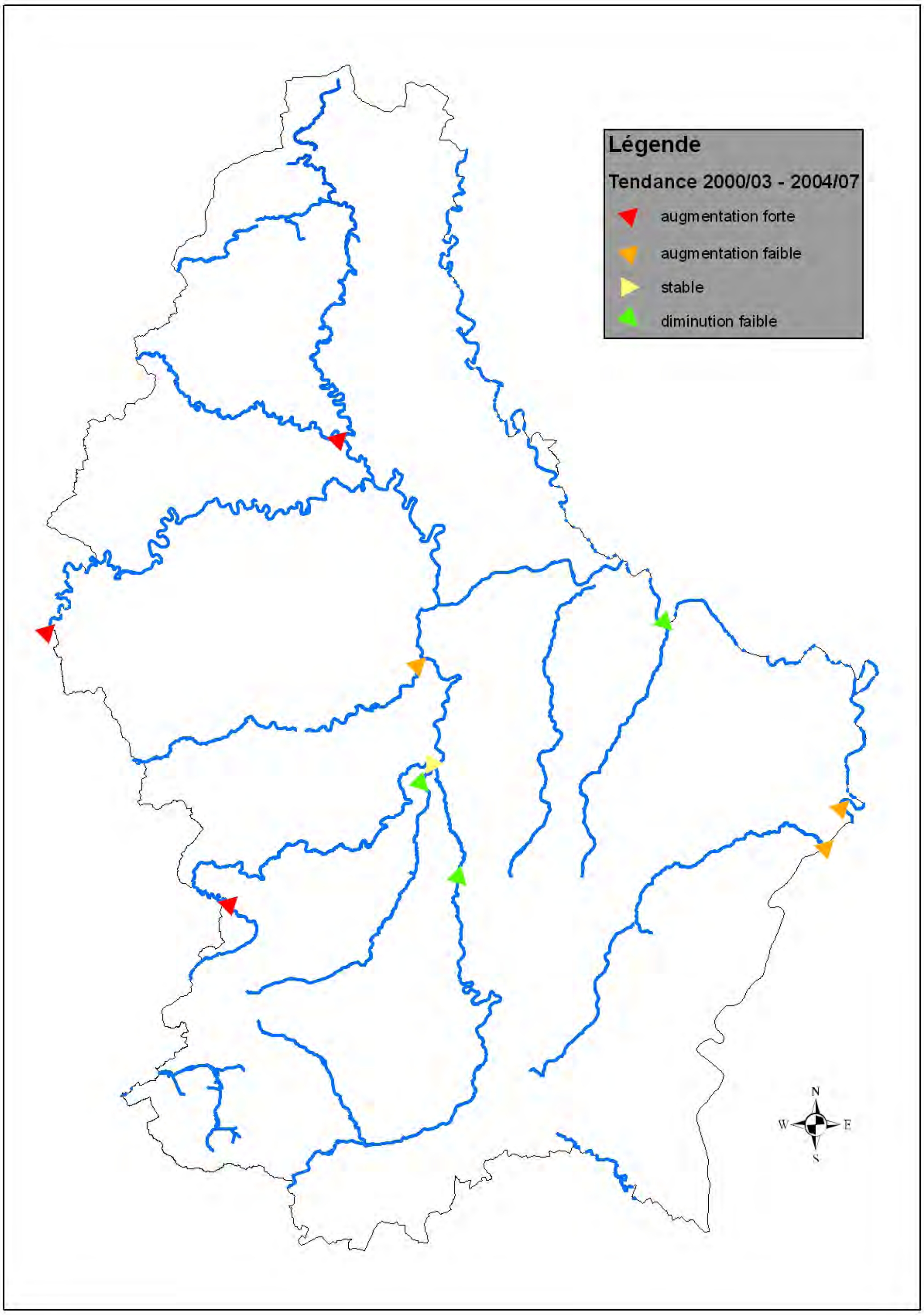


Figure 4 Trends in nitrate trend for the surface waters in Luxembourg between the 2000-2003 and 2004-2007 period.
Red = strong increase; orange = weak increase; yellow = stable; green = weak decrease.

Table 5 Nitrate and phosphorus concentrations as indicators for the level of the eutrophication potential of surface waters in Luxembourg for the 1996-1999, 2000-2003 and 2004-20007 period.

		Nitrate			Phosphorus		
National code	Name of the station	Average 1996/99	Average 2000/03	Average 2004/07	Average 1996/99	Average 2000/03	Average 2004/07
L104030A10	Mamer/Mersch	22	23	21.03	0.5	0.3	0.33
L100011A15	Alzette/Steinsel	14	18	16.52	1.0	0.5	0.56
L202030A12	Syr/Mertert	19	20	22.93	0.5	0.3	0.35
L105030A04	Eisch/Steinfort	12	13	19.32	0.5	0.2	0.26
L105030A12	Eisch/Mersch	19	20	20.20	0.3	0.2	0.22
L106030A12	Attert/Colmar-Berg	18	24	25.39	0.7	0.2	0.23
L144030A09	Ernze noire/Grundhof	24	22	26.78	0.5	0.2	0.32
L112010A24	Sûre/Wasserbillig	18	22	25.78	0.5	0.3	0.23
L112010A01	Sûre/Martelange	11	11	17.57	0.3	0.1	0.09
L110030A11	Wiltz/Kautenbach	22	23	30.54	0.4	0.3	0.22

Table 6 Evaluation of the eutrophication potential of surface waters in Luxembourg for the 2004-2007 period.

National Code	Name of the station	Nitrate	Phosphorus
L104030A10	Mamer/Mersch	low	moderate
L100011A15	Alzette/Steinsel	low	high
L202030A12	Syr/Mertert	low	moderate
L105030A04	Eisch/Steinfort	low	moderate
L105030A12	Eisch/Mersch	low	moderate
L106030A12	Attert/Colmar-Berg	moderate	moderate
L144030A09	Ernze noire/Grundhof	moderate	moderate
L112010A24	Sûre/Wasserbillig	moderate	moderate
L112010A01	Sûre/Martelange	low	low
L110030A11	Wiltz/Kautenbach	moderate	moderate

Groundwater

A clear trend concerning nitrate concentration measured on the different monitoring stations can not be seen (Table 7). The main reason is the small number of the monitoring stations.

Table 7 Nitrate concentration in groundwater in Luxembourg as in percentage of monitoring stations per nitrate pollution category and per aquifer.

	2000-2003				2004-2007			
Aquifer	Number of monitoring stations	< 25 mg l^{-1}	25-50 mg l^{-1}	> 50 mg l^{-1}	Number of monitoring stations	< 25 mg l^{-1}	25-50 mg l^{-1}	> 50 mg l^{-1}
Dévonien	3	33.3	66.7	0.0	3	33.3	66.7	0.0
Lias inférieur	8	12.5	37.5	50.0	8	12.5	50.0	37.5
Lias moyen	1*	100.0	0.0	0.0	1*	0.0	100.0	0.0
Lias supérieur	1	100.0	0.0	0.0	2	100.0	0.0	0.0
Trias	6	66.7	33.3	0.0	6	66.7	33.3	0.0

* different monitoring stations

1.5 Overview of monitoring networks

Surface Waters

Sixteen surface monitoring stations established on ten rivers are used to monitor the water quality of the surface waters (Table 8).

Table 8 Code and location of the 16 surface water monitoring stations in Luxembourg.

New number	Name of the station	Code	X coordinates †	Y coordinates †
1	Clerve - amont Clervaux	L110040A03	69,767	127,233
2	Wiltz - Kautenbach	L110030A11	69,139	113,038
3	Sûre - Martelange	L112010A01	49,012	99,758
4	Sûre - amont Esch/Sûre	L112010A04	63,143	108,606
5	Sûre - Wasserbillig	L112010A24	103,696	87,628
6	Alzette – Esch/Alzette frontière	L100011A01	65,580	61,405
7	Alzette – Hesperange	L100011A09	79,138	70,916
8	Alzette – Steinsel/Heisdorf	L100011A15	77,426	82,636
9	Alzette - Ettelbruck	L100011A21	76,011	101,526
10	Ernz noire- Grundhof	L144030A09	91,619	100,216
11	Attert- Colmar-Berg	L106030A12	74,540	97,473
12	Eisch - Steinfort	L105030A04	61,633	80,979
13	Eisch - Mersch	L105030A12	75,731	90,527
14	Mamer - Mersch	L104030A10	74,845	89,168
15	Syr – Mertert	L202030A12	102,624	84,899
16	Chiers – Rodange	L300030A06	56,792	69,261

† X and Y coordinates are according to GAUSS Luxembourg.

Groundwater

Table 9 contains the 21 groundwater monitoring stations (see also Figure 2).

Table 9 Location of the groundwater monitoring stations in Luxembourg.

No.	National Code	Name of station	Aquifer	X coordinate†	Y coordinate†
1	COC-118-11	Schiessentümpel coll. 2	Lias inférieur	89,589	94,791
2	FCC-116-06	Boursdorf	Trias	102,047	92,187
3	FCC-304-04	Weisen 3	Lias moyen	66,902	62,349
4	FCC-704-12	Terrain Football	Trias	79,660	103,213
5	FCP-911-01	Brasserie Simon	Dévonien	62,872	115,124
6	FCS-123-16	Doudboesch	Trias	91,729	78,209
7	FCS-601-39	Emeschbach	Dévonien	64,308	129,094
8	PCC-504-01	Debicht	Lias inférieur	80,898	90,555
9	SCC-111-09	Houschbur 1	Lias inférieur	87,386	100,895
10	SCC-125-01	Eschbour	Lias inférieur	85,107	86,062
11	SCC-132-05	Source Klingelbur	Lias inférieur	86,801	62,779
12	SCC-1-56	Pulvermuehle	Lias inférieur	78,588	74,582
13	SCC-203-01	Lavoir Dippach	Lias moyen	66,587	72,499
14	SCC-303-10	Leitschebierg	Lias supérieur	74,525	58,420
15	SCC-510-08	Aechelbur	Lias inférieur	81,279	96,333
16	SCC-601-01	Troine	Dévonien	58,091	125,386
17	SCC-805-02	Bei Schrodeschweiher	Trias	56,020	93,341
18	SCC-807-03	Maescheierchen 1	Trias	65,738	101,398
19	SCC-809-09	Kuelemeeschter	Trias	58,650	93,573
20	SCP-302-03	Soeur Grosch	Lias supérieur	59,680	66,572
21	SCS-210-52	Feyder 2s	Lias inférieur	67,449	83,610

† X and Y coordinates are according to GAUSS Luxembourg.

2 Effect monitoring

2.1 Strategy for effect monitoring

The selection of sampling points is a compromise made after some discussions with the European Commission. The selected points for the groundwater monitoring contain both wells and boreholes. Normally the groundwater monitoring stations are controlled at least four times a year.

The sampling frequency of the surface water monitoring stations is 10 to 12 times a year.

2.2 Detailed technical description networks used for effect monitoring

Except the two networks for groundwater and surface water monitoring stations mentioned before, there is no special network used for effect monitoring and the techniques used to monitor effects of Nitrates Directives Action Programmes on water quality. The Ministry for Agriculture and the Ministry of Internal Affairs share the responsibility. The main agricultural information comes from the collection of data delivered by the farmers through the annual declaration. All the data are stored in several databases. The water quality information is collected by the Water Agency. Some data, especially for the monitoring sites, come from samples taken by the Water Agency. Other water quality information comes from the local or regional water suppliers. The data is stored in a database.

2.3 Data interpretation

The current system of networks for groundwater and surface water alone does not allow for data interpretation. Other data sources are also often used to get a clearer vision of the actual situation.

3 Discussion

Luxembourg is only at the beginning of setting up 'effect monitoring networks'. The location of sampling points, as mentioned before, is a compromise between Luxembourg and the European Commission. The last two reporting periods have shown some insufficiency in the choice of the sampling points. Few data or no data are making an interpretation very difficult respectively impossible. Also the number of sampling points for some aquifers is not representative. An expansion of the sampling points or at least an analysis of additional data is recommended.

A regular involvement of stakeholders has been considered a positive contribution in the past and will be expanded. The fact that different ministers are responsible for the implementation of different legal requirements, implies that sufficient time is needed for consultation between the different institutions.

The Water Framework Directive will have its consequences not only for the monitoring networks but also for the definition of the environmental goals. The discussions only started and until now the outcome is unclear.

4 References

EC (1991) Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Communities, L375, 31/12/1991, 1-8.

Ministère de l'Intérieur (2008) Rapport conformément à l'article 10 de la directive 91/676/CEE concernant la protection des eaux contre la pollution par les nitrates d'origine agricole (Report in accordance with Article 10 of the Directive 91/676/EEC regarding the protection of waters against pollution by nitrates from agricultural origin). Administration de la Gestion de l'Eau, Ministère de l'Intérieur, Luxembourg.

Service Central de Législation (2000) règlement grand-ducal modifié du 24 novembre 2000 concernant l'utilisation de fertilisants azotés dans l'agriculture qui a transposé la directive CEE 91/676 du Conseil du 12 décembre 1991 concernant la protection des eaux contre la pollution par les nitrates à partir de sources agricole (Directive Nitrates). Mémorial, A – N° 124, 11/12/2000, 1-6.

Service Central de Législation (2005) règlement grand-ducal du 25 avril 2005 modifiant le règlement grand-ducal du 24 novembre 2000 concernant l'utilisation de fertilisants azotés dans l'agriculture'. Mémorial, A – N° 66, 13/05/2005, 990-993.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Netherlands

B. Fraters[1], M.H. Zwart[1], L.J.M. Boumans[1], J.W. Reijs[2] and M. Kotte[3]

[1] *National Institute for Public Health and the Environment, P.O. Box 1, NL-3720 BA Bilthoven, the Netherlands*
e-mail: dico.fraters@rivm.nl; manon.zwart@rimv.nl; leo.boumans@rivm.nl

[2] *Agricultural Economics Research Institute, P.O. Box 29703, NL-2502 LS The Hague, the Netherlands*
e-mail: joan.reijs@wur.nl

[3] *Rijkswaterstaat Centre for Water Management, P.O. Box 17, NL-8200 AA Lelystad, the Netherlands*
e-mail: marcel.kotte@rws.nl

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the Netherlands and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). Although the Netherlands applies their Nitrates Directive Action Programmes to the entire territory, legislation distinguishes between soil types and the measures are based on soil vulnerability to nitrate leaching. The effect monitoring programmes therefore focus on the level of the main soil type regions in the Netherlands, which means, sand, loess, clay and peat regions. The monitoring of the effects of the Action Programmes consists of the regular monitoring programmes for agricultural, groundwater, and surface water, and of a specialised monitoring programme, the Minerals Policy Monitoring Programme (LMM). The LMM monitors farm management (agricultural practices) and water quality, and it registers interfering factors, such as weather and soil characteristics. The EU commission decision of December 2005 granting a derogation requested by the Netherlands obliged an extension of LMM in 2006 in order to monitor 300 farms that benefit from derogation.

1 Introduction

1.1 Environmental goals and measures

Goals

The environmental goals for nitrogen and phosphorus in the Netherlands are based on the interpretation of the Nitrates Directive by the Dutch government. This interpretation developed in the process of the implementation of the Nitrates Directive as a result of discussions with stakeholders, policymakers, members of parliament, scientists and the European Commission.

For nitrogen, the Netherlands has set targets for nitrate and total nitrogen concentrations in water leaching from the root zone to groundwater and/or to surface waters for deriving nitrogen fertilisation standards. Nitrate concentrations in water leaching from the root zone of agricultural land on sandy soils and loess soils should not exceed the standard of 50 mg of nitrate per litre (11.3 mg of nitrate-N per litre). For these soils nitrogen occurs for over 80% in the form of nitrate (Figure 1). For agricultural land on clay and peat soils the total nitrogen concentration should not exceed the standard of 11.3 mg of nitrogen per litre in water leaching from the root zone or in ditch waters.

For phosphorus, the Netherlands set as goal to reach an equilibrium fertilisation state in 2015. This means that the level of the phosphate application standards equals, on average, the crop uptake, including an inevitable loss of 5 kg of phosphate (P_2O_5) per ha.

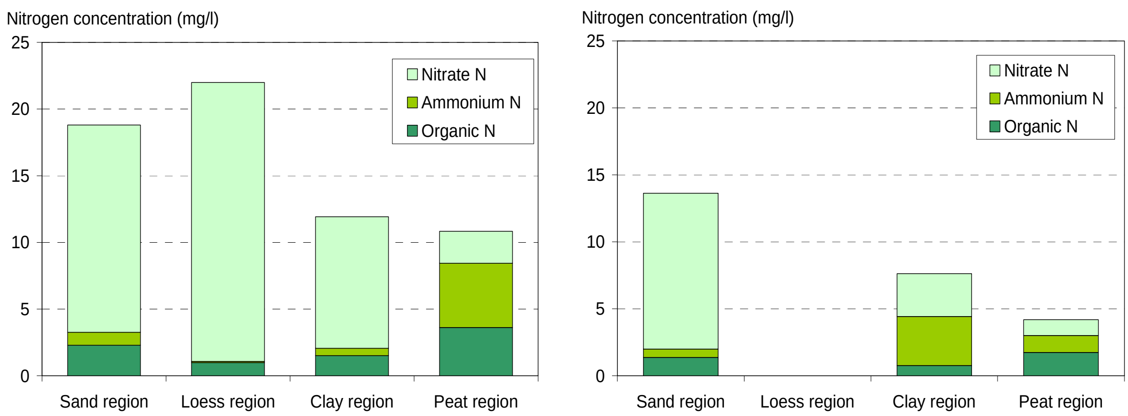


Figure 1 Nitrogen concentration (mg l^{-1}) in water leaching from the root zone (left) and ditch waters (right) on farms in the sand, loess (no ditches), clay and peat regions of the Netherlands.
Average for farms sampled in the 2004-2006 period (data LMM).

Measures

The Netherlands has taken the approach in line with Article 3.5 of the Nitrates Directive (EC, 1991). This means the application of an Action Programme throughout the country and thus no individual nitrate vulnerable zones (NVZs) are delineated (Werkgroep Aanwijzing EG-NO_3, 1994). Nevertheless legislation distinguishes between soil types and soil fertility. For example, measures for nitrogen are, amongst others, based on soil vulnerability to nitrate leaching and for phosphorus measures proposed in the fourth Action Programme are, amongst others, based on the soil phosphorus fertility level.

Under the 1986 Manure Act, each farm was required to calculate an annual reference level of manure production in phosphate terms and the application limits for animal manure were lowered step-wise in the 1987-1998 period (OECD, 2007). During the first and second Nitrates Directive Action Programme, covering the periods 1996-1999 and 2000-2003 respectively, a new system was introduced and developed in the 1998-2003 period. A system of manure bookkeeping was replaced in 1998 by the system of minerals accounting at farm level, based on the mineral balance of nitrogen (N) and phosphorus (P) (farm gate balance). In this system, limits are set on the level of the N and P surplus on farms (MINAS loss standards). The loss standards have gradually been tightened. On 1 January 2002, the Manure Transfer Contracts (MAO) system became effective in order to comply with the application standards for manure stipulated by the Nitrates Directive. Livestock farmers who produced too much manure were obliged to enter into manure transfer contracts with arable farmers, other less intensive livestock farmers or manure processors (Zwart et al., 2008). The European Commission criticised the lack of application limits for N from animal manure and the lack of specific prescriptions and regulations for the use of animal manure and fertilisers in the Action Programme. The European Commission considered the responses of the Dutch government to be insufficient. By the end of 1999, the Commission brought the Dutch government to the European Court of Justice, which subsequently condemned the first Action Programme of the Netherlands in an arrest of 2 October 2003. During the third Action Programme (2004-2009), the Netherlands adopted a manure policy based on application standards instead of mineral loss standards in January 2006 (see Textbox 1). The MAO system was abolished in early 2005. The new manure policy, including application limits for nitrogen in manure and fertilisers as required by the Nitrates Directive, sets tighter limits on the use of nitrogen and phosphorus compared with the previous MINAS. This third Action Programme has a longer time span than four years due to extended measures following the derogation granted to the Netherlands (Zwart et al., 2008).

Textbox 1 Application standards

From 2006 onwards manure application standards are introduced in the Netherlands. Three different standards are distinguished:

- An application standard for nitrogen in animal manure. This is 170 kg per ha, according to the Nitrates Directive, except for farms with a derogation, that, under certain conditions, may apply up to 250 kg N from manure from grazing livestock.
- Application standards for the total amount of available nitrogen per ha. These application standards are differentiated for different combinations of crops and soils (sand, clay, peat, loss). These standards are primarily based on agricultural fertilization standards, but are adjusted downwards when this is necessary to achieve the goal of 50 mg nitrate in the root zone. These adjustments are based on the maximal N surplus on the soil surface balance that is allowable to achieve this goal (for example, Schröder et al., 2004). The nitrogen application standards are gradually tightened during the period 2006-2009 and afterwards. The proposed nitrogen application standards in 2010/2011 vary between 30 kg N for peas on all soil types and 350 kg for grassland on clay soils.
- An application standard for the total amount of phosphate. In 2006 a standard of 110 kg P_2O_5 per ha on grassland and 95 kg P_2O_5 per ha on arable land were introduced. These standards were gradually decreased to 100 and 85 kg P_2O_5 per ha respectively in 2009. From 2010 onwards the phosphate application standards will also be related to the soil phosphorus fertility level. The proposed phosphate application standards in 2015 vary between 80 kg P_2O_5 per ha (high soil fertility status) and 100 kg P_2O_5 per ha (low soil fertility status) on grassland and between 50 kg P_2O_5 (high soil fertility status) per ha and 75 kg P_2O_5 per ha (low soil fertility status) on arable land.

The application standard for animal manure is 170 kg per ha according to the Nitrates Directive. In December 2005, the Commission granted the Netherlands a derogation. During the period 2006-2009, grassland farms with 70% or more grassland may apply 250 kg N per hectare to their land as manure when it originates from grazing livestock (cattle, sheep and goat), under certain conditions. Grassland is the main type of agricultural land use in the Netherlands (Figure 2). About 25,000 farms, 31% of the total number of farms, benefited from derogation in 2006 and 2007. They cultivate about 900,000 ha, about 50% of the total cultivated area in the Netherlands.

Additional measures in the third and fourth Netherlands Action Programme are related to closed period, storage capacity for manure and buffer strips, a summary is given in Textbox 2.

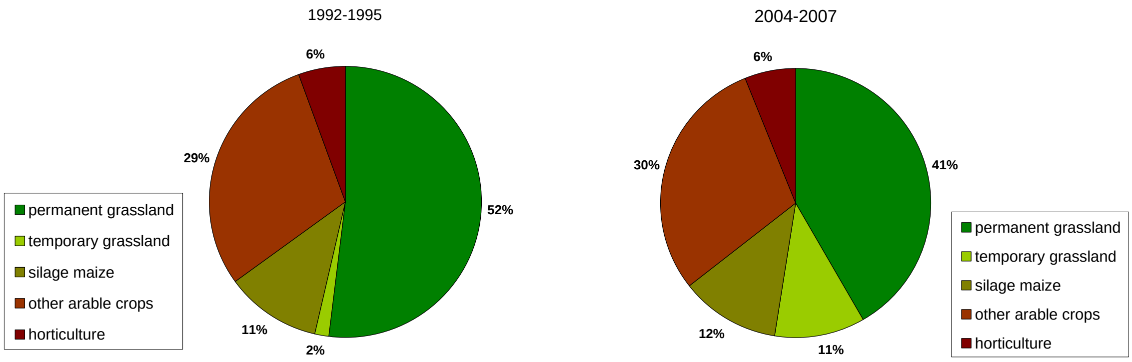


Figure 2 Agricultural land use in the Netherlands in the 1992-1995 and the 2004-2007 period.
Temporary grassland is grassland used by a farmer for less than five years.

Textbox 2

Summary of main additional measures in the third and fourth Action Programme

- From 2006 onwards the storage capacity of manure has to be equal to six months of manure production (minus net manure removal). From 2012 onwards this will be increased to seven months.
- There are no restrictions to the grazing period in the Netherlands.
- The closed period for fertilizer application is from 16 September to 31 January. In this period it is not allowed, with a few exceptions, to add any fertilizer to the soil. For slurry manure application the closed period is extended. On sandy and loess soils slurry manure application is currently (2009) not allowed from 1st September onwards. In 2012 the closed period for slurry manure will start on 1 August for both arable land and grassland on all soil types. For inorganic fertilizer the closed period will remain from 16 September to 31 January.
- The area of unfertilized buffer strips is currently restricted to 2,000 ha in High Netherlands. Whether the area of unfertilized buffer strips will be increased, will depend on a large research programme in the Dutch situation that will be finished in 2010 (Noij et al., 2008).

1.2 Overview of trends in nitrogen and phosphorus loads and surpluses

The nitrogen surplus in Dutch agriculture shows an almost continuous decrease in the 1986-1990 period (Figure 3). This trend stagnates in subsequent years

(1991-1998) and the year to year fluctuations can be mainly attributed to weather-based fluctuations in crop production. The nitrogen surplus decreases substantially after 1998. This can be largely attributed to the new regulatory system based on the farm gate balance (MINAS) introduced in 1998, especially for dairy farms which reduced the use of nitrogen fertiliser by 40-50% (Zwart et al., 2008). The phosphorus surplus shows an almost continuous decrease over the entire 1986-2002 period. This decrease is mainly a result of the decrease in manure produced by reduced livestock numbers and more efficient feeding practices. From 2002 onwards, the decrease in the nitrogen and phosphorus surpluses has stagnated. The fluctuations are probably related to weather fluctuations, resulting in higher crop production in 2002 and 2004 (Zwart et al., 2008).

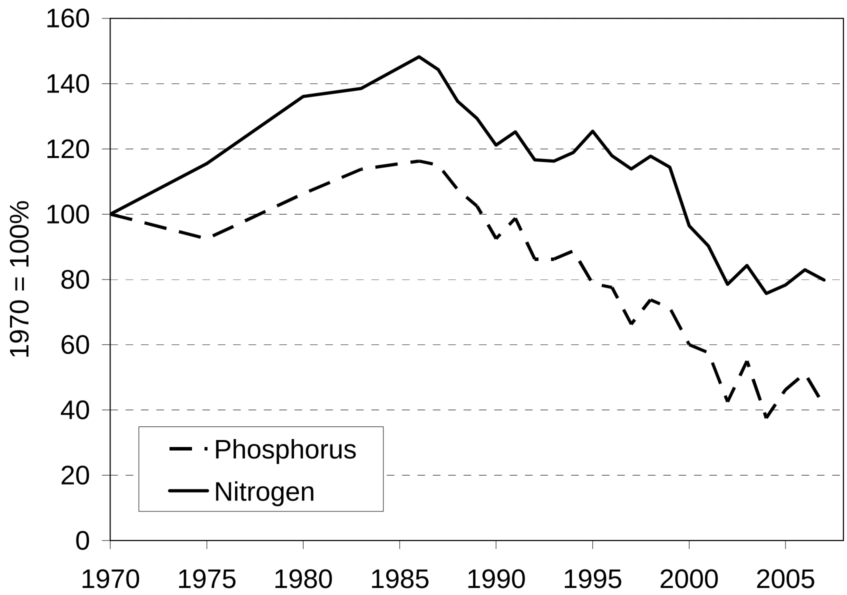


Figure 3 Trend of the nitrogen and phosphorus surplus in Dutch agriculture in the 1970-2006 period, with the 1970 value fixed at 100. Source: CBS, 2008a.

The nitrogen surplus on the soil surface balance decreased from 510 million kg in the 1992-1995 period to 323 million kg in the 2004-2006 period (Table 1), while the phosphorus surplus on the soil surface balance decreased from 68 to 36 million kg of P between these periods.

Table 1 Nitrogen soil surface balance for total cultivated area (million kg N per year). Source: CBS (2008b).

	1992-1995	1996-1999	2000-2003	2004-2007#
Input† as:				
Manure	495	448	367	334
Fertilisers	382	384	296	276
Atmospheric deposition	75	78	62	57
Other‡	39	39	39	40
Total input	991	948	763	705
Total output (harvested crops)	481	450	399	382
Surplus	510	498	364	325

† Ammonia emission from manure and fertiliser is excluded.
‡ Includes: crop residues, seeds and plant materials and other organic fertilisers (compost).
# Preliminary figures over 2007.

The largest input term (manure) shows a decrease of almost 33% between the first and last periods, whereas the fertiliser input is almost 28% lower. The nitrogen output consists entirely of the crops harvested from the fields. The harvest differs from year to year due to variable weather conditions. The nitrogen in harvested crops decreased by 21% between the first and last periods. It is plausible that this decrease is due to a decrease in nitrogen uptake. There is no indication that crop production has decreased as a result of lower nitrogen fertilisation (Zwart et al., 2008).

Nitrogen surpluses on the soil surface balance differ between soil type regions and farm types (Table 2). N surpluses are highest on dairy farms with mainly grassland (> 70%) in the sand region.

Table 2 Nitrogen surplus on the soil surface balance (kg ha^{-1})†.

	Sand region	Loess region	Clay region	Peat region
Arable farms	118	n.a.	133	n.a.
Dairy farms	174	90	157	132

† Average value for 2004-2006 period (Zwart et al., 2008).

1.3 Overview of trends in nitrate, nitrogen and phosphorus concentrations

Nitrate concentrations in water leaching from the root zone are highest for farms in the sand and loess regions of the Netherlands and lowest in the peat region (Figure 4). Large variation in average concentration is observed between years due to fluctuation in precipitation excess (Boumans et al., 2001).

Computed standardised nitrate concentrations decrease for agriculture in the sand, loess and clay regions (Figure 5). They reflect the decrease in nitrogen surplus in Dutch agriculture between 1994 and 2002. Nitrate concentrations in the peat region are low due to the strong denitrification capacity of the soils and high groundwater levels. The lag of trend in LMM data in the loess region is probably due to the short monitoring period.

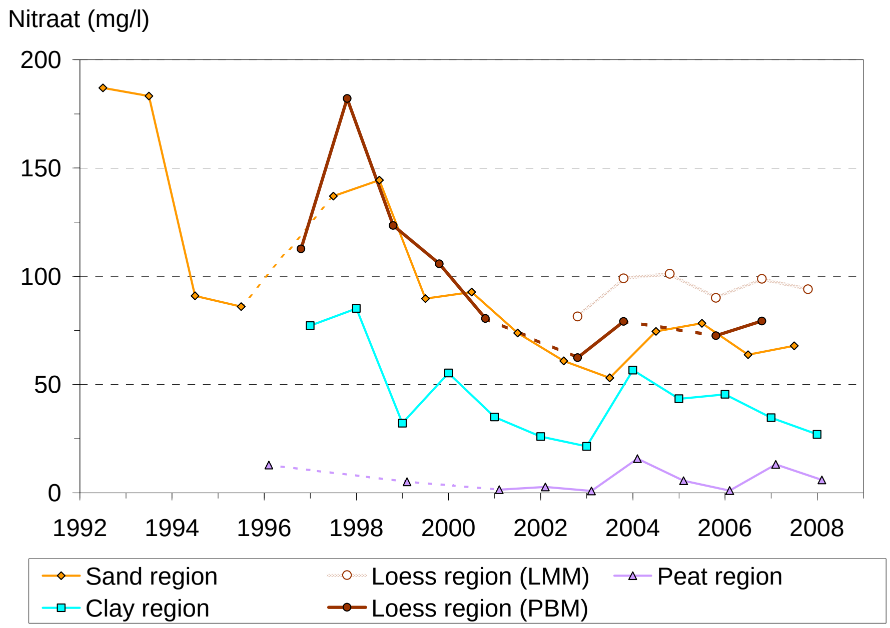


Figure 4 Nitrate concentrations in water leaching from the root zone of farms.
Annual average of measured concentrations in the upper metre of groundwater within 5 m of the soil surface (peat, sand), soil moisture at 1.5-3 m below soil surface (loess) or tile drain water and groundwater (clay) of farms for the period 1992-2007. For summer 2007 and winter 2007-2008 provisional data are provided. Sources: LMM and Soil Moisture Monitoring Network of Province of Limburg (PBM).

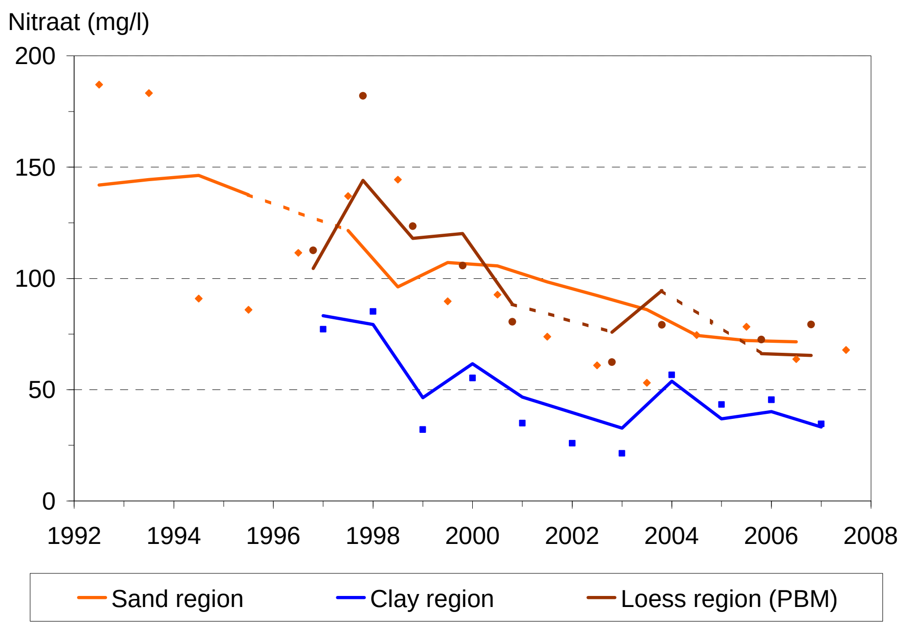


Figure 5 Computed standardised (line) and measured (points) nitrate concentrations in water leaching from the root zone of farms.
See also text Figure 4. Sources: LMM and Soil Moisture Monitoring Network of Province of Limburg (PBM)

Nitrate concentrations in groundwater at agricultural sites at depth of 5-15 m below the surface level are on average around 35 mg l^{-1} in the sand region and less than 10 mg l^{-1} in the clay and peat region. At 15-30 m depth the concentration in the sand region is around 10 mg l^{-1}. Groundwater in the loess region generally occurs at depth of more than 30 m, but nitrate concentrations in water from springs at the edge of the loess plateaus often exceeds 50 mg l^{-1} (Hendrix and Meinardi, 2004) .

The vast majority of freshwater locations (97%) have a winter average nitrate concentration below the EU target value of 50 mg l^{-1}. Winter average concentrations relate best to agricultural influences. Nitrate concentrations decreased between 1997 and 2002 and stabilised thereafter (Figure 6). There is no significant difference between agricultural waters and main locations since 1998 (Zwart et al., 2008).

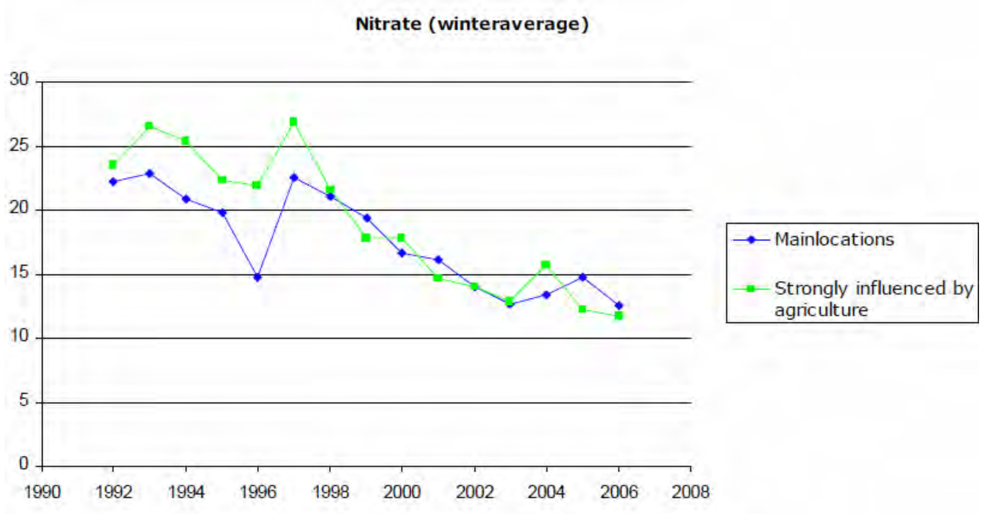


Figure 6 Winter average nitrate concentrations (mg/l) in main fresh surface waters (river, lakes) and regional surface waters strongly influenced by agriculture.

Summer average concentrations in freshwaters relate best to the possible impact on biological water quality. Total nitrogen summer averages decreased between 1991 and 2002 and stabilised thereafter (Figure 7, left). The largest reduction is realised in surface water strongly influenced by agriculture. The nitrogen concentration in agricultural influenced water is in the summer significantly higher than in the main fresh water locations. The Dutch target value of 2.2 mg l^{-1} for total nitrogen is however still exceeded at more than 75% of all locations. Total phosphorus concentrations decreased in main fresh water between 1993 and 2004, but no change was observed for the strongly influenced agricultural freshwater (Figure 7, right) (Zwart et al., 2008). Although phosphorus surpluses decreased, the amount of readily available soil phosphorus for leaching is still large (Schoumans et al., 2008). This might be part of the explanation of the lack of change in total phosphorus in regional surface waters strongly influenced by agriculture.

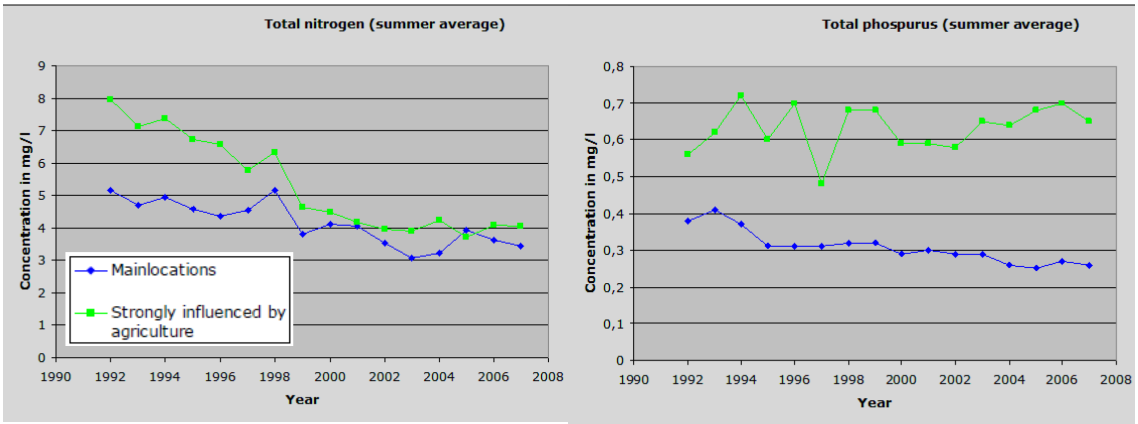


Figure 7 Summer average total nitrogen (left) and phosphorus (right) concentrations in main fresh surface waters (river, lakes) and regional surface waters strongly influenced by agriculture.

1.4 Overview of monitoring networks

Agriculture

Statistics Netherlands collects general information on such topics as acreage and number of farm animals for all farms larger than three ‘Dutch Size Units’ (DSU). The annual data collection is called the ‘Agricultural Census’. The Dutch Agricultural Economics Research Institute (LEI) collects more specific information on farm economics and technical management through the Farm Accountancy Data Network (FADN) (Vrolijk et al. 2009; Lodder and De Veer, 1985). This farm management information includes environmental relevant data such as mineral balances (inputs and outputs of minerals), the use of pesticides, water and energy consumption, fertiliser, import and export of minerals and grazing frequency. The FADN represents 1,500 farms, selected from the Agricultural Census through stratified random sampling and forms a representative sample of Dutch agriculture. The FADN represents about 90% of the total agricultural production in the Netherlands (Vrolijk et al., 2009). The FADN network is a participant in the EU networks (EU Council Regulation 79/65/EEG).

Effect monitoring

Monitoring of the effects of the Action Programme consists of the regular agricultural, groundwater, and surface water monitoring programmes, described below, and a specialised monitoring programme, the LMM. The LMM was developed to assess the contribution of nitrate from agriculture to receiving waters and the effects of changing agricultural practice on these losses. It would thus monitor the effect of policy measures on water quality. The LMM monitors both water quality and farm management, which means, agricultural practices. Policy measures aim to change farm management in such a way that water quality will improve. The water quality of groundwater and surface waters is generally not only influenced by farm practice, but also by other sources of pollution and environmental factors such as weather. To exclude other sources of pollution as far as possible, water quality of on-farm waters (such as the upper metre of groundwater within five metres of the soil surface or soil moisture between 1.5 and 3.0 m depth if groundwater is at greater depth, tile drain water or ditch water) is monitored. This type of water also reflects the effect of recent management (less than four years ago). To be able to distinguish between the effects of measures on water quality and the effects of confounding factors, such as weather, these confounding factors are monitored as well (see Boumans et al., 2001).

Groundwater quality

The National Groundwater Quality Monitoring Network (LMG), established between 1979 and 1984 by RIVM, comprises about 360 locations spread over the whole of the Netherlands (Van Duijvenbooden, 1987). The main criteria for site selection were type of soil, land use and hydrogeological state. Permanent wells are placed for the purpose of monitoring outside the fields. At each location groundwater is sampled at depths of 5-15 m and 15-30 m below surface level. Shallow well screens in sandy regions are still sampled every year; while shallow well screens in other regions (clay and peat) are sampled every two years. Deep well screens are sampled every four years; shallow well screens with high chloride concentrations (more than 1,000 mg/l due to marine influence) are also measured every four years. Most of the 12 provinces of the Netherlands have groundwater quality networks comparable to the national network LMG. Differences with respect to sampling depth and especially site selection occur due to provincial specific goals. The data are not used for Nitrates Directive reporting. For the Water Framework Directive a selection of wells from both the national and the provincial networks will be used.

Drinking water quality

Water production companies carry out monitoring programmes focusing on quality control of the water resource (both groundwater and surface waters), the production process and the end product. Companies report results annually to the national Inspectorate for the Environment, which is a statutory obligation. Data management and reporting are carried out by RIVM. This report uses data on the quality of water resources and not the quality of the end product (tap water).

Surface water quality

The Centre for Water Management of the Ministry of Infrastructure and the Environment (IenM) collects data from 39 stations in marine waters (including the Zeeland estuary) and at around 30 stations in large (national) fresh surface waters, such as larger rivers, canals and lakes. The frequency of sampling in marine waters is once a month in winter and once every two weeks in summer. The sampling depth for marine waters is about 1.5 m below water level, and 3.5 m below water level for North Sea locations. The sampling frequency at most large freshwater stations is once every four weeks; for stations bordering with Germany and Belgium it is once every two weeks. The sampling depth is about 0.5-1.0 m below water level. The 26 regional Water Boards and some of the regional departments of the Ministry of IenM all have their own Regional Water Status Networks. These networks together comprise several thousands of freshwater monitoring locations in regional waters. The frequency of sampling varies but is usually once every four weeks. Depth of sampling depends on local conditions but is normally about 0.5-1.0 m below water level.

For more detail we refer to Zwart et al. (2008).

2 Effect monitoring

2.1 Strategy for effect monitoring

Effects of the Dutch minerals policy are monitored with a special purpose monitoring network, the LMM, in addition to the regular agricultural, groundwater and surface water monitoring programmes. To underpin claims that policy measures change agricultural practices and thereby ameliorate water quality, within LMM programmes farm practices are registered, on-farm water quality is measured and data are collected on environmental factors, like precipitation, evapotranspiration, soil type and soil drainage. Measurements and data collection are on farm level. The sampling unit is a farm, but statements on status and trend are passed on the scale of soil type regions and/or farm types. Data are used to develop statistical models. These models are used together with available data on a national scale to assess status and trend in on-farm water quality in the Netherlands.

The LMM was developed to assess the contribution of nitrate from agriculture to receiving waters and the effects of changing agricultural practices on these losses. The regular agricultural, groundwater, and surface water monitoring programmes – described in the previous chapter – are used to monitor the effects of the Action Programme as well. Especially the agricultural influenced monitoring points in Regional Water Status Networks provide valuable additional information about eutrophication status of fresh waters.

LMM consist of several programmes: a programme for trend detection, a surveillance monitoring programme, and an investigative programme. In 2006 LMM is expanded with a derogation monitoring network. Although the different programmes have their own goals, some farms may and do participate in one or more of the programmes.

The LMM programme for trend detection is on a stratified random sample of farms. Main stratification is by soil type region (sand, loess, clay, peat), farm type (arable farming, dairy farming, factory farming and crop-livestock combination farming), and farm area size (three classes). The sample is limited to farm types that are representative for the major part of agricultural land use in the region and each farm type forms a rather homogeneous group. Dutch agriculture has a high level of dynamics. Farmers sell and buy land and they start new promising activities and stop less profitable ones. These changes may lead to a shift of farms between farm types. The number of farms in the Netherlands is decreasing still, and therefore some of the LMM participants stop farming. These changes result in a need to replace participants that quit LMM or who do no longer fall into the sample definition. By excluding heterogeneous farm types, like horticulture, that are representative for the minor part of agricultural land use, we lower the cost for monitoring. We decrease the variation in farm practices and water quality within the sample and, in this way, increase the ability to observe a change in farm practice and water quality. For similar reasons farms less than 16 Dutch Size Units (DSU) and greater than 800 DSU are excluded from LMM, and a minimum of 10 hectares of land is used as criterion for participation.

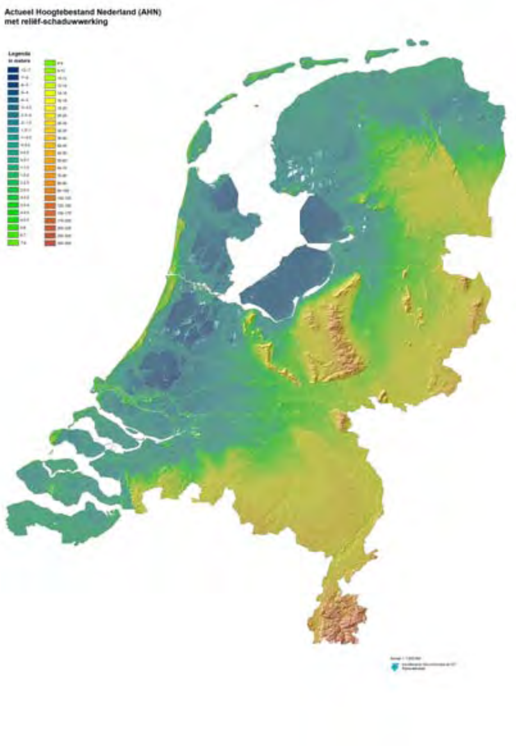
A surveillance monitoring programme exists in order to get some idea of farm practices and water quality on farm types excluded from the LMM sample for trend detection or to intensify monitoring within existing groups to answer specific questions. For example, a group of outdoor vegetable growing farms in the sand region is monitored in the 2007-2009 period. This type of farming is considered to give high risks for nitrate leaching. Other farm types or groups of farms that are excluded from the LMM sample for trend detection will be selected for this programme in the future.

The investigative LMM programme concentrates on the impact of intended policy measures. This programme joins in two projects of institutes of Wageningen University and Research. One project regards dairy farms, Cows and Opportunities (www.koeienenkansen.nl, Oenema et al., 2001), the other regards arable farms, Farming with a Future (www.telenmettoekomst.nl). In these projects farmers, together with extension officers and researchers, work towards sustainable production systems. They consist of research into farms, which obviously use, amongst others, fewer than average nutrients in the agricultural sector.

The derogation monitoring network of 300 farms is set up to fulfil the requirements of the EU Netherlands derogation decision and to show the effects of the requested derogation on farm management and water quality.

In all programmes of the LMM on-farm waters are monitored to exclude other sources of pollution of water as far as possible. Water quality of groundwater and surface waters is generally not only influenced by farm practice, but also by other sources of pollution and environmental factors such as the weather. Therefore water leaching from the root zone is measured, such as the upper metre of groundwater, soil moisture within five metres of the soil surface, or tile drain water. In addition ditch water, if present, is sampled. These types of waters also reflect the effect of recent management (less than four years ago). To be able to distinguish between the effects of measures on water quality and the effects of confounding factors, such as the weather, these confounding factors are monitored, as well.

For water sampling a distinction is made between the Low and the High Netherlands, see Figure 8a, left. The Low Netherlands covers the clay and peat regions, and those soils in the sand region that are drained via ditches, whether or not in combination with drainage pipes or channels. The High Netherlands covers the other sand and loess soils. Water leaching from the root zone in the High Netherlands is sampled once a year. In the Low Netherlands the sampling frequency varies between two to four times per winter period for water leaching from the root zone. Ditch water is sampled four times per winter period. The precipitation surplus in the High Netherlands infiltrates to deeper groundwater layers and flow of the surplus to surface waters via these deep layers takes many years. In the Low Netherlands groundwater flow to surface waters is very shallow. The precipitation surplus is mainly transported via surface or subsurface flow to surface waters in the winter period. Infiltration of the surplus to deeper groundwater layers is negligible. The difference in hydrology between the Low and High Netherlands is the reason for different sampling methods and frequencies used in these parts of the Netherlands.



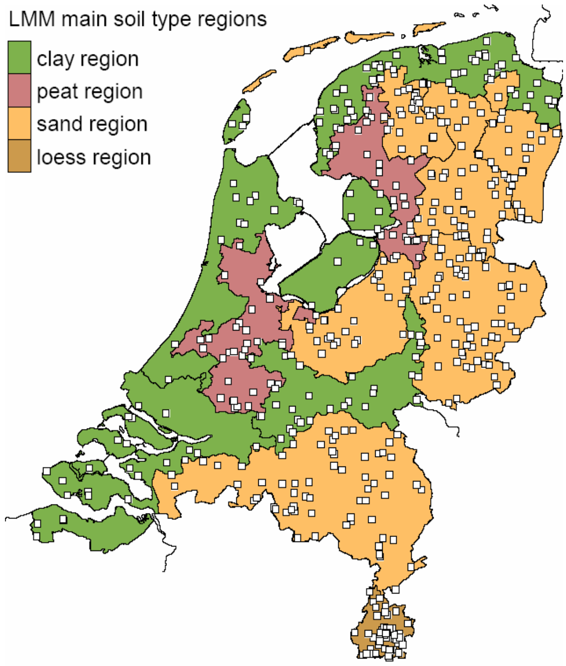


Figure 8a Geographic relief map of the Netherlands.
Blue colours are areas below sea level.

Figure 8b LMM soil type regions and participating farms in the 2006-2009 period.

2.2 Detailed technical description of networks used for effect monitoring

The LMM has been jointly developed and managed by the National Institute for Public Health and the Environment (RIVM) and the Agricultural Economics Research Institute (LEI). In addition, some programmes are or have been managed in collaboration with other organisations. LEI is responsible for the registration of farm practices. The LMM is linked to the Farm Accountancy Data Network of LEI (FADN). Registration of farm practices is done within the framework of FADN. All activities are handled by LEI employees. RIVM is responsible for water quality monitoring and collection of the additional data. Water sampling is carried out partly by private companies under the responsibility of RIVM and partly by hired personnel, trained and supervised by RIVM staff, using RIVM equipment.

The recruitment of LMM farms is targeted at farms in the FADN. In 2006 the additional recruitment for derogation farms was initially targeted at FADN farms as well. For this, all suitable FADN farms were approached that had applied for derogation in 2006. Once the recruitment under FADN farms had been completed, it was determined which strata needed additional farms. Additional farms were selected from a database, compiled by the National Service for the Implementation of Regulations of the Ministry of Economic Affairs, Agriculture and Innovation, which contains all farms that had applied for derogation in 2006.

LMM developed from a regional network to a national network in the 1992-2002 period. The number of LMM farms increased significantly since the start in 1992 and in particular in 2006 with the set-up of a derogation monitoring network (Figure 9). Figure 8b shows the location of the farms participating in the 2006-2009 period.

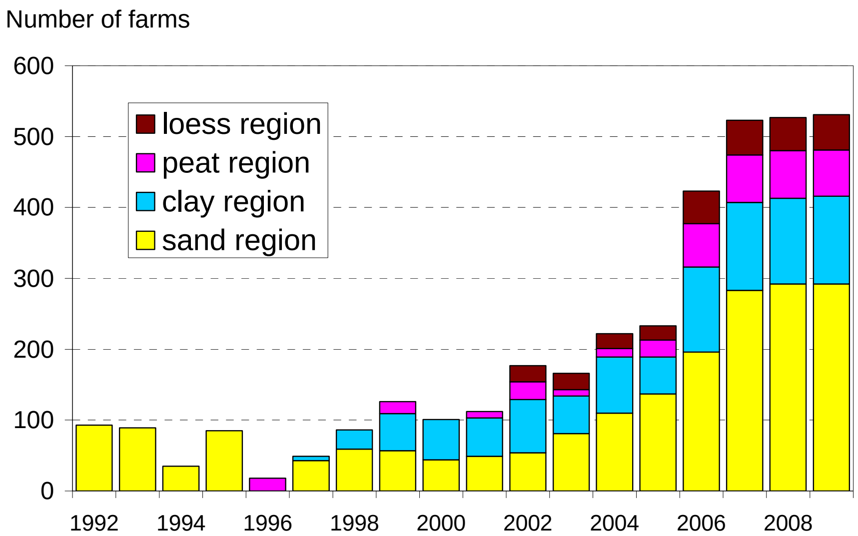


Figure 9 Number of LMM farms with a water quality sampling per soil type region per year in the 1992-2009 period.

Before the year 2000, farms in the FADN, and thus in LMM, were actively replaced after five to seven years. In the early 2000s the FADN switched to a policy of minimal rotation (Vrolijk and Cotteleer, 2005). Active replacement of LMM farms was stopped in 2006 as a consequence of the change of replacement approach in the FADN, and the obligation arisen from the EU Netherlands derogation decision to monitor a non-changing group of derogation farms during four years.

For LMM farms, like all FADN farms, a detailed set of financial-economic and environmental data are maintained. LEI collects and records the operational data in the FADN database. All the invoices of the participating farms are processed. Initial and end supplies of mineral stocks are taken, as well as, additional data such as the crop rotation, grazing system and the composition of the livestock population. Participants receive a report from LEI, largely containing annual totals (such as profit and loss accounts and a balance). The set of operational data that LEI records from participants in the monitoring network has been considerably extended in 2006 as a consequence of the derogation. Most of the data in the FADN are converted into annual totals corrected for stock adjustments. The feed concentrate use per year, therefore, emerges from the sum of all purchases between two balance dates, minus all sales, plus the starting stock, minus the end stock. The use of fertilisers is known not just on an annual basis but also on a growing season basis running from the moment that the prior crop was harvested until the harvest of the current crop.

Water leaching from the root zone is sampled in different ways depending on hydrological conditions. Groundwater levels in agricultural soils usually occur within 1 to 1.5 m of the soil surface. In the High Netherlands leachate is collected by sampling the upper metre of groundwater (Figure 10). In case groundwater levels occur at a depth deeper than five metre below surface level, like in the largest part of the loess region, soil moisture is sampled from the layer between 1.5 and 3.0 m below the surface level (Figure 11). In the Low Netherlands soils are often artificially drained by tile drains and/or ditches (Figure 12). If farms are drained by tile drains, these drains are sampled. Otherwise the upper metre of groundwater is sampled. In both cases ditch water is sampled as well. In the peat region ditch water is considered as water leaching from the farms, since fields are often drained by gullies.

Figure 10 Sampling the upper metre of groundwater (left) and field analysis (down right) on a farm in the sand region.

In general 16 sample locations for groundwater, soil moisture and/or tile drain water are selected per farm and 8 sample locations for ditch water using a protocol to have a randomised selection. Actual sampling locations are administrated using GPS. Individual groundwater and ditch water samples taken during the same farm sampling visit are analysed in the field for nitrate (Nitrachek, colour method), pH, electric conductivity, and oxygen. Groundwater level (indicative) and a brief soil profile description are registered. Individual soil moisture, tile drain water, and other ditch water samples are analysed for nitrate, nitrite, pH, and electric conductivity in the laboratory. In the field tile drain flow rates, and some ditch characteristics are registered, for example Secchi Depth Transparancy.

Individual samples are filtered (0.4 µm), preserved and mixed. Mixed samples, one for tile drain water and two for other waters, are analysed for:

- major components: DOC (dissolve organic carbon), Cl, SO_4, Na, Ca, and Mg;
- major nutrients: total N, NH_4, NO_3, ortho-P (molybdate reactive P), total-P, and K;
- micro elements: Al, As, Ba, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Sr, and Zn.

Figure 11 Sampling of soil below the root zone in the loess region (upper pictures) and extraction of soil water (lower pictures).

Figure 12 Sampling of tile-drain water (left) and ditch water (right) in the clay region.

The farm area is put down in GIS and overlays are made with the soil map and soil drainage map (50 × 50 m^2 grid cell; De Vries and Denneboom, 1992). Precipitation and evaporation data of the Royal Dutch Meteorological Institute (KNMI) are collected (10-day average values for 15 weather districts).

2.3 Data interpretation

LMM data are used to detect trends in nitrate leaching due to policy measures, to check compliance with environmental standards, and to underpin policy measures such as nitrogen fertilisation standards and the derogation.

Trend detection

To evaluate the effectiveness of the mineral policy, trends in nitrate concentrations are evaluated for each of the soil type regions, see Figure 4, with the exception of the peat region where nitrate concentrations are low. Differences in sample group and environmental conditions in time have to be taken into account in the analysis and interpretation of the data. The LMM sample group changes in time. Therefore differences occur in the ratio between farm types, soil type acreage, soil drainage type acreage, et cetera. The variation in precipitation excess strongly influences measured nitrate concentration and has to be taken into account as well (Boumans et al., 2001).

LMM is a stratified random sample and therefore certain farm types may be overrepresented in LMM. In addition the ratio between farm types in a region will change over time due to the high level of dynamics in Dutch agriculture. Data of the Agricultural Census are used to account for the influence of these factors when calculating the change in average nitrate concentration in time.

It should be realised that on farms different soil types and drainage classes occur. For example, the LMM dairy farms in the sand region had an average of 17% peat soils or organic rich reclaimed peat soils and an average of 6% clay soils in the 1991-2004 period. Figure 4 shows that soil type has a large effect on nitrate leaching. Soil drainage class strongly influences the fraction of the nitrogen surplus that leaches from the root zone from sandy soils. Less than 30% of the nitrogen surplus leaches from poorly drained soils compared with well drained sandy soils (Fraters et al., 2007a). The fractions of soil types and drainage classes differ between years and therefore we account for this in the trend analyses.

The fraction of nitrogen surplus that leaches from the root zone is lower for grassland than for arable land. For well drained sandy soils the leaching fraction for arable land is 0.89 and for grassland 0.46 (Fraters et al., 2007a). In the 1991-2004 period, the acreage of LMM dairy farms in the sand region consisted for 73% of grassland, while on about 17% of the acreage fodder maize was grown. This annual average percentage of grassland differs between years and ranged from 63% to 82% in the 1991-2004 period. We do not account for this effect in trend analysis as it might be considered as an effect of policy. It is well known that grazing increases nitrate leaching. As N loss standards decreases farmers may limit grazing to use N more efficient. This might also be considered as an effect of policy.

Summarizing, we distinguish five types of effects on measured nitrate leaching, which have to be taken into account for detection of a policy induced decrease in nitrate concentrations:

1. Policy effects (loss standards, period and method of N appliance).
2. Farm management effects (for example, maize – grass ratio, grazing) which could be related to policy.
3. Environmental effects (precipitation excess, soil type, soil drainage), which are well known.

4. Possible environmental effects, changing the soil N pool, mineralisation, denitrification, crop uptake and not related to 3, which have to be investigated.
5. Monitoring effects being changes in the assembly of monitored farms and the number of farms per soil region and farm type.

Compliance checking

There is a vivid discussion in the Netherlands about the compliance checking level (De Klijne et al., 2009). The Nitrates Directive nor the Water Framework Directive clarifies how compliance with environmental standards should be checked. Nitrate shows a decrease in concentration with depth in groundwater in the Netherlands. LMM data reflect the quality of water flowing in or into the upper part of the groundwater body. Nitrate concentrations are therefore much higher than measured with the National Groundwater Quality Monitoring Network (LMG) at 10 and 25 m below the surface level. Current policy uses LMM data to check compliance, since nitrogen fertilisation standards in agriculture are derived using LMM data with the aim to assure that nitrate concentrations in the upper groundwater in the soil regions will, on average, not exceed the 50 mg l^{-1} (Schröder et al., 2004).

Derivation of fertilisation standards

The derivation of environmentally sound nitrogen fertilisation standards is carried out as part of the cycle of the evaluation of the Minerals Law (see Figure 13). The underpinning of the standards is carried out with a model developed and maintained by an expert group (Schröder et al., 2004, 2007). Two empirically derived relationships are used. First, a relationship between nitrogen use and nitrogen surplus on the soil surface balance, derived from data from field experiments. And, secondly, a relationship between nitrogen surplus and nitrogen leaching, derived from data from farms in the LMM; the leaching fraction.

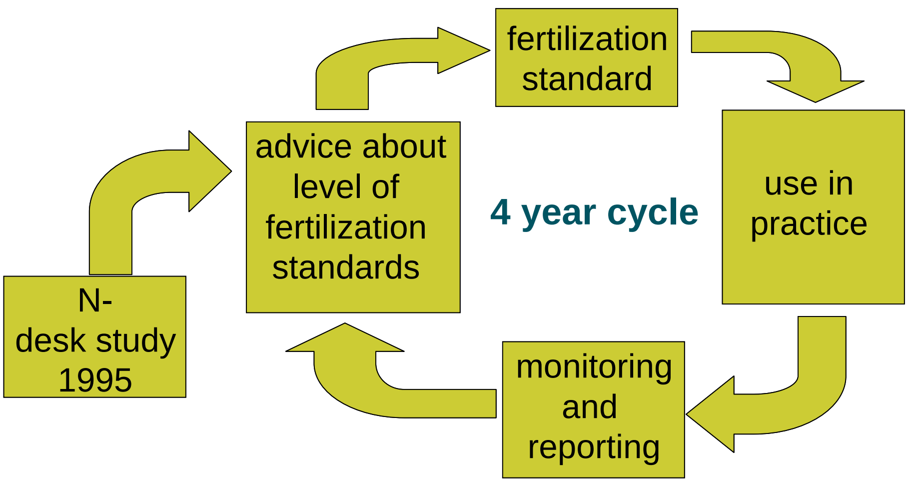


Figure 13 Cycle of evaluation of fertilisation standards as part of the evaluation of the Minerals Law.

An annual average leaching fraction is calculated for grassland and arable land on well drained sandy soils, on clay soils and on peat soils. For each LMM farm the nitrogen surplus on the soil surface balance and the nitrate/nitrogen leaching from the root zone is calculated. The nitrogen surplus on the soil surface balance is based on the surplus on the farm gate balance. Initially, the surplus on the farm gate balance is calculated by adding the supply and removal of nutrients registered in the bookkeeping. This surplus is calculated with the inclusion of stock mutations. Regarding nitrogen, the surplus calculated on the farm gate balance is then corrected for net mineralisation, atmospheric deposition, N fixation by legumes, volatilisation from housing and storage and by application and grazing (Fraters et al., 2007b).

The data of the special derogation monitoring network are reported to the European Commission (Zwart et al., 2009; Fraters, 2007b), but a first analysis of trend will be carried out in 2010 when the water quality data for 2007-2009 are available that reflect the agricultural practices since 2006, the first year the derogation was granted. The current derogation was underpinned using the above mentioned model and additional data of LMM and other projects (Schröder at al., 2007, 2009).

3 Discussion

Representativeness of farm types in LMM

The LMM programme for trend detection represents about 80% of the agricultural land use in the Netherlands. Status and trend of agricultural practices and water quality for the major part of the agricultural land can be provided. Additional information about the water quality status of other agricultural land use is derived from the other LMM programmes. However, there is currently no road map for a systematic approach of characterising the 20% of agricultural land not included in the LMM programme for trend detection. This point will be put on the agenda of the evaluation of the LMM programmes in 2009.

Representativeness of individual farms in the LMM

The farms participating in the effect monitoring of the LMM are a sub-selection from the FADN. For the LMM sub-selection, within each stratum of soil type region and farm type, three groups are made based on farmland use area. Each area size group within a stratum has an equal area. Farm types and farms were excluded if the land use area of the farm type or farm was too small (< 10 ha). Some farms with a vast area of land use were also excluded. The result is that larger farms, farms with a larger land use area, are over represented in the sub-selection per soil type/farm type stratum compared with their number in the Agricultural Census. For the detection of trends the area per farm type per soil type region was taken into account but there was no weighing to correct for the higher land use area per farm. This year the current method for trend detection will be evaluated and – if necessary – revised.

Focus on nitrate as water quality indicator in the clay and peat region

LMM data interpretation focuses on nitrate. For the clay region and, especially, the peat region the concentration of total nitrogen in water leaching from the root zone and ditch water is probably more relevant than the nitrate concentration. One of the reasons that total nitrogen has not received equal attention, is the lack of formal environmental quality standards for nitrogen in on-farm waters in the winter. Environmental quality standards are derived for larger surface water and for the summer period, the period with biological activity. Recently published provisional WFD nitrogen standards for ditch waters are about 4 mg of nitrogen per litre. This is much lower than the current point of departure of 11.3 mg l^{-1} used for the derivation of environmentally sound fertilisation standards. Another reason for the lower level of attention is the lack of evidence of a relationship between ammonium and organic nitrogen concentrations and nitrogen surplus on the soil surface balance. Ammonium and organic nitrogen are the two major nitrogen forms in the peat region. High concentrations may be due to a higher mineralisation of peat in the subsoil, rather than high fertilisation. The management by the Water Bzoard and/or the farmers of the ditch water level, in combination with the presence or absence of upward seepage of nutrient rich groundwater is in some cases dominant over the fertilisation practices.

For estimating the effect of the Action Programme on surface waters, especially with respect to eutrophication, some improvements of the programmes have been made recently. The LMM focuses on nutrient concentrations in ditch water on farms in the winter period. Some information about the presence of vegetation covering the water surface (mainly duckweed) and water column transparency are registered. In 2008 a surveillance programme started to collect data on ditch water quality in the summer months (four-monthly sampling starting in June).

Use of surface water quality census data for monitoring effectiveness of Action Programmes

The Surface Water Quality Census collects data from agricultural surface water stations from the Regional Water Status Networks of the regional Water Boards. These stations are better equipped, since more parameters are determined and measurements are taken during the entire year. However, one should realise that the water quality of regional surface waters in clay and peat regions in summer is strongly influenced by the quality of larger rivers due to letting fresh water into polders in the summer. In some regions the surface water quality is also influenced by the up-welling nutrient rich groundwater.

There are several drawbacks of this Surface Water Quality Census for agricultural influenced surface waters (Portielje et al., 2002). Some are due to the fact that it has only been recently developed. There are specific areas where there is a lack of monitoring stations. There are also indications that not all selected stations are representative for agriculturally influenced water. Stations are located at easily accessible locations and are therefore usually larger waters in comparison with the ditch water monitored in the LMM. The responsible Water Boards have selected the monitoring stations. A quality control has not yet been performed on consistency of choices between Water Boards. It should be noted that the main reason for monitoring water quality arises from the fact that as of 2000 the Water Framework Directive came into effect. The WFD demands that water managers – for example, the Water Boards – define water bodies. The various water bodies need to be monitored. Small waters, such as ditches, are not part of these water bodies. In 2008 a project started to harmonise surface water quality monitoring by the Water Boards, the Centre for Water Management and RIVM and to look for methods to perform quality control and trend analysis on existing data.

Phosphorus

The fourth Nitrates Directive Action Programme (2010-2013) includes measures to reduce the impact of both nitrogen and phosphorus leaching. Phosphorus surpluses on the soil balance are calculated and phosphorus concentrations in water leaching from the root zone and in ditch water are measured. However, the relationship between surplus and losses are difficult to establish for phosphorus. Phosphorus concentrations in on-farm waters are due to the amount of readily available phosphorus in the soil as well. This amount is more related to soil type and fertilisation history in the last decades than to actual P surpluses. The ratio between critical P concentrations in on-farm water and the amount of P in the soil stock or the annual amount of P fertiliser applied is much lower in comparison with N. Soil stock and plant available P and N are, amongst many other soil quality parameters, monitored in the framework of the National Soil Quality Monitoring Network (LMB). LMB farms generally do not participate in LMM and/or FADN for methodological reasons. Many farmers have their fields sampled and analysed for plant available P for determination of fertilisation demand. Only derogation farms have an obligation for such a sampling. The results are registered in FADN. The sampling depth is relatively shallow, 0.1 m for grassland and 0.2 m for arable land, and it is not yet clear whether this is representative for the deeper soil layers. In LMB soil samples are taken from the layers 0.0-0.3 m and 0.3-0.6 m in addition to the upper 0.1 m samples.

4 References

Boumans, L.J.M., Fraters, B. and Van Drecht, G. (2001) Nitrate in the upper groundwater of ‘De Marke’ and other farms. Netherlands Journal of Agricultural Science, 49, (2-3), 163-177.

CBS (2008a) Mineralen in de landbouw, 1970-2007 [Minerals in agriculture, 1970-2007]. Web article, 12 December 2008, http://www.cbs.nl/nl-NL/menu/themas/natuur-milieu/publicaties/artikelen/archief/2008/2008-mineralen-in-de-landbouw-pub.htm.

CBS (2008b) Mineralen op landbouwgrond (bodembalansen) [Minerals on agricutural soil (soil balances). Web table, 17 July 2008, http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=37502&D1=0-1,7,22,37-38,41-42,49-50&D2=0-1&D3=a&HD=090402-1326&HDR=T&STB=G1,G2.

De Klijne, A., Groenendijk, P., Griffioen, J., Velthof, G.L., Janssen, G. and Fraters, B. (2009) Compliance checking level for nitrate. Overview research 2008 [in Dutch]. RIVM report 680747001, National Institute of Public Health and the Environment, Bilthoven, the Netherlands.

De Vries, F. and Denneboom, J. (1992) Digital soil map of the Netherlands. SC-DLO, Technical document no. 1, Wageningen, the Netherlands (in Dutch).

EC (1991) Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Communities, L375, 31/12/1991, 1-8.

Fraters, B., Boumans, L.J.M., Van Leeuwen, T.C., Reijs, J.W. (2007a) Leaching of nitrogen surplus to groundwater and surface waters on farms [in Dutch]. RIVM report 680716002, National Institute of Public Health and the Environment, Bilthoven, the Netherlands.

Fraters, B., Van Leeuwen, T.C., Reijs, J., Boumans, L.J.M., Aarts, H.F.M., Daatselaar, G.H.G., Doornewaard, G.J., De Hoop, D.W., Schroder, J.J., Velthof, G.L. and Zwart, M.H. (2007b) Agricultural practice and water quality on farms benefiting from derogation. Design and organisation of the monitoring network for 2006-2009 and annual report from 2008. RIVM report 680717002, National Institute of Public Health and the Environment, Bilthoven, the Netherlands.

Hendrix, P.A.M. and Meinardi, C.R. (2004) Springs and small streams in Southern-Limburg; Quality of groundwater, spring water and streams [in Dutch]. RIVM report 500003003, National Institute of Public Health and the Environment, Bilthoven, the Netherlands.

Lodder, K. and De Veer, J. (1985) The statistical framework of the LEI-Farm Account Network. Paper presented at the 'Seminar on Methodological Questions Relating to Farm bookkeeping Data', Voorburg, the Netherlands, 21-25 October 1985; organised by the FAO, Statistical Commission and Economic Commission for Europe.

Noij, G.J., Heinen, M., Groenendijk, P. and Heesman, M. (2008) Effectiveness of unfertilized buffer strips in the Netherlands - Mid-term report 2008. Effectiveness of buffer strips publication series 7, Alterra, Wageningen, the Netherlands.

OECD (2007) Instrument mixes for environmental policy. Organisation for Economic Co-operation and Development, Paris, France, ISBN 978-92-64-01780-1.

Oenema, J., Koskamp, G.J. and Galama, P.J. (2001) Guiding commercial farms to bridge the gap between experimental and commercial dairy farms; the project Cows and Opportunities. NJAS - Wageningen Journal of Life Sciences 49 (2-3):277-296.

Portielje, R., Van der Gaast, J.W.J., Van der Kolk, J.W.H., Schoumans, O.F. and Boers, P.C.M. (2002). Nutrient concentrations and trends in small agricultural influenced fresh surface waters, 1985-2000 [in Dutch]. RIZA rapport 2002.008, Centre for Water Management, Lelystad, the Netherlands. ISBN 9036954274, 62 pp.

Schoumans, O.F., Willems, J. and van Duinhoven, G. (2008) 30 vragen en antwoorden over fosfaat in relatie tot landbouw en milieu [30 questions and answers about phosphate in relation to agriculture and environment] (in Dutch). Alterra,Wageningen, the Netherlands

Schröder, J.J., Aarts, H.F.M., De Bode, M.J.C, Van Dijk, W., Van Middelkoop, J.C., De Haan, M.H.A., Schils, R.L.M., Velthof, G.L. and Willems, W.J. (2004) Nutrient use standards using different agricultural and environmental points of departure. Wageningen, the Netherlands, Plant Research International, report 79 (in Dutch).

Schröder, J.J., Aarts, H.F.M., Van Middelkoop, J.C., Schils, R.L.M., Velthof, G.L., Fraters, B. and Willems, W.J. (2007) Permissible manure and fertiliser use in dairy farming systems on sandy soils in the Netherlands to comply with the Nitrates Directive target. Europ. J. Agronomy 27:102-114.

Schröder, J.J., Aarts, H.F.M., Van Middelkoop, J.C., Velthof, G.L., Reijs, J.W. and Fraters, B. (2009) Nitrates Directive requires limited inputs of manure and mineral fertiliser nitrogen in dairy farming systems. Wageningen, the Netherlands, Plant Research International, report 222.

Van Duijvenbooden, W. (1987). Groundwater quality monitoring networks: design and results. In: Van Duijvenbooden, W. and Van Wageningh, H.G. (eds.), Vulnerability of Soil and Groundwater to Pollutants. Proceedings of the International Conference, Noordwijk aan Zee, the Netherlands, 30 March – 3 April 1987, pp. 179-191.

Vrolijk, H.C.J. and Cotteleer, G.C. (2005) Non response and rotation in the Farms Accountancy data Network; quantitative and qualitative analyses of effects [in Dutch]. The Hague, the Netherlands, Agricultural Economic Research Institute, LEI Wageningen UR report 1.05.01.

Vrolijk, H.C.J., Van der Veen, H.B. and Van Dijk, J.P.M. (2009) Sample of Dutch FADN 2006. Design principles and quality of the sample of agricultural and horticultural holdings. The Hague, the Netherlands, Agricultural Economic Research Institute, LEI Wageningen UR report 2008-081

Werkgroep Aanwijzing EG-NO_3 (1994) De aanwijzing van kwetsbare zones in het kader van de EG nitraatrichltijn: milieukundige onderbouwing [The designation of vulnerable zones in the framework of the EU Nitrates Directive: environmental underpinning]. Ministry of Public Housing, Spatial Planning and the Environment, The Hague, the Netherlands.

Zwart, M.H., Hooijboer, A.E.J., Fraters, B., Kotte, M., Duin, R.N.M., Daatselaar, C.H.G., Olsthoorn, C.S.M. and Bosma, J.N. (2008) Agricultural practice and water quality in the Netherlands in the 1992-2006 period. RIVM report 680716003. National Institute of Public Health and the Environment, Bilthoven, the Netherlands.

Zwart, M.H., Daatselaar, C.H.G., Boumans, L.J.M., Doornewaard, G.J. (2009). Agricultural practice and water quality on farms registered for derogation. Results for 2008 in the derogation monitoring network.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Slovak Republic

M. Holubec[1], K. Slivková[1], K. Chalupková[1], A. Májovská[2], A. Vančová[2] and L. Mrafková[2]

[1] Water Research Institute, Nábr. Arm.gen. L. Svobodu 5, SK-812 49 Bratislava, Slovak Republic
e-mail: holubec@vuvh.sk

[2] Slovak Hydrometeorological Institute, Jeséniová 15, SK-833 15, Bratislava, Slovak Republic
e-mail: lea.mrafkova@shmu.sk

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the Slovak Republic and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). The implementation plan for EU Nitrates Directive for the Slovak Republic was developed in 2001. It includes a timetable of securing relevant activities in the field of planning, legislative measures, monitoring, advocacy, reports translation, communication and it determined the organisations, which are responsible for its realisation. The Code of Good Agriculture Practice was developed and published in 2001. For the creation of the NVZ map, space overlap of digital municipal cadastres layers and production blocks with the help of digital layers of soil blocks was used. Also the completion of the groundwater monitoring network with about 702 new observation wells and extension of monitoring in 300 existing monitoring objects was done. In addition, modelling to support experimental research on nitrogen transformation processes and for the evaluation of groundwater pollution risk was performed, as well as an assessment of surface water eutrophication based on surface water monitoring data. The general evaluation of NVZs can be summarised as follows: (a) stabilisation has taken place of present level of pollution in all NVZs and (b) the progress towards a full recovery is very slow, and it will probably require the period of 15 years or more.

1 Introduction

1.1 General

The implementation plan for EU Nitrates Directive (EC, 1991) for the Slovak Republic was developed in 2001 (Anonymous, 2001). It includes a timetable of securing relevant activities in the field of planning, legislative measures, monitoring, advocacy, reports translation, communication and it determined the organisations, which are responsible for its realisation.

By the Regulation of the Government of the Slovak Republic No. 249/2003 Coll. (SR, 2003), which stipulates sensitive and vulnerable zones with effect from

1 August 2003, which was replaced by the Regulation of the Government No. 617/2004 Coll. from 27 October 2004 (SR, 2004), nitrate vulnerable zones (NVZs) were designated, with list of land registers which belong to these zones.

The Code of Good Agriculture Practice was developed and published in 2001. It is related to the water sources protection in the right of Nitrates Directive. The code was published by the Ministry of Agriculture, 10,000 copies were printed and distributed to the users. The complete version of the code is published on the website www.vupu.sk.

The ordinance of the Ministry of Agriculture No. 392/2004 Coll, which establishes the programme of measures in the designated NVZs, is valid since 23 June 2004 and at the present time it is replaced by the Ordinance of Ministry of Agriculture No. 199/2008 Coll. from 1 July 2008. Maps of groundwater risk were established and the system was set up of inner differentiation of NVZs on the areas with different claims for management restrictions due to the Nitrates Directive, based upon these maps.

1.2 Determination of nitrate vulnerable zones

Many expert studies and analyses were carried out in 2001-2003 aiming at the assessment of existing status in concentration of nitrate and other nitrogen substances in waters of the Slovak Republic (SR) for the evaluation of NVZs range and subsequently the range of NVZs was established. Based upon these works only groundwater was specified as vulnerable.

Vulnerable zones for the Nitrates Directive purposes are the zones in which increased concentrations of nitrate in groundwater are found or zones which are endangered by nitrate. Zones have been processed in a GIS environment at a scale of 1:50,000. As a supplementary GIS layer in marking the NVZs were also used:

– GIS layer of rivers and streams in SR: it contains streams, which are part of the basic water management map in scale 1:50,000;
– GIS layer of villages of SR: it contains villages which are part of the basic territorial identification register of SR;
– digitalised map of agricultural land of SR and digitalised map of potential nitrate formation in agricultural land of SR;
– map of protected water management areas;
– map of river basins.

The water quality in specific sampling points was assigned to the following nitrate concentration classes:

a) from 0.25 to 25 mg NO_3 l^{-1},
b) from 25 to 50 mg NO_3 l^{-1},
c) from 100 to 150 mg NO_3 l^{-1},
d) > 150 mg NO_3 l^{-1}.

Nitrate concentrations in all groundwater samples averaged 36.17 ± 71.25 mg l^{-1} with a median of 8.8 mg l^{-1}. The latter results from an extremely specific distribution of nitrate contents as nearly one-third of the samples contained less than 3 mg l^{-1} and almost 55% of them contained less than 11.3 mg l^{-1}. The low concentrations occur exclusively in mountain areas and in the case of river Danube, in the near-bank zone of surface-water infiltration.

The groundwater with nitrate content over 25 mg l^{-1} was classified as water facing the risk of nitrate contamination.

For the creation of the NVZ map, spatial overlap of GIS municipal land registry layers and production blocks with the help of GIS layers of parcels was used, at which the spatial analysis of municipal land registry intersection and agricultural production was made. The result is a map of NVZs (Figure 1).

Concerning the high detail of the GIS processed vector layer on one hand and the required precision for reporting (scale 1:1,000,000) on the other and, it was proved that mentioned layer needs to be generalised. The followed specific conditions were considered:
– high disintegration of objects;
– large distance of some, mainly small area objects;
– existence of 'island' objects (object with one or more 'holes').

The procedure to derive the maps with NVZs is given in Figure 2.

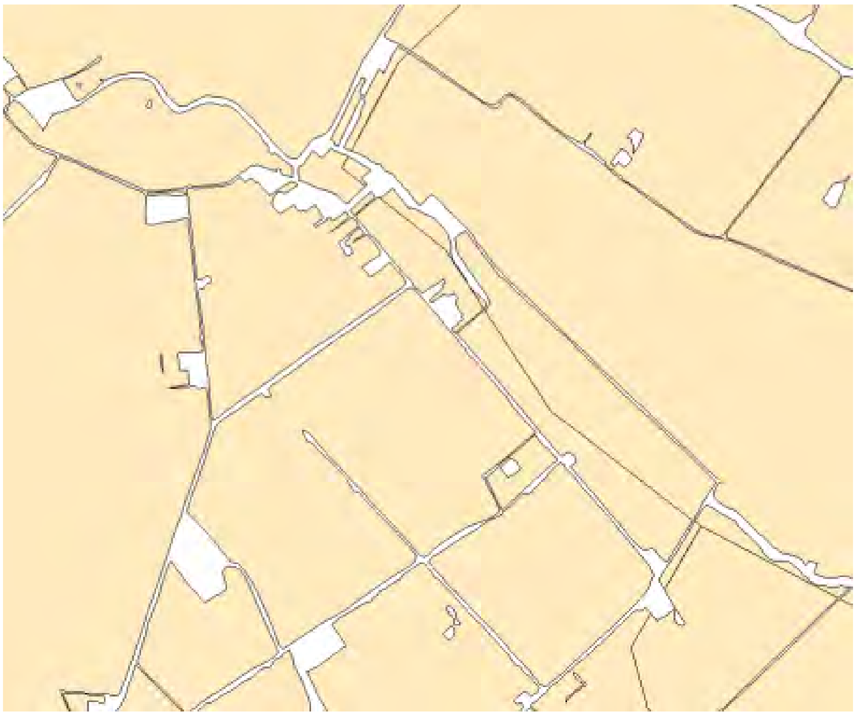


Figure 1 Detail of a nitrate vulnerable zone map with use of parcels.

The transformation of a GIS vector layer into a raster with resolution of 25 m was made as a first step. In the next step the entire raster was converted again into vector. An algorithm for filling empty areas within particular objects was used at the end. In order to retain empty areas which represent town residential areas, empty areas (holes) were filled only if their surface area was smaller than 50 ha. In this way we obtained the final generalised vector layer of NVZs of SR (Figure 3). Designated NVZs in terms of Nitrates Directive take approximately 55% of the total agricultural land area of SR.

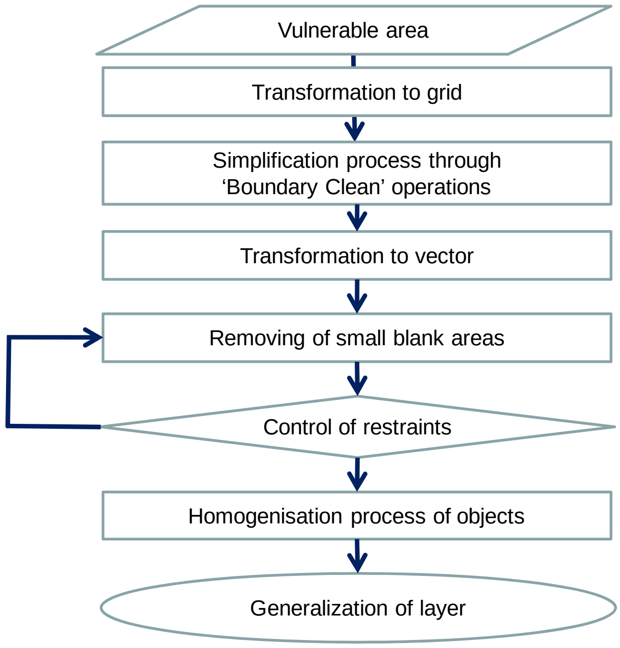


Figure 2 Algorithm to derive a generalised GIS layer of NVZs as used in the Slovak Republic in 2001-2003.

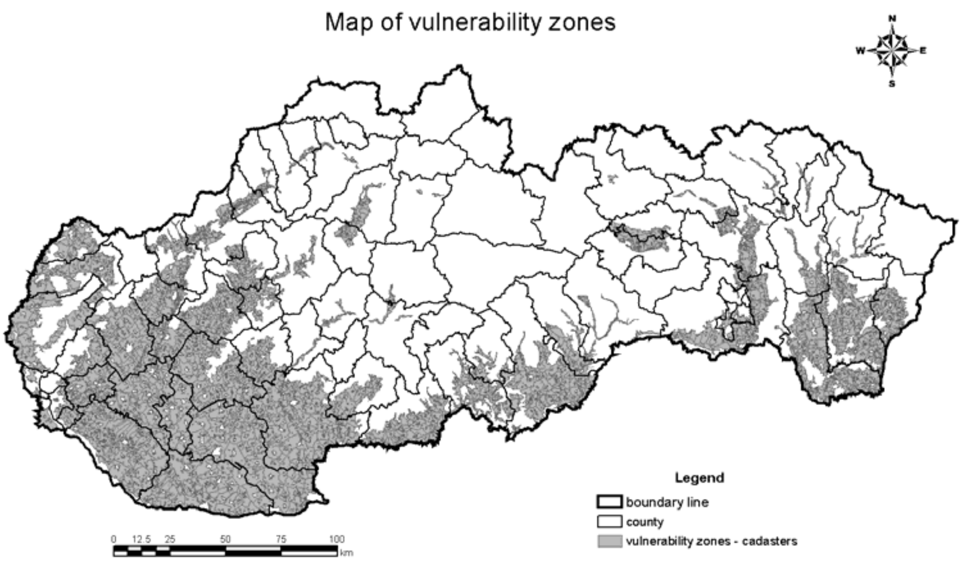


Figure 3 Map of designated nitrate vulnerable zones (NVZs) in the Slovak Republic based on groundwater vulnerability.

Map processing was carried out with the help of GIS technologies. The area was divided into polygons in term of the current and potential groundwater utilisation. The result is division into areas with high, middle and low groundwater risk (Figure 4).

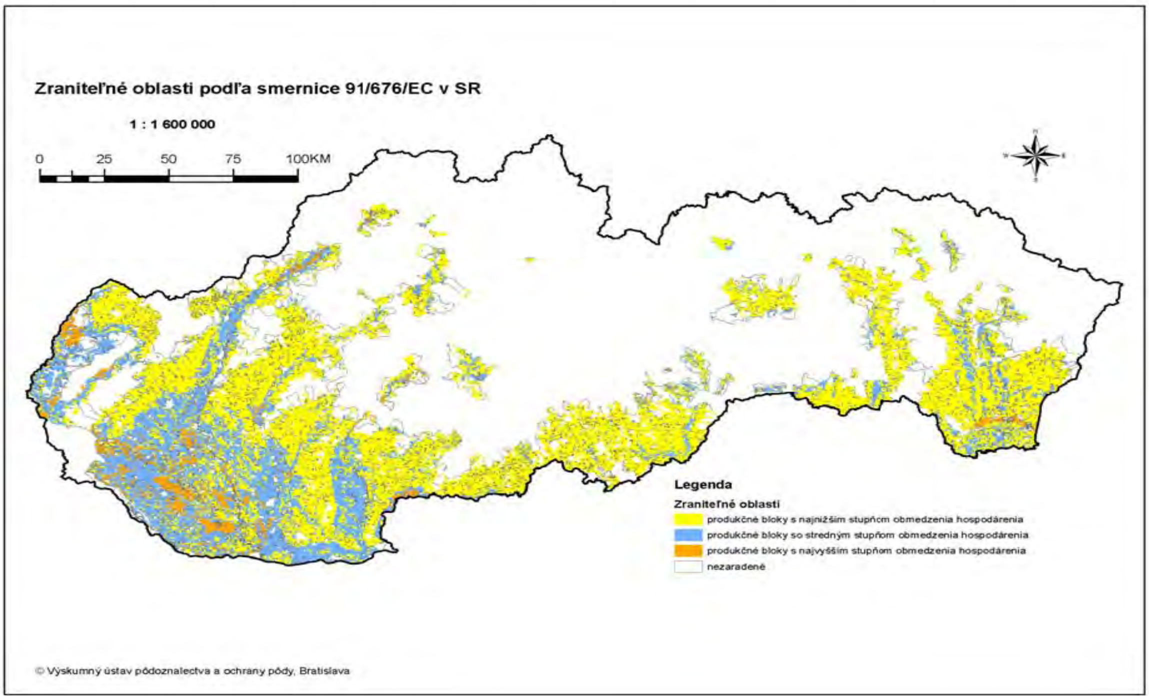


Figure 4 Vulnerable zones division based on a risk assessment for groundwater nitrate contamination.
Yellow area=production units with lowest degree of management restrictions;
Blue area= production units with medium degree of management restrictions;
Orange area= production units with highest degree of management restrictions;
White area=not classify.

2 Monitoring and modelling

2.1 Overview of groundwater monitoring networks

The main obligation resulting from the Nitrates Directive is the execution of monitoring, which serves the control and evaluation of the impact of agricultural activities on groundwater quality.

Groundwater monitoring network has to be designed to provide a continuous and comprehensive view about chemical and quantitative groundwater status in all vulnerable areas and to uncover a long-term impact of agrochemicals applications, mainly the increasing trend in monitored concentration of nitrate and other nitrogen substances. It also has to make possible the evaluation of adopted measures in the Nitrates Directive Action Programmes and to identify specific producers of water pollution. The smallest administrative unit is the cadastre municipality. Therefore a rule was accepted that monitoring has to allow identifying contaminators in every cadastre classified in a vulnerable zone.

Analyses of original status of groundwater monitoring within SR were made. On the basis of these analyses, a plan and programme of groundwater monitoring in terms of the concentrations of nitrogen substances was processed. Also completion of monitoring network with about 702 new observation wells and extension of monitoring in 300 existing monitoring objects was done.

Localisation of wells was made with the help of orthophoto maps, water management maps, and reconnaissance of terrain before borehole realisation. The following criteria were considered:

- availability of a well in any of the meteorological conditions within SR;
- representativeness in term of agricultural exploitation of land;
- minimalisation of point-sources pollution impact of industrial and urbanized areas;
- direction of groundwater flow.

A part of the geological activities was the geodetic localisation of boreholes, with the determination of their x, y and z coordinates in the JTSK system (national reference coordinates system for the Slovak Republic) and allocation in the map in scale 1:50,000, sampling and laboratory works. The bottleneck boreholes with diameter of 60-80 mm were drilled, into the depth of 2-5 m under minimal groundwater level, with granular wall of borehole with diameter of 100 mm, with perforation 5 m from the bottom (see Figure 5). The concrete foot was stepped for prevention of casing water circulation. They allow for evaluation of groundwater quality in first water horizon. Density of monitoring objects increased from one object per 25 km^2 to one object per 10 km^2. Comparison of the increase in density of wells in the monitoring network is shown in Figures 6 and 7.

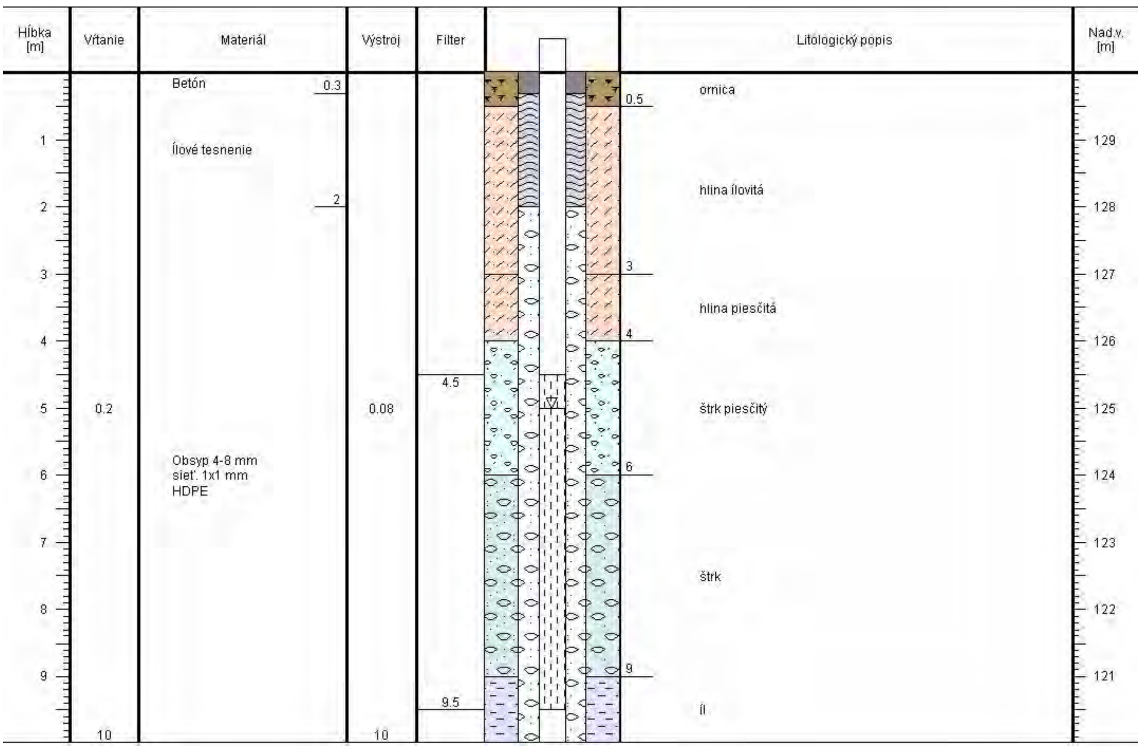


Figure 5 Example of borehole construction for additional wells in the Nitrate monitoring network in the Slovak Republic.

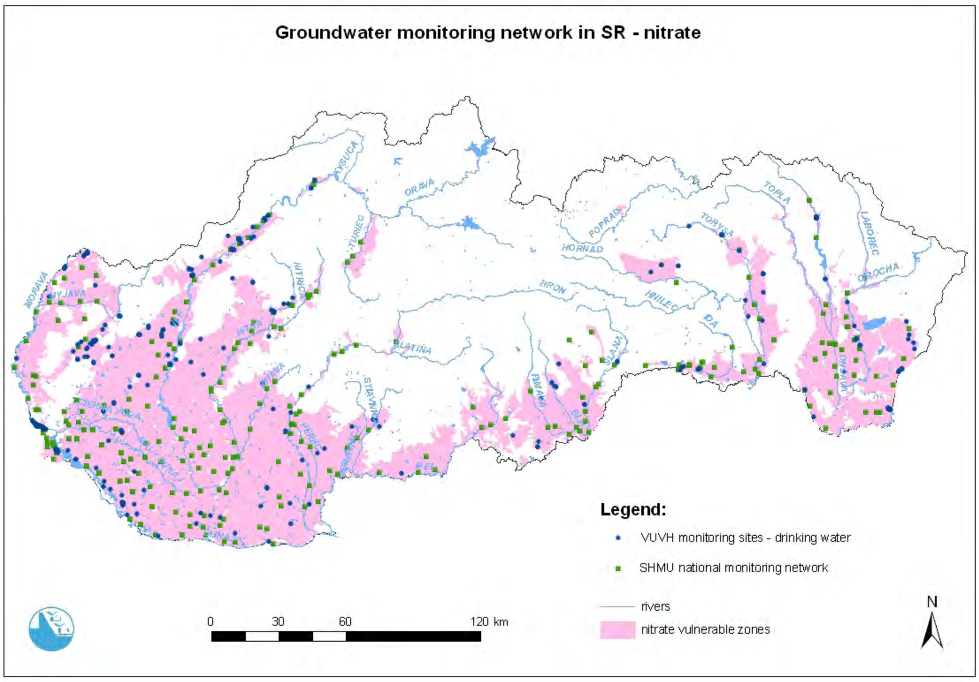


Figure 6 Monitoring network before the installation of additional monitoring wells to increase network density.

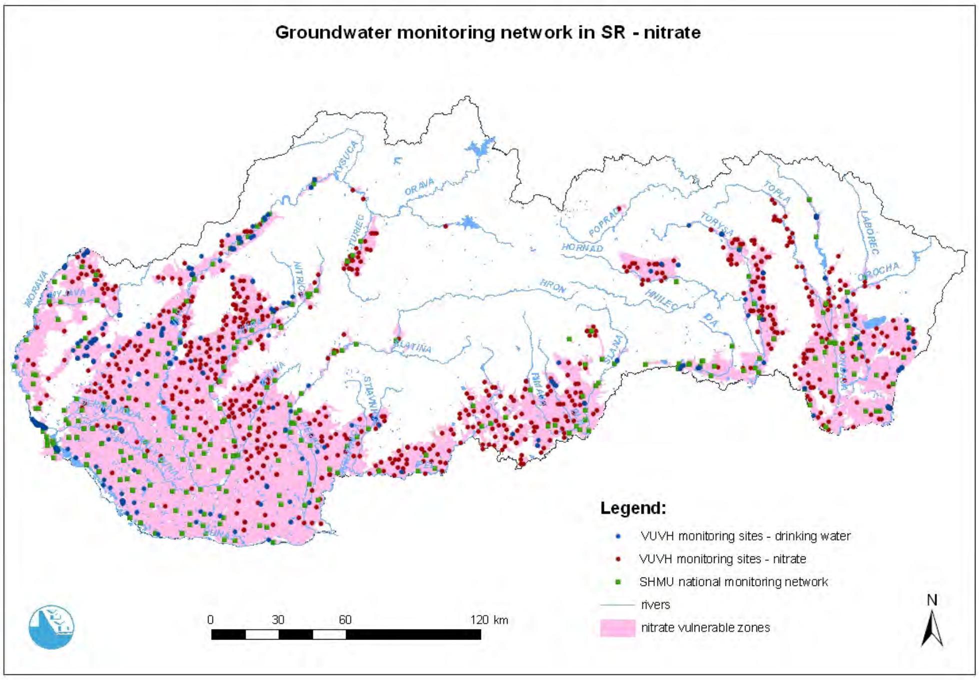


Figure 7 Monitoring network after installation of additional monitoring wells, this means, new denser network.

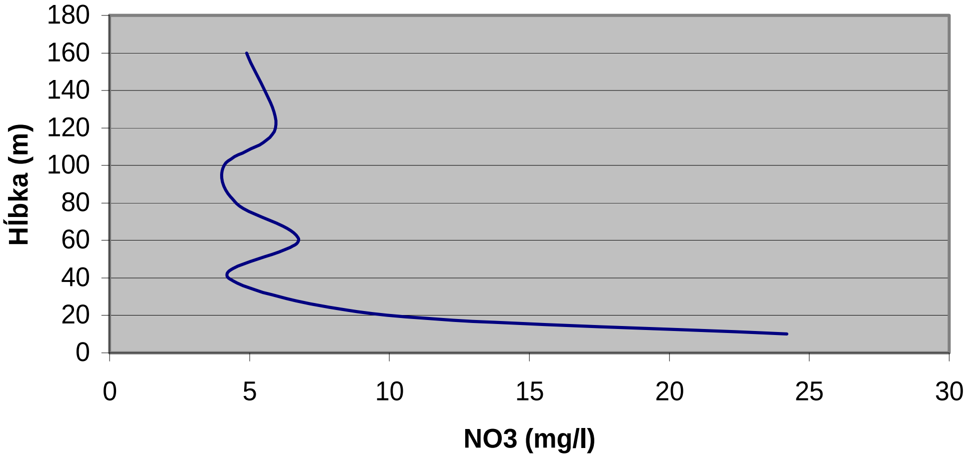


Figure 8 Average nitrate concentration (mg l^{-1}) in dependence to groundwater depth (m) in Žitný ostrov area.

2.2 2.2 Overview of modelling groundwater pollution

Modelling is an important tool to study the impact of agricultural production impact on groundwater quality. Following modelling activities are continuously carried out:

- modelling to support experimental research on nitrogen transformation processes (laboratory, lyzimeter);
- modelling for the evaluation of groundwater pollution risk.

Modelling for experimental research

Laboratory research is carried out by modelling the flow in columns in unsaturated state. Experiments are realised for different soil types, transport conditions, and different types of applied fertilisers. Results of monitoring for the application of the fertiliser DAM 390 and its impact on concentrations of NH_4 and NO_3 in different soil depths (K) are shown in Figures 8 and 9, respectively.

Results show that in the first soil layer below the depth of 20 cm there was no transformation of various forms of nitrogen and only sorption, desorption and ion exchange were taken into account. More significant transformation is visible in the soil profile layer deeper than 30 cm. Primary concentration of nitrate is increasing to the level five times greater than the concentration in the inorganic DAM 390 fertiliser, which is caused by the dominant process of nitrification.

Other experiments using lysimeters and with application of ammonium sulphate fertiliser confirm the sorption of ammonium ions in the upper soil layer and intensive nitrification, at which concentration of NO_3-N exceeds the concentration of NH_4-N in percolate more than ten times. More than double concentration of NO_3-N was recorded in the 50 cm layer of the lysimeters than in the 30 cm layer of the lysimeters.

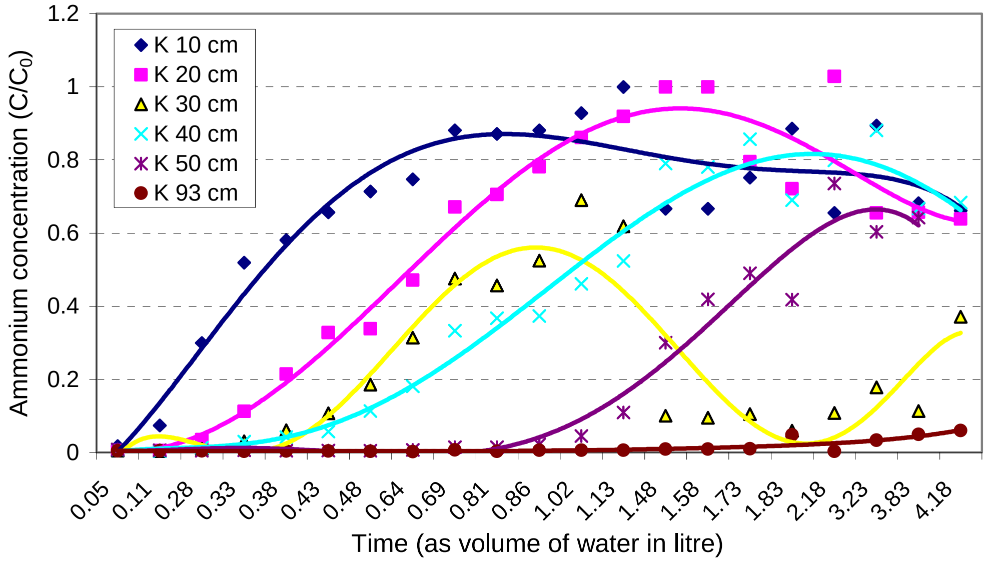


Figure 9 Impact of application of DAM 390 fertiliser on ammonium (NH_4) concentration for different depth below the soil surface (K).
C/C_0 is the normalised NH_4 concentration, time is expressed as volume of water percolated into the soil column at the top of the column.

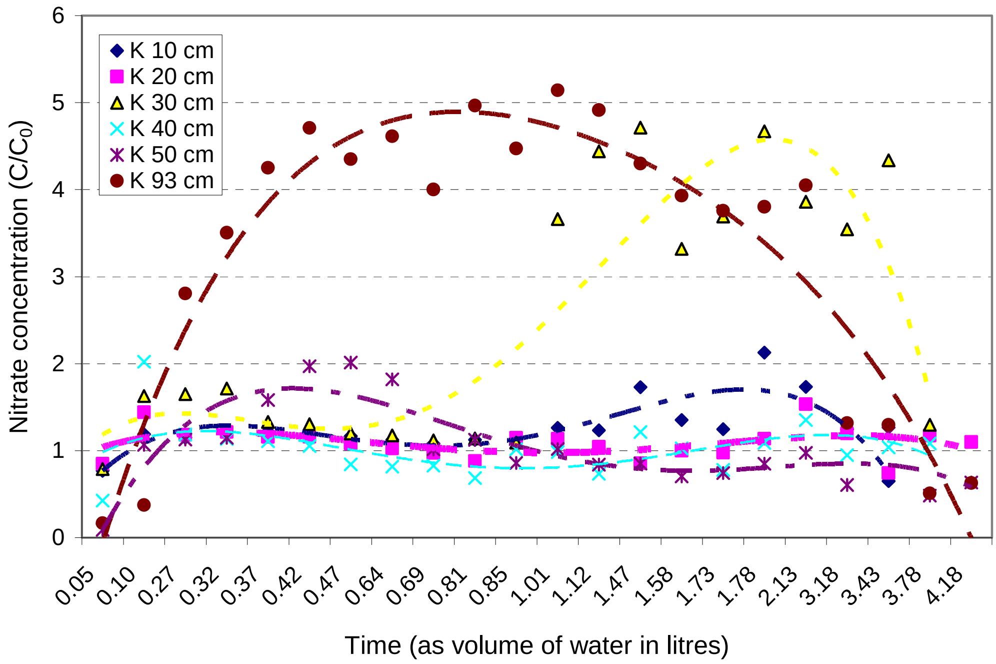


Figure 10 Impact of application of DAM 390 fertiliser on nitrate (NO_3) concentration for different depth below the soil surface (K).
C/C_0 is the normalised NO_3 concentration, time is expressed as volume of water percolated into the soil column at the top of the column.

There are neither nitrate nor chloride anions sorbed in soils where fertilisers were applied. These anions are leaching into the soil profile by the application of potash (K) fertilisers of chloride types, similar as nitrate leaching. An important factor is the soil acidity, which significantly affects the chemical and physical processes in soil. There is a change of leaching of nitrate after application of organic fertiliser aused by mineralisation of organic nitrate, soil organisms death loss and other natural sources (leguminous).

Modelling for the evaluation of the risk of groundwater pollution

More than 84% of drinking water supply in the Slovak Republic originates from existing groundwater sources and resources. More than one half of groundwater sources are located in Quaternary hydrogeological structures consisting of fluvial sediments deposit of rivers (59%) (mainly Danube River Basin and other large river basins in Slovakia), which extend over 26% of Slovakia's territory and represent the most significant area for water supply. These areas are also extremely commercially utilised and therefore the groundwater is at risk.

Risk evaluation is based on evaluation of primary attributes (inflow from surface, soil, aeration zone, saturated zone) and additional attributes. Map of risk gives a complex view of the significance of water sources and the protective function of the geological environment above the continual aquifer. Protective functions of natural environment are classified with regard to the parameter characteristics for particular elements of the groundwater accumulation system:
- soil (type, content, thickness, permeability);
- unsaturated zone (thickness, permeability, content);
- level depth and groundwater regime.

The map of risk of groundwater pollution combines the information about groundwater utilisation (map of groundwater classes) with the information about the groundwater vulnerability (vulnerability map). Basically it is a complex map that evaluates the potential risk of groundwater pollution with regards to groundwater water quality preservation. Figure 11 shows an example of a map resulting from the groundwater risk evaluation for the region Žitný Ostrov, the most important water source region in Slovakia.

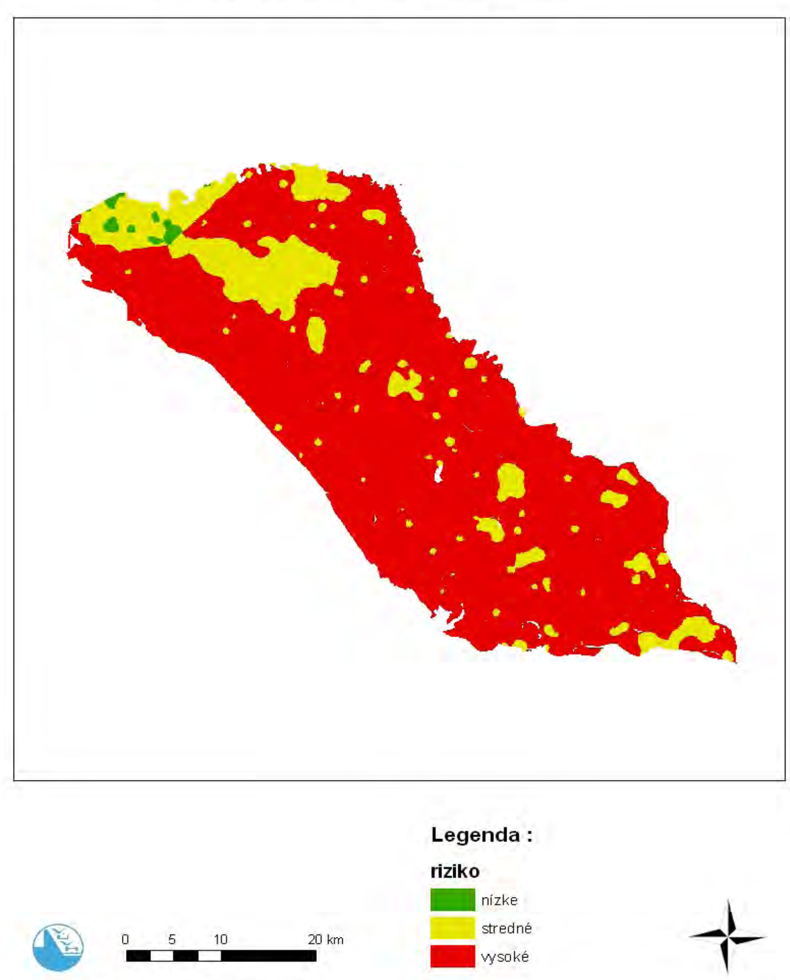


Figure 11 Map of risk of groundwater pollution for the region Žitný Ostrov.
Green = low risk; yellow = medium risk; red = high risk.

The evaluation of the risk resulting from applied fertilisers is based on:
- data on fertilisers consumption (amount of applied fertiliser) on cadastres level after recalculation into the agricultural land (kg N ha^{-1} per year);
- the score systems based on the amount of applied fertilisers in nitrate vulnerable zones and the level of groundwater threat.

The final score is the conjunction of two attributes: assigned score of groundwater pollution threat and the amount of applied nitrate (kg N ha^{-1} per year).

Based on the score system, the vulnerability of a groundwater body as an evaluation of the potential influence of the total amount of nitrogen applied was assigned as follows (see Table 1):
- risk score 0-450 : not at risk (0);
- risk score > 450-510 : potentially at risk (3);
- risk score > 510 : risk (6).

Figure 12 shows the map of evaluation of groundwater pollution risk. For the white area no data were available.

Table 1 Approach to assess the vulnerability (risk of pollution) of a groundwater body in response to the application of N fertiliser.

Applied amount of nitrogen (in kg N ha^{-1} per year)	Vulnerability classes for groundwater † Low (0)	Average (3)	Maximal (6)
120	0	360	720
150	0	450	900
170	0	510	1020

† Classes of vulnerability for groundwater are:

0 – low vulnerability (good natural protection area)

3 – average vulnerability (average natural protection area)

6 – maximal vulnerability (soft natural protection area)

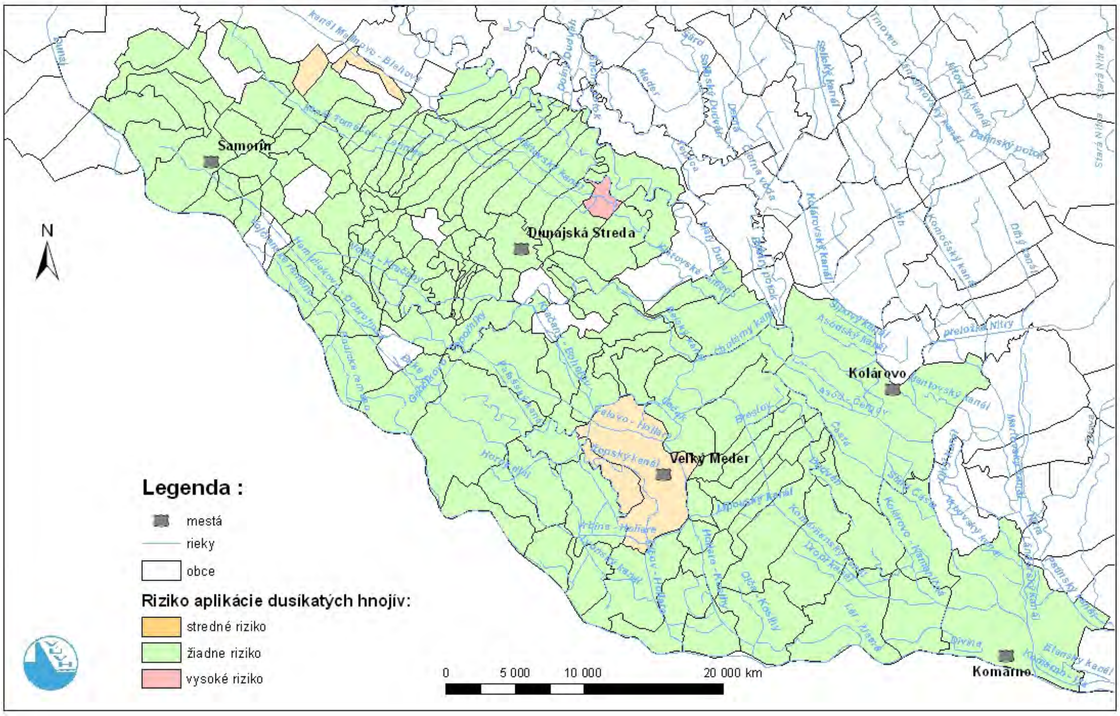


Figure 11 Evaluation of groundwater pollution risk resulting from application of nitrogen fertiliser in the region of Žitný Ostrov.

Green = no risk; orange = medium risk; red = high risk. Blue lines are rivers, grey areas are cities.

2.3 Overview of surface water monitoring networks and statistical evaluation

Surface water quality evaluation

Data regarding quality of surface water (water courses) were processed for the periods (previous – the first phase: 2000-2003 and the current phase: 2004-2007). We used data from SHMU Bratislava surface water quality database. The data are stored in the database of the Microsoft SQL server at the Department of Surface Water Quality.

In the previous (first) period 2000-2003, the monitoring network consisted of approximately 200 sampling points in the given year in which indicators related to nutrient pollution – and in areas with intensive agricultural production also with impact on eutrophication – were monitored. Sampling points for assessment of nitrates were selected with a minimum sampling frequency 6 times per year. This condition was successfully met by a total of 188 sampling points. Maximum frequency was 25 times per year (3 sampling points, transboundary waters). Frequency of taking samples was not the same for all required and measured indicators (NO_3, P total, ortho-P, chlorophyll-ɑ) in above mentioned 188 sampling points. For the assessment of trophic status, 63 areas were monitored. Insufficient number of chlorophyll-ɑ measurements (from April to September) resulted in exclusion of many sampling points from statistic assessment of the trophic status.

The National Programme for Water Monitoring in the Slovak Republic in the second period, 2004-2007, included 397 sampling points of surface water of Slovakia distributed over sub-basins. In the framework of basic monitoring, 195 sampling points were monitored, out of which 39 located on transboundary waters. Out of 397 sampling points, 224 were selected for the monitoring. In the second phase, selection of sampling points was based on data availability for individual indicators and monitoring frequency. Sampling points for the assessment of nitrates were selected with a minimum sampling frequency 6 times per year. This condition was successfully met by a total of 224 sampling points. Out of the 224 sampling points, 199 had the minimum sampling frequency of 12 times per year. This selection of the sampling points includes points monitored according to agreements between neighbouring states which had the monitoring frequency of 12-24 times per year. Similarly to the first period, frequency of taking samples was not the same for all required and measured indicators (NO_3, P-total, ortho-P, chlorophyll-ɑ) in above mentioned 224 sampling points. For the assessment of trophic status, 49 areas were monitored. In this case, limiting selection criterion was measurement of chlorophyll-ɑ (from April to September). Only those sampling points which monitored chlorophyll-ɑ during the minimum 2-year period were included into assessment of trophic status (in both periods). The total assessment of trends in trophic status development by comparison of 2 phases was possible at 31 surface water monitoring points.

Until 2007, lakes were not monitored in the Slovak Republic because the surfaces of natural lakes are small (less than 0.5 km^2). Monitoring of water reservoirs started only in 2007.

In the Slovak Republic, no special monitoring (effect monitoring) for the assessment of surface water has been put in place for the purpose of nitrates and eutrophication assessment. Instead, data from basic and operational water monitoring have been used for this purpose.

During the initial assessment of NVZs, surface water in the Slovak Republic has not been considered as relevant for this purpose.

In the Slovak Republic, models for optimisation of monitoring network have not been used so far.

Evaluation of nitrate in surface water

Assessment of nitrates (NO_3) in surface water was done according to recommendations of the Guideline for Reporting (EC, 2000). In the framework of required statistic data processing regarding nitrates, averages, maximum values for the two periods (2000-2003, 2004-2007), and winter averages (October-March) for both periods (2000-2003 – the first phase, 2004-2007 – the second phase) were evaluated. Data from autumn of the previous year (October-December 1999, 2003) were included into the assessment of the two periods.

Statistical assessment of nitrates was not based only on the mentioned statistical parameters but also on the development of trends (between two periods) and the share of sampling points assigned to individual, in advance prepared categories of nitrate concentrations.

The goal of the above mentioned statistical assessment (statistical indicators and trends) of the two periods is to find out the status of nitrate concentrations and the trophic status development.

For surface water quality six classes were distinguished to categorise the nitrate concentrations in surface waters: < 2 mg l^{-1}, 2-10 mg l^{-1}, 10-25 mg l^{-1}, 25-40 mg l^{-1}, 40-50 mg l^{-1}, and > 50 mg l^{-1}. The percentage share was assessed of individual sampling points in the rivers for the above mentioned statistical values (annual average, winter average, maximums) for the both periods (2000-2000 and 2004-2007). In the first category (< 2 mg NO_3 l^{-1}) only 0.4% sampling points were included in the second period. As shown by other results, maximum share of sampling points falls down in the second class (2-10 mg NO_3 l^{-1}) and the highest number of sampling points in this class is in the second phase. The highest value 73.7% sampling points was identified for average values. In the third class (10-25 mg NO_3 l^{-1}) there was percentage share of sampling points higher in the first phase (63.35% for maximum values). In the fourth class (25-40 mg NO_3 l^{-1}) the highest values in both periods were for maximum values (11.74% and 12.9%). In addition, maximum values were identified in the fifth (40-50 mg NO_3 l^{-1}, and sixth class (> 50 mg NO_3 l^{-1}), however, with minimum percentage share of the sampling points.

Annual average nitrate concentrations show that values in both periods are within 2-40 mg NO_3 l^{-1}, and that three surface water quality classes (the first, fifth and the sixth) were not present. Values of annual averages have the highest percentage of sampling points in the second water quality class (2-10 mg NO_3 l^{-1}) both in the first period (68%) and in the second period (73.7%).

Maximal values ranges from 2 mg l^{-1} up to > 50 mg l^{-1}. The highest percentage share of sampling points is in class 10-25 mg l^{-1} (63.35% in the first phase and 61.2% in the second phase). Minimal percentage share is in the classes of 40-50 mg l^{-1} and over 50 mg l^{-1}. Only in the first phase 2.42% of the sampling points were present in the class from 40-50 mg l^{-1}. In the class over 50 mg l^{-1} it presented 3.23% (the first phase) and 1.3% sampling points (the second phase). Maximum nitrate concentrations were identified in the range of 2.88 mg l^{-1} to 127 mg l^{-1}. The total number of sampling points with maximum nitrate concentrations over 50 mg l^{-1} was 8 in the first phase and 3 in the second phase. This point was due to the fact that the number of areas with higher nitrate concentrations in the surface waters of Slovakia is minimal.

Assessment of surface water eutrophication

The number of sampling points for eutrophication assessment was limited due to the above mentioned assessment of chlorophyll-ɑ. Therefore, in the assessment were included the sampling points monitored during two or four years. Because of this condition, selection of sampling points was reduced in both phases – in the first phase there were 63 points and in the second phase there were only 49 sampling points. In the selected sampling points also other indicators were monitored, which are necessary for assessment of eutrophication (assessment according to reporting guideline, EC, 2000). The limit values are shown in Table 2.

Average values for nitrate, orthophosphate and total phosphorus were calculated using summer periods of the periods 2000-2003 and 2004-2007. In case of chlorophyll-ɑ, the maximum summer values for the two periods were compared. These values were compared with limits shown in the Table 2 and assigned into appropriate trophic status. The final trophic status presented the worse assignment from all measured values and years.

At the end, the two periods (2000-2003 and 2004-2007) were compared and results were evaluated only for those sampling points which had results from both periods. The total number of sampling points in which it was possible to assess the development trend was 31. The selection of sampling points for chlorophyll-ɑ was done in places endangered by eutrophication. These were, in general, surface water sampling points in lowlands, polluted by surface pollution sources, facing increase of temperature during the summer months, reduction of flows as well as surface water flow velocity. These pressures are the main factors endangering water courses with regard to eutrophication.

Table 2 Criteria for trophic status evaluation for surface water in the Slovak Republic.

Determinants	Trophic status: Ultra-oligotrophic	Oligotrophic	Mezotrophic	Eutrophic	Hyper-eutrophic	Unit
	Eutrophication level: I	II	III	IV	V	
Nitrate	2	10	25	40	50	mg NO_3 l^{-1}
Orthophosphate	0.1	0,5	1	2	-	mg PO_4 l^{-1}
Total phosphorus	0.05	0.2	0.5	1	-	mg P l^{-1}
Chlorophyll-ɑ	2.5	8	25	75	-	max. µg l^{-1}

Source: Guideline for reporting (EC, 2000), model: France, Seq-eaux.

An overview of the sampling points assigned to individual trophic status levels is given in the following Table 3.

Table 3 Trophic status of surface waters in the Slovak Republic in two periods. Number of monitoring points per trophic status class.

Trophic status	Period 2000-2003	Period 2004-2007
Ultra-oligotrophic	-	2
Oligotrophic	1	15
Mezotrophic	5	23
Eutrophic	29	9
Hyper-eutrophic	28	-
Total sampling points	63	49

Based on the 31 sampling points where we assessed the final trend of eutrophication development, we concluded that the status has improved at each of those sampling points. In 2 cases, the status improved from mezotrophic into oligotrophic and in one case, the status improved from mezotrophic into ultra-oligotrophic. Out of the 13 point with the eutrophic status, 5 improved into the oligotrophic status and 8 into the mezotrophic status. Out of the 15 point with the hyper-eutrophic status, 11 improved into mezotrophic status and 4 into the eutrophic status.

3 Conclusion

Generally it can be said that the quality of groundwater in nitrate vulnerable zones (NVZs) in the Slovak Republic is in the stage of stabilisation on the present level of pollution. Additional care must be taken into account in areas with increasing trend of nitrate concentrations in groundwater, which is approximately 25% of total area designated as NVZs.

Concerning the total trend of fertiliser consumption, which is not possible to reduce now, additional reduction is possible only through the measures in the Action Programme for prevention of leaching of nitrate into groundwater. It needs to be mentioned, that there are relatively few areas (15-20% of total groundwater sources in the Slovak Republic) where nitrates concentrations in groundwater of the Slovak Republic exceeds the standard of 50 mg l^{-1}.

Finally, we can conclude that the assessment of the overall trend in nitrate concentration development shows a decrease of nitrate concentrations in surface waters of the Slovak Republic. Also we can conclude that in the 31 evaluated sampling points there is an influence of agricultural activities, together with influence from point source pollution.

The general evaluation of NVZs can be summarised as follows:
- A stabilisation has taken place of present level of pollution. The current level of pollution is stabilised in all NVZs.
- The progress towards a full recovery is very slow, and it will probably require the period of 15 years or more.

4 References

Anonymous (2001) Kódex správnej poľnohospodárskej praxe v SR – ochrana vôd pred znečistením dusičnanmi z poľnohospodárskych zdrojov, Ministry of Agriculture of the Slovak Republic, Bratislava.

EC (1991) Council directive concerning the protection of water against pollution caused by nitrates from agricultural sources (91/676/EEC), Officiel J. Eur. Commun. No L375.

EC (2000) Nitrates Directive 91/676/EEC, Status and trends of aquatic environment and agricultural practice, Development guide for Members States` reports. European commission, Office for the publications of the European communities, Luxembourg.

SR (2003) Nariadenie vlády SR č. 249/2003, ktorým sa ustanovujú citlivé oblasti a zraniteľné oblasti, Zbierka zákonov č. 249/2003, čiastka 125, str.1490 – 1524.

SR (2004) Nariadenie vlády SR č. 617/2004, ktorým sa ustanovujú citlivé oblasti a zraniteľné oblasti Zbierka zákonov č. 617/2004, čiastka 262, str. 6162.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by Sweden

E. Wirgen and C. Carlsson Ross

Swedish Board of Agriculture, SE-551 82, Jönköping, Sweden
e-mail: carina.carlsson-ross@jordbruksverket.se

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in Sweden and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). Since 2003 there has been a number of changes made in the Swedish monitoring network, both in order to follow up the effectiveness of the EU Nitrates Directive Action Programmes in Sweden, but also in order to fulfil the requirements of the Water framework Directive. A major change of the Swedish Action Programme was made in 2004 when the nitrate vulnerable zones (NVZs) were extended. The emphasis of this paper is on the monitoring programmes and large-scale models used for effect assessment and on the monitoring programmes used for baseline monitoring. Monitoring programmes within the NVZs have been running for a long time. A revision of the monitoring programmes on a national level and some technical changes towards automated sampling has been made since 2003. Improvements in the large-scale simulations of leaching and nutrient loads to the sea have also been made. The methods and results of these simulations are described briefly in this report. Results of simulations show a decrease in root zone leaching and indicate that this reduction is due to changes in land use in combination with measures of the Action Programme to reduce leaching. Whereas some of the national goals for reduction of nutrients will be achieved, it is difficult to fulfil the goal of 30% reduction of nitrogen load to the sea. Some limitations of the strategy to combine monitoring programmes and large-scale simulations are discussed.

1 Introduction

1.1 Goals and measures

Environmental goals

In 1999 the Swedish government adopted 16 different environmental quality objectives. One of them is called zero eutrophication which defines the reduction of nitrogen and phosphorus to the sea and air. The quality objective has been broken down into the following interim targets that are overall targets for all sectors in the Swedish society:

– By 2010 Swedish waterborne anthropogenic emissions of phosphorus compounds into lakes, streams and coastal waters will have decreased by at least 20% from 1995 levels. The largest reductions will be achieved in the most sensitive areas.

- By 2010 Swedish waterborne anthropogenic emissions of nitrogen compounds into sea areas south of the Åland Sea will have been reduced by at least 30% compared with 1995 levels.
- By 2010 emissions of ammonia in Sweden will have been reduced by at least 15% compared with 1995 levels.

Swedens plan of action and its targets

For the agricultural sector, the goals for nitrogen and phosphorus reduction have been further specified. The root zone leaching of nitrogen should decrease by 7,500 tonnes from 1995 to 2010 and the emissions of ammonia should decrease by 7,300 tonnes from 1995 to 2010. For phosphorus the target is a continuous reduction of losses to lakes and rivers. The reason for this is uncertainty about which measures would be most effective to reduce losses of phosphorus.

For phosphorus there is some evidence that losses from agricultural land are decreasing. On a national level, phosphorus emissions from the industry and from wastewater works have decreased by approximately 25% from 1995. However, it is difficult to see changes in emissions to coastal water, probably because the pool of phosphorus in soils and in sediments is large and the complex processes where phosphorus is involved, do not allow any quick changes.

The root zone losses of nitrogen have diminished with 8,000 tonnes from 1995 to 2005 (Johnsson et al., 2008), which means that the interim target for agriculture is reached. Some calculations show a decrease by 24% of the emissions to the sea south of Åland Sea (Brandt et al., 2008), but it still will be difficult to reach the target of a 30% reduction of nitrogen to the sea. For ammonia, the goal of a decrease by 7,500 tonnes is already achieved. Measures of the action plan.

Legislation

One of the strongest and most consequently applied measures is legislation, namely the ‘Ordinance on Environmental Concern in Agriculture and The Swedish Regulation on Environmental Considerations in Agriculture’. The following is only a brief outline of legislation.

Special regulations are implemented within the nitrate vulnerable zones in accordance with the Nitrates Directive In 2003 a revision of the NVZs was made and in 2004 the zones were extended as shown in Figure 1. Farmers should be able to store manure from six to ten months depending on type of animals and size of herd. Storage vessels should also be safe and free from leaks. Spreading of manure is also regulated, especially spreading in autumn and through the winter months, when spreading is often forbidden altogether. It is not allowed to spread fertilisers on sloping land or within 2 m of a watercourse. It also includes minimum shares of land under vegetative cover during autumn and winter.

The maximum application rate of nitrogen from livestock manure is 170 kg of nitrogen per hectare, as stated in the nitrates directive. However, a large majority of farms already comply with this rule, because of a limitation of a maximum application rate of 22 kg of phosphorus per hectare.

Financial instruments
Financial support can be given to farmers that implement measures with the aim to reduce nutrient losses. This is done within the Rural Development Programme (RDP) which is partly financed by the EU. The programme includes buffer strips (1,400 hectares with support), wetland and ponds (6,500 hectares constructed or renewed from 1995-2006) and reduced nitrogen leaching through catch crops and spring tillage (135,000 hectares). From 2007, there is also a support programme for environmental protection measures (240,000 hectares). This consists of a package of measures to be applied by the farmer, including soil analysis for the whole farm, nutrient balances, analysis of slurry and detailed crop planning.

Figure 1 Nitrate Vulnerable Zones (NVZs) in Sweden designated in 1995 (grey areas) and designated in 2004 (hatched areas).

Extension services
The programme 'Focus on Nutrients' is an advisory programme in Sweden with the aim to reduce losses of nutrients to air and water from livestock and crop production. The campaign provides training and advice to farmers. The programme 'Focus on Nutrients' was extended in 2003 and again in 2005 and now covers all areas with major agricultural production, including all the NVZs. It is also possible for farmers outside the NVZs to get advice on environmental questions through the Rural Development Programme.

Research and development
Programmes cover a range of questions related to leaching of nitrogen. In 2008 a new research programme focusing on the decrease of leaching of phosphorus was launched.

1.2 Overview of trends in agriculture

Nitrogen and phosphorus surpluses

Nitrogen and phosphorus balances for agriculture is calculated every second year by Statistics Sweden. Two different methods exist. The farm gate balance method is applied to calculate the balance between input and output at farm level while the soil surface method calculates input and output to the ground. The farm gate method also includes fodder to animals and the actual animals on the farm while the soil surface method doesn't take these into account. The differences between the methods means that the results should not be compared. The most common method to use is the soil surface method since it is based on methods used by OECD and EUROSTAT. The calculation of the balance is based on a combination of interview answers from farmers on manure use and calculations of total agricultural production in Sweden.

Surpluses calculated with the soil surface method
In 2005 the surplus for the Swedish agricultural land was calculated with the soil surface balance method. The surplus was 40 kg of nitrogen and 1.8 kg of phosphorus per hectare, compared to 46 kg and 2.1 kg respectively for 2003. The decrease was larger in inputs than in outputs. Mineral fertiliser nitrogen decreased with 6 kg per hectare and the application of livestock manure with 2 kg per hectare. At the same time, there was a decrease in harvests of 4 kg per hectare. Between the years 1995 and 2005, the surplus of nitrogen in the Swedish agriculture has decreased with 20% which means that the efficiency in nitrogen use on the farms has increased significantly (Statistics Sweden, 2007).

Use of mineral fertiliser
The amounts of mineral fertilisers show a steady decrease over the years. This is true in large for phosphorus as well as for nitrogen after 1973. The decrease in use of fertiliser can be attributed to a higher efficiency in agricultural production due to higher prices for inputs in general in combination with concern to cut costs and to reduce the impact on the environment. There has also been an increase in organic farming, making leguminous plants a more important source of nitrogen. In 2005, 25% of the land was not fertilised at all.

Use and production of manure
The production of manure is slowly decreasing as shown in Figure 3. The assessment is made by Statistics Sweden through interviews with farmers. The decrease in produced quantities is coupled to a decrease in the number of animals. From 1980 to 2007 the number of animals decreased by 20%. From 1995 to 2005 the decrease was 10%. This is counteracted by increasing production per animal. As seen in Figure 4, livestock density is decreasing as an average for the country.

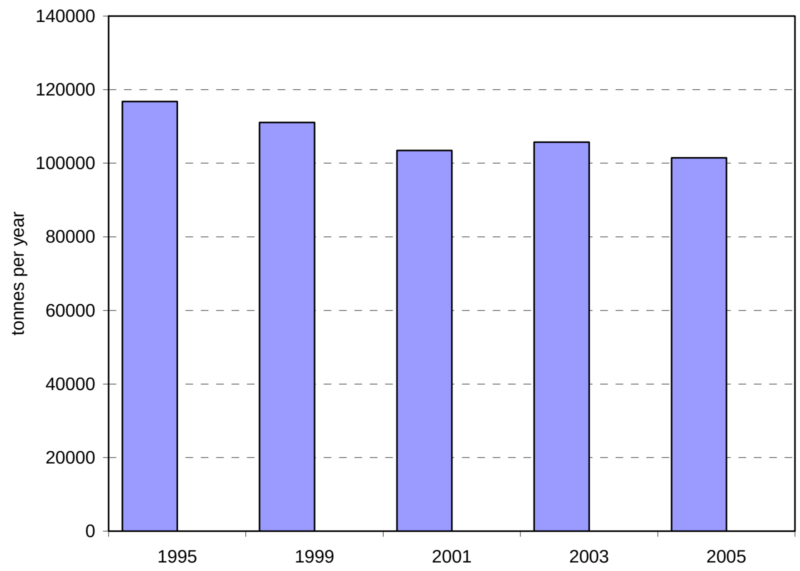


Figure 3 Produced quantities of manure in tonnes per year for the period 1995-2005, (Source: Statistics Sweden, 2007).

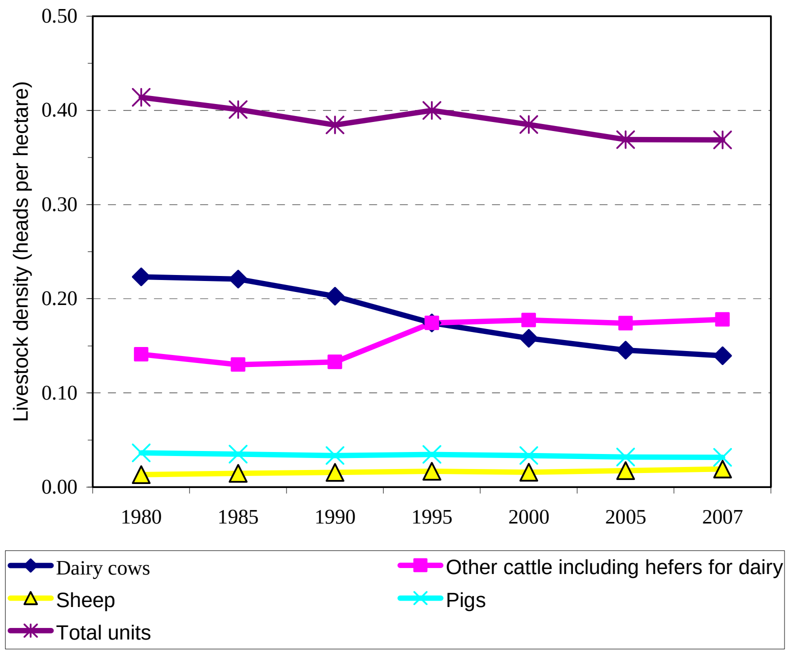


Figure 4 Livestock density (head per hectare), totals and per species, during the period 1980-2007 (Source: Statistics Sweden, 2008).

Major changes in land use

The land use since 1995 is shown in Table 1. A number of factors have an impact on land use. Sweden joined the European Union in 1995. Since then, set-aside and ley has been increasing. Diary production has been undergoing a continuous structural rationalisation, with fewer and bigger farms as a result. The area of intensively grown grass and leguminous plants is much the same, which means that the increase in grass and leguminous plants is of an extensive character. As an effect of financial support and advisory programmes there has also been an increase in the use of catch crops from the year 2000 (Figure 5). Cereal production was increasing until 2005, when the decoupling of the area payment made cereals less profitable. Now cereal production is subject to changes in market prices and cultivation may vary from year to year. Grazing of permanent pastures have been encouraged in the RDPs for the sake of biodiversity, and the area increased up till 2005 when the single payment scheme was introduced (not shown in the table).

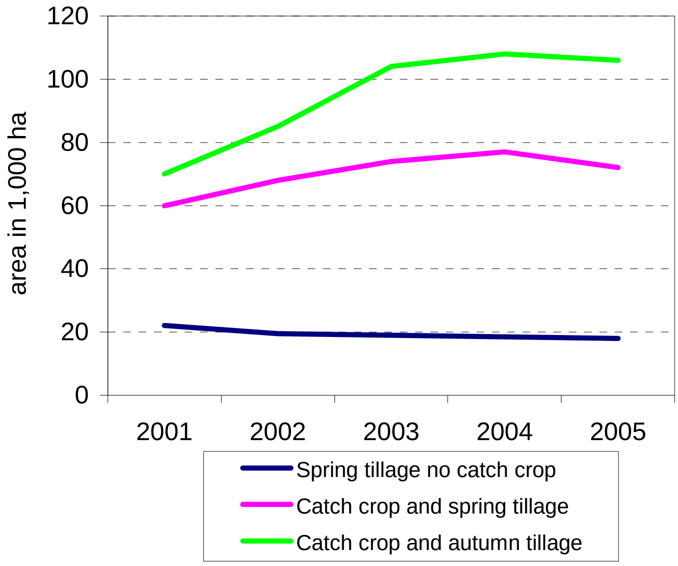


Figure 5 Areas with catch crops and spring tillage (in 1,000 of hectares) in Sweden in the period 2001-2005 (Anonymous, 2007).

Table 1 Arable land use in 1990, 1995, 2002 and 2007, in hectares (Source: Statistics Sweden 2009).

Crop	1990	1995	2000	2007
Cereals	1,335,700	1,104,500	1,228,900	990,100
of which wheat	349,700	261380	401,600	361,500
barley	543,400	453375	411,200	326,700
oats	387,800	278322	295,500	207,900
Leguminous plants	32,700	21,400	37,300	28,600
Ley	968,500	1,058,900	920,800	1,141,800
Potatoes	36,200	35,000	32,900	28,400
Sugar beets	49,900	57,500	55,500	40,700
Oilseed rape and turnip rape	167,900	104,600	48,200	87,800
Other crops	31,600	46,400	55,000	39,500
Set-aside	176,100	278,600	247,700	280,600
Other areas	46,400	59,800	79,700	10,200
Total arable area in Sweden	2,845,000	2,766,700	2,706,000	2,647,700

1.3 Overview of trends in nitrate, nitrogen and phosphorus concentrations

There are many surveys of nutrient levels in water, but it is difficult to find statistically significant time-correlated trend. Concentrations were measured in 34 lakes within the NVZ during 10 years (1997-2006) at 2-4 times per year. Trends were analysed statistically with the Kendall seasonal test Even though the trend analysis was made on data from some of the most eutrophic lakes, few significant trends could be found for nitrate and phosphorus. Only one of the lakes had a significant decrease in nitrate concentration for the period. For the rest of the lakes no significant trends could be found. For total nitrogen there was a decreasing trend for 30% of the lakes. However, because total nitrogen is dominated by organically bound nitrogen, the variation probably reflects normal variation in organic matter (Fölster et al., 2008).

A trend analysis was also carried out for the 211 rivers within the nitrate vulnerable zones in the same way as for the lakes. Nitrate levels, total nitrogen and total phosphorus were measured with a frequency of six to twelve times per year from 1997-2006. Average nitrate levels higher than 10 mg per litre were found in 69 of the rivers. In 13% of the rivers a statistically significant trend for nitrate was found. Decreasing trends of nitrate levels (10%) were more common than increasing trends (3%). This was also true for total nitrogen and total phosphorus. In some cases it was possible to couple these changes to decreased leakage from agriculture (Fölster et al., 2008).

The studies show that in most rivers and lakes, nutrient concentrations vary more between the years, then they do over a longer period of time, but also that, especially for rivers, decreasing trends are more common than increasing trends.

1.4 Overview of monitoring networks

Baseline monitoring

There is an extensive monitoring network in Sweden, which was described more in detail in the report of 2005 (Bång, 2005). In the beginning of 2007, the freshwater monitoring programme was reorganised into a trend programme and a recurrent programme in order to fulfil the requirements of the water framework directive. The trend programme is designed to follow variations between years in a representative group of lakes. Data is collected from groundwater, lakes, rivers and river mouths. The recurrent programme, where 4,824 lakes are measured every sixth year, enables a long-term assessment of the overall environmental status for the country (Swedish EPA, 2008). In 2007 the programme for coastal and marine waters was reorganised in a similar way and the number of measurement points was increased. Monitoring here focuses on three different problems: eutrophication, pollutants and biodiversity (Swedish EPA, 2007). There is also a groundwater monitoring programme run by the Geological Survey of Sweden.

Effect monitoring programmes

The effect monitoring is used to follow up both the biological and chemical state in different waters. The interpretation follows the Swedish EPA’s criteria for assessment, which is a system for classification of environmental data. Along with measurements, model calculations are used. The sub-programmes, ‘Observation Fields’ and ‘Small Catchments’ are specially designed to monitor the effect of agricultural measures. The sub-programmes along with the large-scale simulations will be described in the following chapter.

2 Assessment of effects

2.1 Strategy

The networks and research programmes for effect monitoring were described in detail in the previous workshop report (Bång, 2005). Sweden has an extensive programme for making measurements and storing data, where the Swedish EPA has an important role in supervising measurements, and universities and national agencies are responsible for interpreting and storing the data.

The strategy to follow up the effects of the action programme is a combination of monitoring and modelling leaching. It is important that models take into account local variations and help in finding out how much nitrogen comes from agriculture and from other sources. To estimate the effects of different measures it is also important to see how much nitrogen is of anthropogenic origin and how much is background leaching.

2.2 Technical description of the monitoring networks

The sub-programme Observation Fields

The 13 fields, which are between 4 and 34 hectares, are chosen in a way that there is no incoming surface water from surrounding fields to the drainage system. The fields form part of the ordinary crop rotation of the farms where they are situated. The farmers give a yearly report on crops, manure, tillage, and other agricultural measures taken. The fields are mainly situated within the NVZ.

The Swedish EPA is responsible for the budget of the observation fields as well as for the guidelines for sampling and analysis. The Swedish University of Agricultural Sciences is responsible for the monitoring, stores the data and publishes yearly reports on the results (Löfgren, 2008).

Sampling and analysis of the observation fields
Water flow is measured continuously with a stream gage at a Thomson-weir and is registered with OTT Thalimedes data logging. In this way both surface water and drainage water is measured together. Water samples from the drainage water are taken manually every other week, with a higher frequency at peak flow. Measurements include precipitation and discharge, drainage water flow, groundwater pressure (nine fields), pH, conductivity, Total Organic Carbon (TOC) and wide range of ions including, NH_4, NO_3 and PO_4, as well as total nitrogen and phosphorus.

There are also measurements taken from groundwater, in tubes, where the depth varies from 2 to 6 metres. Samples are taken every other month and groundwater pressure is measured through sounding once a month. The samples reach the laboratory within 24 hours (Johansson and Gustafson, 2008).

Short and long term studies of the observation fields
In the report for the year 2006/2007, graphical representations of the yearly means for the period 1977 to 2006 were also published. Analysis is based on flow-adjusted nitrogen transports. The average values for nutrients of

2006/2007 are also compared to long-term averages. The variations in leaching between years can often be coupled to management measures. Some measures reduce leaching, such as winter crops and crops grown in late autumn. In drainage water, the long-term averages for all the fields are 8.5 mg l^{-1} for NO_3-N and 9.7 mg l^{-1} for total nitrogen. In 2002 a trend analysis was carried out for nitrate but no significant trends were found. The long term average nitrate-N concentrations for groundwater are all between 0.1 mg NO_3-N l^{-1} (minimum) and 9.8 mg NO_3-N l^{-1} (maximum), which is well within the limits of the Nitrates Directive (Johansson and Gustafson, 2008).

The sub-programme Small Catchments

Measurements were started in the 1980s and the number of catchments studied increased to the mid 1990s when 40 catchments were studied. In 2002 the programme was reorganised and at present there are eight catchments in a national programme and seven in different regional programmes. The catchments in the national programme are followed with a higher frequency of measurements compared to the regional programme.

In the eight catchments of the national programme, where arable land makes up 60-95% of the surface area, effects of agricultural measures have been studied more closely. In order to do this, yearly interviews with farmers are made to collect data about crops, manure, tillage, and other information for every field. The catchments are placed in areas with low influence from point sources, which are surveyed regularly. The catchments vary in size between approximately 100 hectares up to 3000 hectares (Löfgren, 2008).

Sampling and analysis of the small catchments
The frequency of measurements for water flow and nutrient concentrations have varied over the years. In 2005, flow-regulated automatic measuring was introduced and is made alongside with manual measurements. Samples are taken every week. Groundwater is also measured, four times per year at three locations per catchment. In the regionally administrated small catchments, measurements are made according to similar principles but with less frequency. Measurements include water flow, total-N, nitrate-N, ammonium-N, total-P and ortho-P (molybdate reactive phosphorus). The samples are analysed at the laboratory of the Swedish university for agricultural sciences and are done according to the Swedish EPA manual (Kyllmar, 2006).

Trend analysis of the small catchments
The trend analysis was done for the eight national small catchments. The aim was to assess the impact of cultivation and use of manures on nutrient loads. Transports were normalised with respect to flow with a semi-parametric statistical model. After this, transports were tested for trends with a Seasonal Mann-Kendall non-parametric test. In two of the eight areas a significant decrease in nitrate levels was found. In none of the areas there was a significant increase of nitrate levels, nor of any other fraction of nitrogen. The decrease in nitrate levels was attributed to an increase of catch crops and grass and in some areas to a decrease in animals and use of manure (Kyllmar, 2006).

2.3 Models

In 2008 two major and related simulations were made as a way of describing and studying leaching from agricultural land and nutrient loads to the sea. The

Fifth Pollution Load Compilation (PLC-5), henceforth called the PLC-5, forms a basis for Sweden in the Baltic Marine Environment Protection Commission, or Helsinki Commission (HELCOM), and is made up of calculations of gross-loads, net-loads and retention (Brandt, et al., 2008). It is further a derivation of nutrient loads to different sources, for instance agriculture, forestry and industry in different regions.

In another simulation of leaching from agricultural land, a comparison was made between normalised leaching in 1995 and 2005 from different types of cultivation, soils, slope gradients, and phosphorus content of the soil. Through this simulation, which we hereafter will call the study of normalised leaching from agricultural land (Johnsson et al., 2008), leaching coefficients were calculated (mg l^{-1}), which were afterwards used in the PLC-5 to calculate the gross load from agricultural land.

The study of normalised leaching from agricultural land

The model
The NLeCCS (Nutrient Leaching Coefficient Calculation System) is a method and a system to calculate normalised leaching of nitrogen and phosphorus from agricultural land. It consists of databases built up around a randomized crop sequence generator, the SOILN(DB) model for nitrate leaching calculations and the ICECREAM(DB) model for phosphorus leaching calculations.

The SOILN model was developed in Sweden in the mid 1980s and has been tested on a series of field trials. The SOILN(DB) database and modelling tool, allows for processing of large quantities of data and reduces the laborious work of setting the parameters.

The ICECREAM model has its predecessor in the CREAMS model from the USA and has been developed in Finland during the 1990s and was adapted to Scandinavian conditions. The model has been enhanced with a unit that calculates porous flow, which is an important way of phosphorus leaching in Sweden. It has then been tested in field trials in western and eastern Sweden with good results. The ICECREAM(DB) database and modelling tool is then built around the ICECREAM model.

In order to generate normalised leaching, climate data for a 20-year period was used and combined with 500 possible crop rotations. In this way the actual distribution of crops of the 2 years can be compared as if there was no difference in hydrological conditions. Coefficients were calculated and compared for 1995 and 2005 for 22 leaching regions, 13 crop classes, 10 soil texture classes, 2 fertilisation regimes, 3 slope classes and 3 soil-phosphorus classes.

Data used for model calculations
The 22 leaching regions are made up of the 18 regions used by Statistics Sweden for agricultural statistics and are then combined with hydrological data from the Swedish Metrological and Hydrological Institute (SMHI). Data about cultivation in each of the leaching regions comes from a database used for administration of farm payments. The soil texture classes follow international classification. Soil P classification is made from 3,200 measuring points, over the country, which have been interpolated to raster data. For calculation of slope classes, contour lines of national digital maps were used. Fertilisation regimes

were calculated from data from Statistics Sweden that generally is based on the 18 regions mentioned above.

Results of modelling loses from agricultural land
The losses of nutrients from agriculture in Sweden vary between different regions, with high leaching in the south and in the west and low leaching in the north and the east. The average losses for the different regions varied between 5 and 47 kg N per hectare. From 1995 to 2005, the overall average leaching dropped from 20.7 to 18.1 kg N per hectare (12%). This corresponds to a decrease in total nitrogen concentration from 6.9 to 6.3 mg N per litre. Going from ‘set-aside with stubble’ to a system that requires a catch crop explains most of the decrease (which explains 26% of the total decrease) together with an increase in the total area of set-aside. In areas where catch crops are cultivated, they were an important reason for the decrease in leaching (21%). Sowing a catch crop or grass in the autumn after the main crop reduces leaching substantially. The measure of only turning the soil in spring instead of in autumn did not prove to reduce leaching on a national level. Some of the change also can be attributed to higher N efficiency in crop management, which means, increasing harvest for the same amount of fertiliser (13%).

The overall average leaching dropped from 0.54 to 0.52 kg phosphorus per hectare (4.4%) whereas total loads decreased with 6%. Leaching and total loads of P decreased more in the north of Sweden than in the south. The main reason for this was substituting ‘set-aside with stubble’ for ‘set-aside with catch crops’ (which explains 38% of the decrease). A clear decrease in fertilisation rates (28%) and a decrease of land with agricultural production (24%) were also important factors and also the creation of buffer zones along rivers and streams (11%).

The PLC-5 study

The principles of the calculations
The aim for the study was to calculate the waterborne nitrogen and phosphorus load on the Swedish coastal waters for the HELCOM PLC-5 reporting. The main principle of this simulation is that gross leaching equals retention plus net leaching to the sea. The loads and the retention were separated with respect to anthropogenic and natural sources, with the aim to allocate the responsibility for the nutrient loads to the sea to regions and type of sources. Nutrient load calculations were normalised for the period 1985-2004 to account for natural climatic variability.

The calculations start out by assessing losses from discharges from both point sources and diffuse sources. Diffuse soil leaching is calculated as a product of the area of a certain land use class (km^2), the average leaching concentrations associated with that land use ($mg\ l^{-1}$), and the specific run-off ($l\ s^{-1}\ km^{-2}$).

Retention is the sum of all the processes that stop nutrients on their way to the sea, including processes like sedimentation and nitrate reduction. Net load is the same as the freshwater discharge at river mouths into the sea.

Data and models
Leaching coefficients from agricultural land came from the study of normalised leaching from agricultural land and were calculated with the SOILN(DB) and the ICECREAM(DB) models. Calculations were made for 12,879 catchments, which

were then summed up into 1,100 PLC-5 areas. A large number of different sources were used for input data. For precipitation, temperature and data about water levels in different dams, data from the SMHI was used. Soil analysis was made in a survey of agricultural land in the late 1990s. The soil texture classes follow international classification. For leaching coefficients from forest, calculations were made out of a combination of tree height, which reflects soil fertility, and from leaching coefficients from previous studies. The percentage of clear fellings as well as tree height came from data from the Swedish Forest Agency. Nitrogen deposition on lakes came from monthly data for NOx and NHx calculated with the MATCH model. Phosphorus deposition on lakes was measured at 19 stations with an estimated average of 4 kg P km^{-2} for all of Sweden. Water discharge was calculated with the HBV model, which has been used by Swedish industry many years. Point source loads were taken from a database (EMIR) used by Swedish authorities. To calculate retention in lakes and rivers the model HBV-NP was used. This model is a development of the HBV model.

Results of modelling with relevance to nitrogen
The net load of total nitrogen on the sea was estimated to 109,100 tonnes per year. The retention under root zone reduced leaching from agricultural land by 19-23%. The retention of nitrogen in surface waters varied between 0% and 93% for different sub-basins. For diffuse sources including forestry and agriculture 97,900 tonnes reached the sea of a total of 134,700 tonnes (27.3% retention). When leaching originated from land far away from the sea, very little nitrogen eventually reached the sea. The size of retention was primarily dependent on nutrient load, weather/climate and the proportion and characteristics of lakes.

Results of modelling with relevance to phosphorus
The net load of total phosphorus on the sea was estimated to 3,030 tonnes per year. This is the first study of this kind where retention of phosphorus has been modelled. There are very large variations in retentions of phosphorus, and water flow has a major impact. Because of this and because total-P and ortho-P are the main fractions measured, it has been difficult to calibrate the retention of P. For diffuse sources including forestry and agriculture 2,710 tonnes reached the sea of a total of 3,930 tonnes (31% retention). The correlation between retention and distance from the sea was stronger for phosphorus than for nitrogen.

Comparison with field measurements
The outcome of the simulation of net load is very close to measured levels of nutrient transport at river mouths. A comparison was also made between simulated and calculated river mouth transport from some of the main rivers in Sweden. There was a good correlation for nitrogen and somewhat poorer correlation for phosphorus. In north Sweden this can be explained with peak flows in spring. In the south of Sweden there is better correlation for both nitrogen and phosphorus and correlation seems to be very good in areas with a high load of nutrients.

It is also possible to compare simulated nutrient leaching from agricultural land with calculated transport in small rivers in agricultural areas. Such comparisons generally show that nitrogen transport and nitrogen concentrations can be predicted with this type of simulation. Phosphorus simulations, however, seem to be less accurate probably because the method is new for phosphorus. In this context it could also be mentioned that if the crop mix and cultivation measures are very different in the studied catchment compared to the average of the region, simulated leaching might not reflect the real situation. However the goal with this simulation is to assess leaching to the sea and not in single catchments.

2.4 Data interpretation

Compliance checking

For compliance checking data from the national monitoring programmes, as described earlier, have been used. The reorganisation of the programmes in 2007 will not necessarily lead to any major change in the choice of sampling stations. Levels of nitrate in lakes and rivers are generally low. Decreasing trends of nitrate, that can be proven as statistically significant, are more common than increasing trends. Levels in the sea are also measured, but do not reflect pollution load, because of complicated biological and chemical processes.

Underpinning of measures

Field studies and simulations contribute to measures for the NVZs. It has been possible to evaluate the effect of different management practices through the monitoring networks and through simulations. Some of these measures are catch crops, buffer zones, and rules about catch crops on set-aside. In simulations it is also possible to distinguish how measures work in different geographical areas and on different soils. Evaluations of these measures also show that they have been effective and are a way to reach the interim goals for agriculture.

The effect of wetlands and ponds are difficult to evaluate from national monitoring data. In this case, assessment of nutrient reduction has been made in other ways, for example, on site measurements and research.

Measurements have been carried out for a long time in the monitoring programmes. The combinations of data from the monitoring programmes, from simulations and from different research projects make a good basis for evaluating agricultural management practises. However when new measures are suggested more research has to be carried out.

3 Discussion

Model calculations show that leaching from agriculture is decreasing. This is also consistent with the study of surpluses from national balances which indicates that nutrient efficiency has increased on a farm level, as well as on a national level. Measures like environmental extension programmes as well as financial support for different practises to reduce nutrient loses from the fields and regulations have all contributed to this.

It is generally recognized that nitrogen causes algal growth in the sea and that phosphorus is the main cause of eutrophication in fresh waters. This redirects focus in freshwater monitoring of nitrogen, firstly towards reduction of leaching from different sources and secondly to nitrate levels in groundwater.

The first large-scale simulations were made in a project to describe nutrient loads on the sea in the mid 1990s. Since then the technique has been refined and the project described in this report is the third large-scale simulation. Before this, the SOILN model, calibrated with field trials and the monitoring programmes were used to describe the effects of different measures in agriculture. Parallel to the development of simulations, the models have been refined and knowledge has increased through research on leaching. The large-scale simulations have resulted in better means to quantify the effects of different agricultural practises. We have a much better picture of the geographical distribution of leaching than before the modelling started.

The accuracy of the outcome naturally depends on the data being used. Extensive work has been made to use high quality input data and also to improve the simulations by comparing the results with measurements of leaching from fields as well as at river mouths. One possible restriction may be that data for fertilisation was gathered for Sweden divided into 18 regions. Interpretation of the results, using a finer scale than this, should be done with some care.

It is often not possible to relate changed management practices to changes in leaching in the national monitoring programme. When making a trend analysis on catchment level it is often difficult to relate the trend to a change in farm management even though this has been possible in some catchments. The effect of different management practices may counteract each other or add up in a way, which makes it difficult to discern the origin of the change. This is particularly true for catchment studies. Even though point sources are surveyed, we do not have full control of changes in retention or in most cases, very little knowledge of the size of the retention that takes place

The catchment studies and the observation fields have been used to refine the models used in the leakage simulations. This seems to be a cost-effective way of using the results, because models describe the complex processes better than simple trend analysis would do.
The large-scale simulations are well-correlated with the total load of nutrients on the sea, even though there is hope of improving the models for phosphorus still further. Leaching can also be calculated accurately for different regions as long as high quality management data is available. Model calculations of nutrient losses from agricultural land is a good complement when evaluating the effect of the action programme, but can only partly replace the actual monitoring. One of the largest problems with models so far, is that they don't give reliable results on a regional level but can be used with some certainty on a national scale. For the regional scale, measurements are still very important to asses the effects of different management practises.

4 References

Anonymous (2007) Sustainability in Swedish Agriculture 2007 (in Swedish; Hållbarhet i svenskt jordbruk 2007). Statistics Sweden, Stockholm, Sweden (http://www.scb.se/statistik/_publikationer/MI9999_2007A01_BR_MI72OP0701.pdf).

Bång, M. (2005) Monitoring effectiveness of the EU Nitrates Directive Action Oprogrammes; apporach by Sweden. In: Monitoring effectiveness of the EU Nitrates Directive Action Programmes (ed. by B. Fraters, K. Kovar, W.J. Willems, J. Stockmarr and R. Grant) (Results of the international MonNO$_3$ workshop in the Netherlands, 11-12 June 2003, pp. 199-215, Bilthoven, RIVM report 500003007.

Brandt, M, Ejhed, H, Rapp, L. (2008) Nutrient Load on the Baltic, Skagerack and Kattegatt 2006 – Swedens contribution to The Fifth Pollution Load Compilation of HELCOM (Summary in English) (In Swedish; Näringsbelastning på Östersjön och Västerhavet 2006. Underlag till Sveriges PLC-5 redovisning till HELCOM). Swedish EPA. Stockholm, Sweden, report 5815.

Fölster, J, Wallin, M and Djodjic, F (2008) Underlag för rapportering av tillstånd och trender i svenska ytvatten enligt nitratdirektivet. Swedish University of Agricultural Sciences. Working material.

Johansson, G. and Gustafson, A. (2008) Observation fields on arable land. Discharge and nutrient losses for the agro-hydrological year 2006/07 and long time review. Swedish University of Agricultural Sciences, Division of Water Quality Management, Uppsala, Sweden, Technical Report 121.

Johnsson, H., Larsson, M., Lindsjö, A., Mårtensson, K., Persson, K. and Torsensson, G. (2008) Leaching of nutrients from arrable land in Sweden-Calculation of nutrients of nitrogen and phosphorus for 1995 and 2005 (Summary in English) (in Swedish; Läckage av näringsämnen från svensk åkermark – Beräkningar av normalläckage av kväve och fosfor för 1995 och 2005). Swedish EPA, Stockholm, Sweden, report 5823.

Kyllmar, (2006) Small catchments dominated by arable land (in Swedish; Typområden på jordbruksmark). Swedish University of Agricultural Sciences, Division of Water Quality Management, Uppsala, Sweden, Technical Report 114.

Löfgren, (2008) Revision of the plant nutrient programmes – Observation Fields and Small Catchments (in Swedish; Revision av växtnäringsprogrammen – observationsfält och typområden). Swedish University of Agricultural Sciences, Uppsala, Sweden, Report.

Statistics Sweden (2007) Nitrogen and phosphorus balances in agricultural land and agricultural sector in 2005. Stockholm, Sweden, report MI 40 SM 0701, ISSN1403-8978.

Statistics Sweden (2009) Online statistics produced by Statistics Sweden. Stockholm, Sweden, www.scb.se.

Swedish EPA (2007) Kust och hav, revision av nationell miljöövervakning (Coastal and marine waters, a revision of national monitoring programs, in Swedish). Stockholm, Sweden, report 5718.

Swedish EPA (2008) Sötvatten, revision av nationell miljöövervakning, (Freshwater a revision of national monitoring programs, in Swedish). Stockholm, Sweden, report 5870.

Developments in monitoring the effectiveness of the EU Nitrates Directive Action Programmes: Approach by the United Kingdom

S.J.M. Noel[1], S. Dawes[1], F. Brewis[2], V. Fitzsimons[2], O. Ruddle[3] and E. Lord[4]

[1] *Department for Environment, Food and Rural Affairs (Defra), Water Quality Division, Ergon House, Horseferry Road, London, SW1P 2AL, United Kingdom*
e-mail: Stephen.noel@defra.gsi.gov.uk or simon.dawes@defra.gsi.gov.uk

[2] *Scottish Government – Water Air Soils and Flooding Division, 1-H Victoria Quay, Edinburgh, EH6 6QQ, United Kingdom*
e-mail: Francis.Brewis@scotland.gsi.gov.uk or Vincent.Fitzsimons@SEPA.org.uk

[3] *Environment and Heritage Service, 23 Castle Place, Belfast, BT1 1FY, United Kingdom*
e-mail: orla.ruddle@doeni.gov.uk

ADAS Wolverhampton HQ, Woodthorne, Wergs Road, Wolverhampton, WV6 8TQ, United Kingdom
e-mail: eunice.lord@adas.co.uk

Abstract
This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the United Kingdom (UK), including England, Scotland and Northern Ireland, and its developments since 2003. The legal requirement for this type of monitoring originates in the Nitrates Directive, Article 5 (6). The UK has well-developed networks for measuring nitrate concentrations in surface waters and groundwater – both networks have improved significantly in recent years. Since 2004, England has adopted a multi-strand approach to effects monitoring which follows the recommendations in the draft EU monitoring guidelines. The whole approach is based around the linkage between field measurements and modelling, and aims to exhibit the impact of the Action Programme measures on nitrate concentrations over time. Scotland, Wales and Northern Ireland have developed similar strategies in relation to their own territories. The UK has considerable experience of several aspects of effects monitoring, some of which are explained in this paper.

1 Introduction

1.1 Environmental goals and measures

Goals

The United Kingdom (UK) aims to reduce water pollution caused by nitrogen from agricultural sources and to prevent such pollution in the future. It has not established any specific targets for the reduction of nitrates. Instead, an Action

Programme in the UK is considered to be effective if sustained, downward trends in nitrate concentrations are identified through the national and farm level monitoring network.

Measures

NVZ Designation

ENGLAND – In 1996, 8% of the country was designated as nitrate vulnerable zones (NVZs). This was increased in 2002 to 55%, and again in 2009 to approximately 70% of England (Figure 1). These increases were a result of periodic reviews of water quality in England, in accordance with the Nitrates Directive requirement.

Figure 1 Designated nitrate vulnerable zones (NVZs) in Britain (Defra, 2008a).

SCOTLAND – a total of 14.3% of land has been designated for the protection of groundwater (smaller surface water NVZs have been subsumed within these groundwater NVZs). These designations were implemented in 2002, and have remained unchanged since (Figure 1).

WALES – in 1996, two very small NVZs were designated. In 2002, following a review of water quality, the area designated was increased to approximately 3%. As of 1 January 2009, the NVZs were extended again to cover approximately 4% of Wales (Figure 1).

NORTHERN IRELAND – Seven small areas, covering less than 0.14% of the country, were designated as NVZs (three in 1999 and four in 2003). Following a consultation undertaken in July 2004, Article 3.5 of the Directive was adopted which established Northern Ireland as the area to which an Action Programme should be applied. This ‘whole territory’ approach came into operation on 1 January 2007.

Action Programmes
A common set of Action Programme measures have been established in all countries in the UK albeit with small differences in relation to some detailed aspects (for example, in regards to the start and end dates of closed periods, that means, periods wherein it is not allowed to apply fertilisers). These differences reflect the environmental conditions prevalent in each country.

The key measures in the current Action Programmes are outlined below.
- A limit of 170 kg N ha^{-1} per year of livestock manure N that is produced on the farm, allowing for livestock manure N that is moved onto the farm or taken off the farm.
- A minimum storage capacity requirement of six months for pig slurry and poultry manure, and five months for all other livestock manures. New or modified stores must meet the appropriate construction standards. Controls on the temporary storage of solid manures in field heaps.
- A requirement to plan the applications of all nitrogen fertilisers for each crop in each year, before any nitrogen is applied.
- A limit on the rate of nitrogen fertilisers that may be applied to individual crops, for example 300 kg N ha^{-1} on grassland. The contribution of crop available manure N to the limit must be calculated using mandatory values for the manure N coefficient (% of total N applied).
- Closed periods during the autumn and winter on all soil types for the spreading of high readily available organic manures to land, ranging from three to five months depending on the soil type and cropping. A closed period for the spreading of chemical nitrogen fertiliser to land.
- Controls on where nitrogen fertilisers may be applied including a requirement to produce a farm-level risk map showing areas that are suitable for spreading manures and for storing solid manures in field heaps.
- Controls on how nitrogen fertilisers are applied so that nitrogen fertiliser or nitrogen-enriched surface run-off does not reach surface waters.
- A requirement to keep specific records for at least five years.

Full details of the Action Programmes can be obtained via:
- England – www.defra.gov.uk/environment/water/quality/nitrate
- Scotland – www.scotland.gov.uk/topics/agriculture/environment/NVZintro
- Wales – www.wales.gov.uk/topics/environmentcountryside/consmanagement/NVZ
- Northern Ireland – www.ni-environment.gov.uk/water-home/agri_regs/nitrate.htm

Derogation
Both Britain (England, Scotland and Wales) and Northern Ireland submitted requests for a derogation to the limit of 170 kg ha^{-1} of nitrogen (N) produced in livestock manures as set out in Annex III/2 of the Directive. The derogation for Northern Ireland was approved by the European Commission (EC) on 15 October 2007. The derogation for England, Scotland and Wales was approved by the EC on 10 March 2009. Although these were two separate requests, effectively the whole of the UK now has the same derogation (Defra, 2008a).

The derogations are applicable throughout the UK and set a limit of 250 kg ha^{-1} of N produced by grazing livestock, but only on farms that have more than 80% of their land as grassland. Derogated farms are required to comply with legally binding measures that are additional to those that have been implemented into national Action Programmes. These additional measures will result in further reductions in the losses of nitrate and phosphorus to water (Defra, 2008a). The additional measures include:

- Livestock manures may not be spread on grassland that is to be cultivated in the autumn.
- Temporary grassland on sandy soils must be cultivated in the spring.
- Ploughed grass shall be followed immediately by a crop with a high nitrogen requirement.
- The crop rotation shall not include leguminous or other plants fixing atmospheric nitrogen.
- The results of nitrogen and phosphorus analysis in soil shall be available. Sampling and analysis must be carried out at least once every four years for each homogeneous area of the farm.
- A fertilisation plan must be prepared for each field using an approved method.
- A P surplus of 10 kg ha^{-1} per year must not be exceeded (Northern Ireland only).

It is estimated that the number of farms seeking a derogation will be up to 1.3% of all farms (1.5% of agricultural land) in Britain. It is estimated that this number is around 400 farms in Northern Ireland.

1.2 Overview of trends in nitrogen and phosphorous loads and surpluses

Trends in N and P surplus in agriculture

The OECD (Organisation for Economic Co-operation and Development) publishes national soil surface balances for nitrogen and phosphorus from agricultural land according to a standard calculation methodology (OECD, 2001). The balance measures the difference between nitrogen inputs and outputs to agricultural land and provides information on potential losses to the environment including water.

Figures 2 and 3 show the changes in the OECD balances for nitrogen and phosphorus from agriculture in the UK between 1985 and 2002 (the latest year with a calculated balance). During this period, the nitrogen balance has declined from 46 to 22 kg N ha^{-1}, and the phosphorus balance from 15 to 12 kg P ha^{-1}.

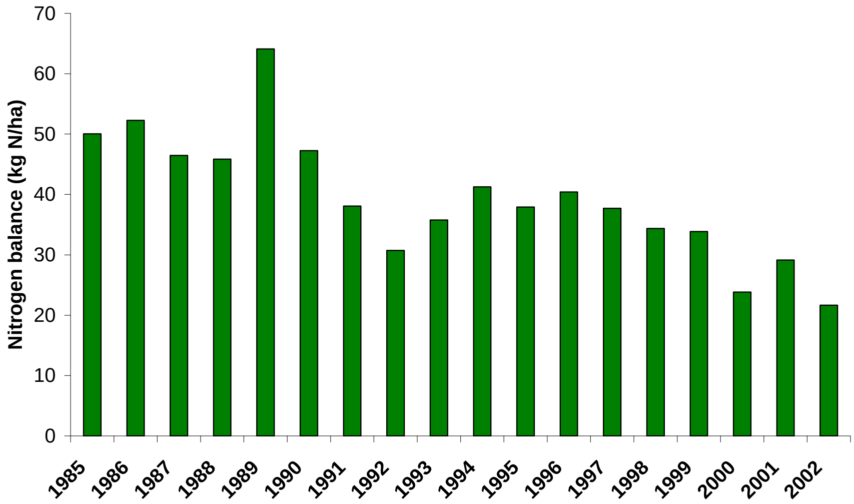


Figure 2 Soil surface nitrogen balance for the UK between 1985 and 2002 (OECD, 2001).

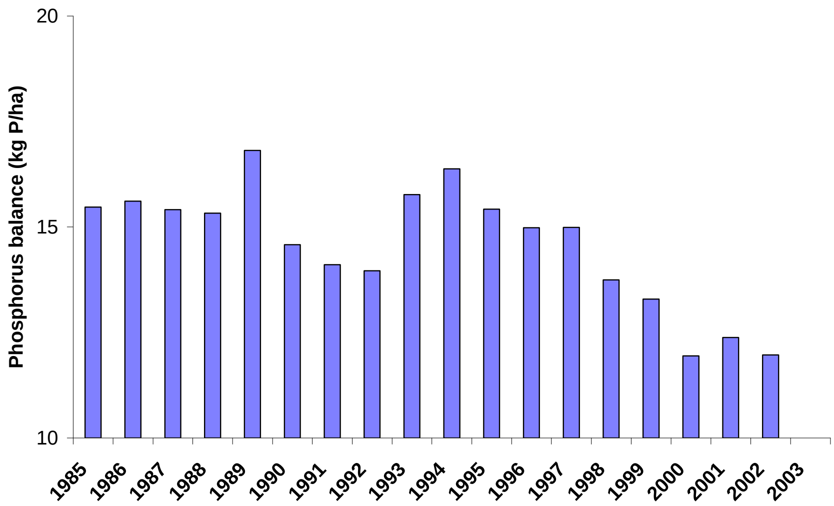


Figure 3 Soil surface phosphorus balance for the UK between 1985 and 2002 (OECD, 2001).

Possible causes for the reduced nutrient surpluses

Reduced use of artificial fertiliser
Each year since 1983, information on the use of chemical fertilisers in British agriculture has been collected as part of the annual British Survey of Fertiliser Practice (BSFP).

These data show that the use of chemical fertilisers has reduced significantly between 1987 and 2007. The total use of chemical nitrogen fertiliser has reduced by 42% in this period, from a maximum of 1,720,000 tonnes of N in 1987 to 1,050,000 tonnes in 2007 (Figure 4). In the same period, the use of chemical phosphorus fertiliser has reduced by 49%, from 214,000 to 107,000 tonnes (Figure 5).

During this same period agricultural productivity has increased, indicating that the efficiency of use of chemical fertilisers by farmers has greatly improved. Advice, regulation and the promotion of good farm practices by Government and the farming industry have been key factors that have resulted in these changes. Farmers now have a much better understanding of the importance of careful nutrient management and the methods for deciding optimum applications.

Reduced use and/or production of manure
Approximately 90 million tonnes of livestock manure are applied annually to agricultural land in the UK (Williams et al., 2000). However, it is likely that this quantity will gradually decline due to the continuing decline in livestock numbers, particularly for pigs and dairy cattle (Figure 6).

Many farms manage their livestock on straw-based systems and produce straw-based solid manure. Around 48% of the total production of livestock manure is handled as solid manure (39 million tonnes of straw-based farmyard manure and 4 million tonnes of poultry manure). Other farms operate slurry-based systems and around 52% of all livestock manure is handled as slurry (42 million tonnes of cattle slurry and 5 million tonnes of pig slurry).

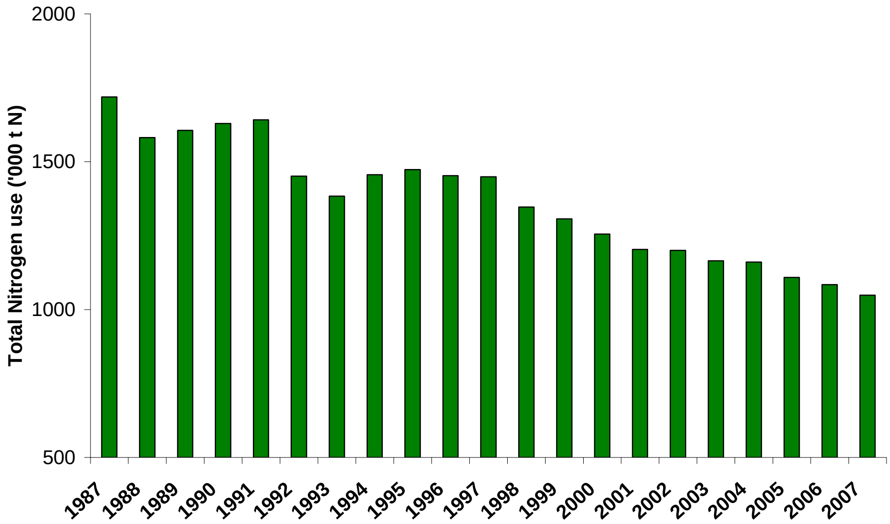


Figure 4 Total use of chemical nitrogen fertiliser between 1987 and 2007 (BSFP, 2007).

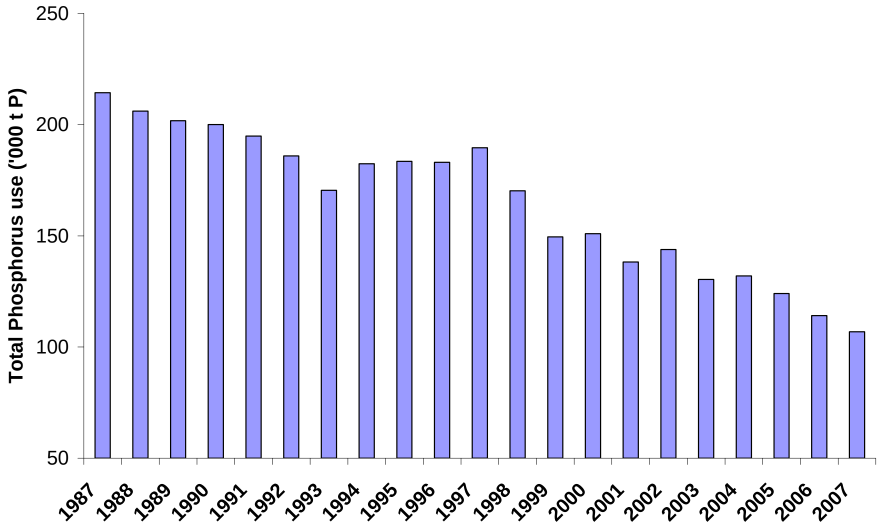


Figure 5 Total use of chemical phosphorus fertiliser between 1987 and 2007 (BSFP, 2007).

Each year, manure is applied to approximately 19% of arable/horticultural land (0.9 million hectares) and 44% of grassland (2.4 million hectares) in Britain.

Livestock manures are estimated to supply approximately 450,000 tonnes of total nitrogen (N) of which a proportion is readily available for crop uptake. In addition, these manures are estimated to supply 120 tonnes of total phosphorus (P) and 330 tonnes of total potassium (K) (Defra, 2008a).

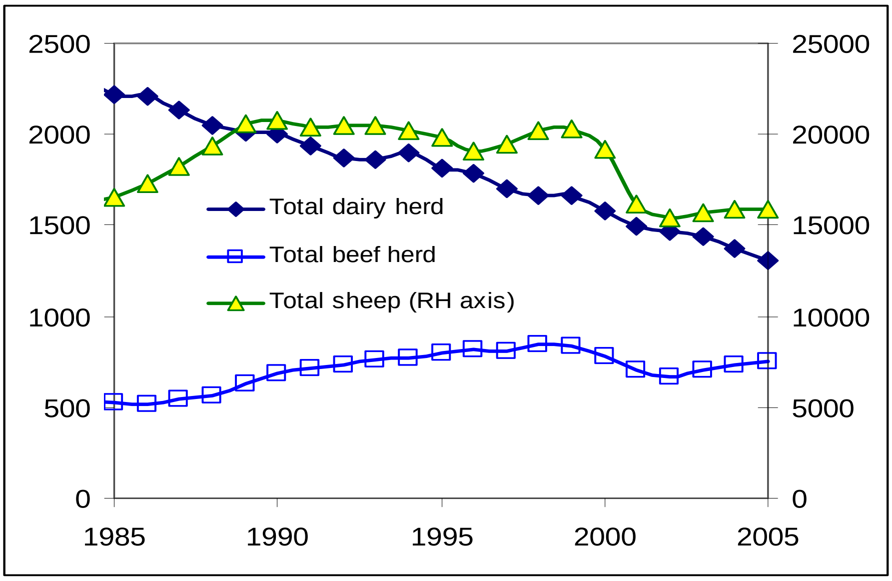


Figure 6 Total number of grazing livestock in the UK (Defra, 2007).

Major changes in land use

Figures 7 and 8 provide summaries of Agricultural Survey estimates for areas of individual major crops, crop groupings and total tillage and grassland categories from 2000 to 2006. There were about 10.6 million hectares of managed agricultural land in 2006 of which 4.3 million hectares (40%) were cultivated for tillage cropping and the remainder, 6.3 million hectares, were grassland (excluding rough grazing). This can be compared to 10.4 million hectares of managed agricultural land in 2000 of which 4.5 million hectares (44%) were cultivated for tillage cropping and the remainder, 5.8 million hectares, were grassland (excluding rough grazing) (BSFP, 2001-2007).

1.3 Overview of trends in nitrate and phosphorus concentrations

Trends in nitrate and phosphorus concentrations

In England, there has been a gradual reduction in the river length with a nitrate concentration over 30 mg l^{-1}. Since 2000, the percentage of the total river length in England with over 30 mg l^{-1} of nitrate has reduced from 39% to 32% (Figure 9). These improvements will in part be due to better farm and nutrient management practices, reduced livestock numbers and reduced use of chemical nitrogen fertilisers (Environment Agency, 2006).

In Wales, there was a large reduction in the river length affected by large phosphate concentration since 1990, from 26% to 10% in 2007. The length of river affected by high nitrate concentration has been between 0% and 1% between 1990 and 2007.

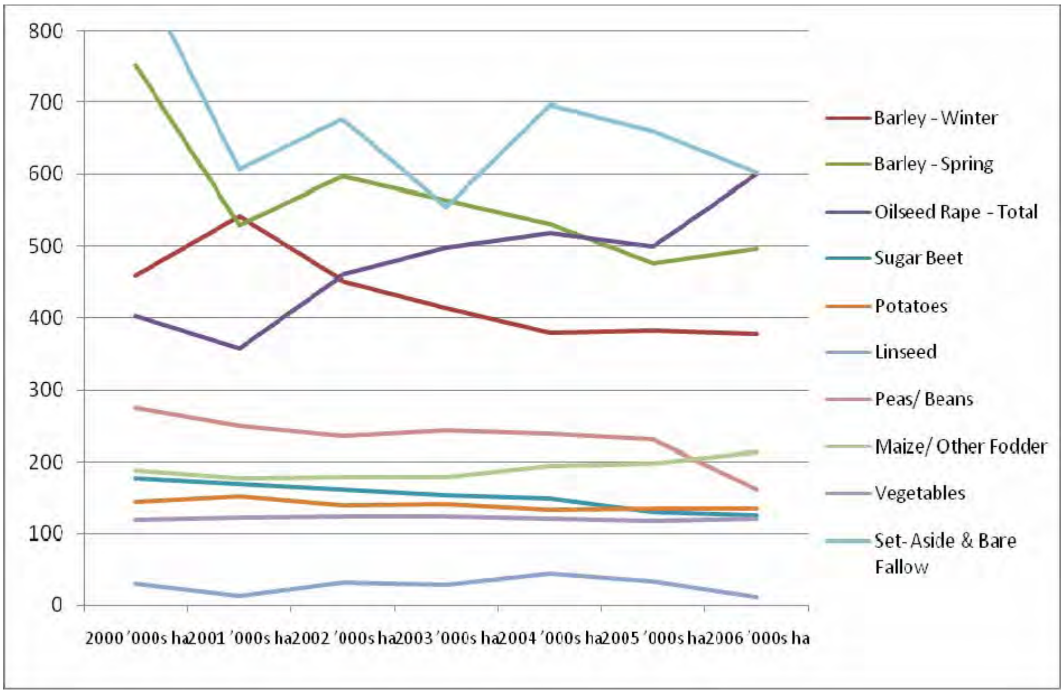


Figure 7 Cropping areas (×1000 ha) in Great Britain 2000-2006 (BSFP, 2001-2007).

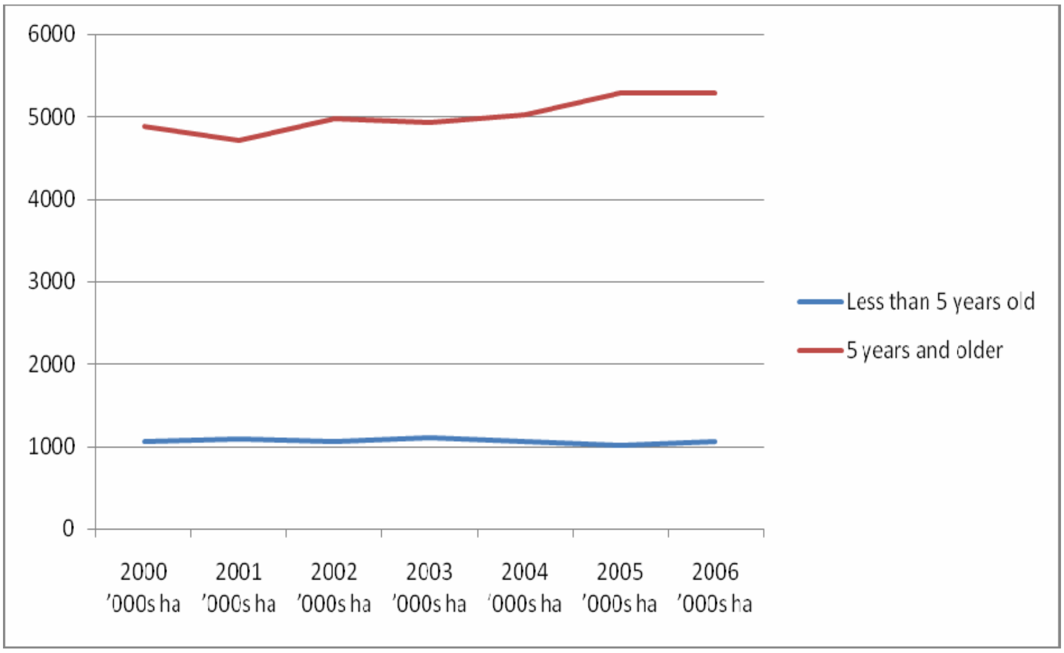


Figure 8 Grassland areas (×1000 ha) in Great Britain 2000-2006 (BSFP, 2001-2007).

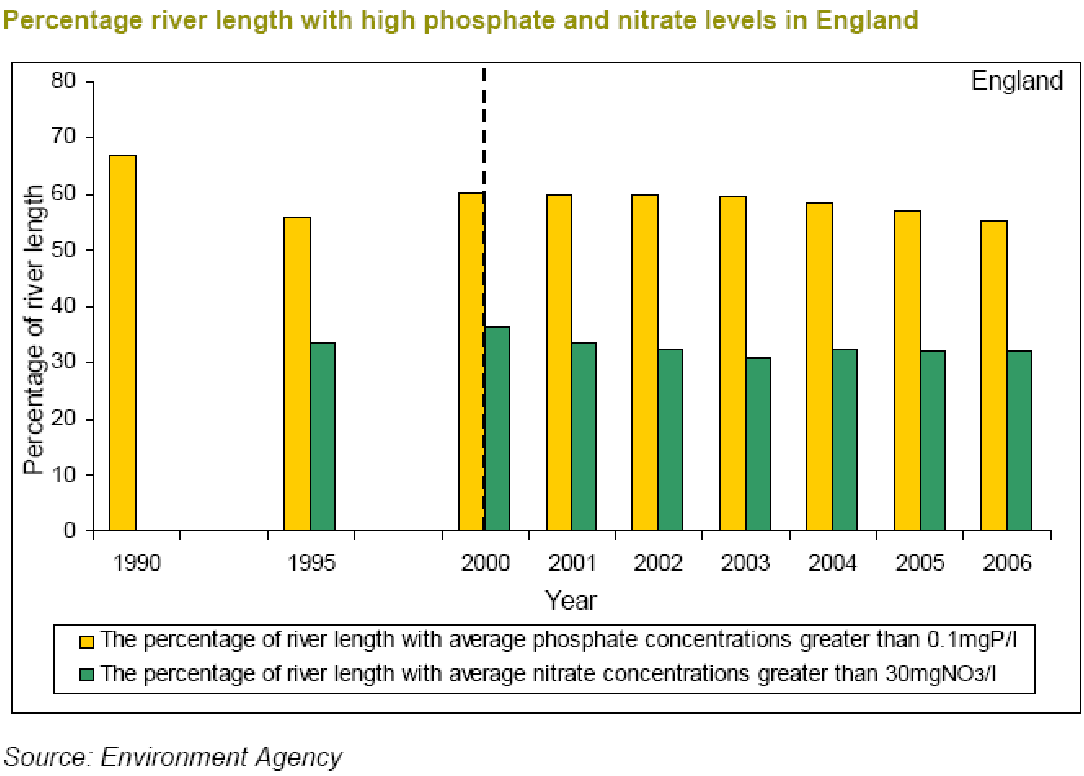


Figure 9 Percentage of river length with high phosphate (> 0.1 mg l^{-1}) and high nitrate (30 mg l^{-1}) levels in England (Source: Environment Agency, 2006).

Possible causes for changes in N and P concentrations

As outlined in section 1.2, reductions in the use of artificial fertilisers and livestock manure, and an increase in grassland, have all lead to a decrease in nitrate levels. Other factors likely to be responsible for the observed reduction in nitrate and phosphorous concentrations are discussed below.

Agricultural measures to limit leaching
It is estimated that the NVZ Action Programme, implemented in England between 1998 and 2008, reduced mean nitrate concentrations by 5-15% in areas with sandy and shallow soil and large numbers of livestock, and by about 2-7% overall (Defra, 2008b).

Code of Good Agricultural Practice
Each country in the UK has its own Code of Good Agricultural Practice which provides advice on best practices for preventing environmental pollution from farming activities. These Codes are being actively promoted throughout the UK and there is evidence to demonstrate that adherence to these Codes is improving, which will have associated positive benefits for the environment.

1.4 Overview of monitoring networks

Monitoring for the identification of waters affected by agricultural nitrate pollution

Groundwater monitoring networks
Monitoring of groundwater quality has increased significantly in recent years, with the objective of better defining the quality of the resource as well as of water abstracted for drinking. Figure 10 and Table 1 presents groundwater sites with measured data for 2002-2003 and 2006-2007.

The sites have been provisionally classified into major aquifer (those sites falling within a defined groundwater which is a major supplier of water) and other sites. The major aquifers are dominantly chalk, limestone and sandstone, and most are deep. The ‘other’ group contains sites not identified as being on major aquifers, and sites with very rapid response (< 10 years). It includes many boreholes which supply only small quantities of water, drawing on small local resources, shallow alluvial groundwaters and other sources which are separate from the main aquifers.

Table 1 Groundwater sites with measured data across the UK (Defra, 2008c).

Country	2002-2003	2006-2007	Common points
England	1,652	2,555	1,557
Scotland †	219	198	172
Wales	40	223	39
Northern Ireland	80	85	75
United Kingdom	1,991	3,061	1,843

† Scotland data is for 2000-2003 and 2004-2007, respectively.

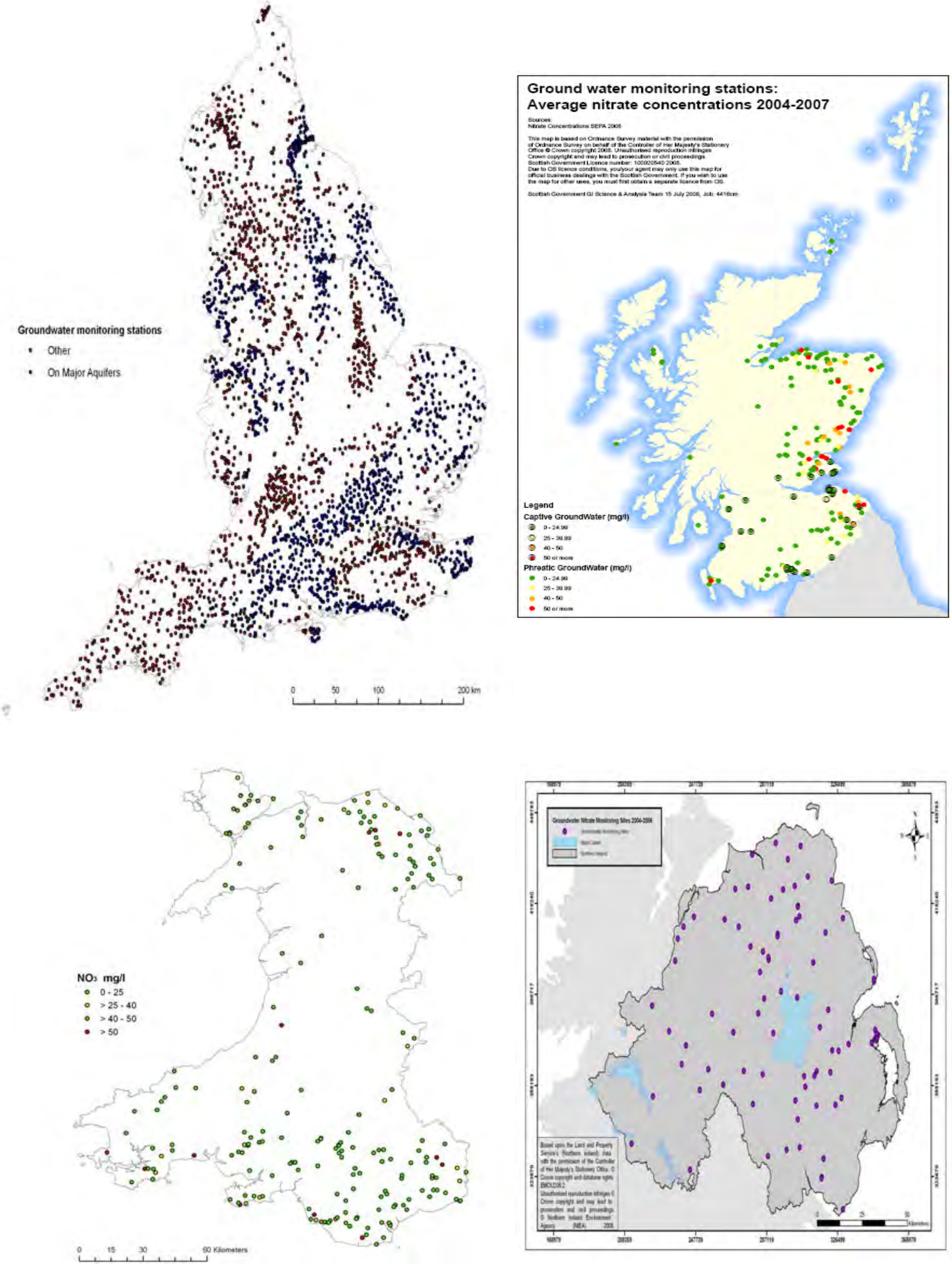


Figure 10 Maps of groundwater monitoring stations across the UK (current monitoring period 2004-2007) (Defra, 2008c).

Response times on some of these 'other' sites are expected to be faster than for the major aquifers. Many will have small catchment areas, making prediction of future water quality difficult without detailed local information. The purpose of the classification, carried out by the British Geological Survey, was to separate the major resources whose quality is of paramount importance both for drinking water and for baseflow in rivers, from others which typically represent smaller local resources, may be shallower, and may be less intensively monitored.

In England the great majority (83%) of groundwater monitoring points have mean nitrate concentrations of less than 50 mg l^{-1} nitrate, and more than half have concentrations below 25 mg l^{-1} nitrate.

In Scotland, for groundwater, concentrations were generally higher than in surface water stations. More than 15% of stations had annual average concentrations in excess of 40 mg NO_3 l^{-1} and 17% had maximum results in excess of 50 mg NO_3 l^{-1}l.

In Wales the great majority (95%) of groundwater monitoring points have mean nitrate concentrations of less than 50 mg l^{-1} nitrate, and 84% have concentrations below 25 mg l^{-1} nitrate.

Monitoring for the period 2004-2006 in Northern Ireland shows 87% of sites had an annual average of less than 40 mg NO_3 l^{-1} and 78% less than 25 mg NO_3 l^{-1}. When maxima are considered, 64% of sites had concentrations less than 25 mg NO_3 l^{-1}.

Surface water monitoring networks
Monitoring of surface water quality has also increased significantly in recent years. Figure 11 and Table 2 presents surface water monitoring sites with measured data for 2002-2003 and 2006-2007.

Table 2 Number of surface water monitoring stations for nitrate concentrations (Defra, 2008c).

Country	2002-2003	2006-2007	Common points
England	5,974	6,929	5,814
Scotland †	361	470	225
Wales	842	981	812
Northern Ireland	382	623	339
The United Kingdom	7,559	9,003	7,190

† Scotland data is for 2000-2003 and 2004-2007, respectively.

Monitoring to assess Action Programme effectiveness on receiving water and monitoring the effects of Action Programmes on nitrate sources
The UK has monitoring networks in place in order to assess the effectiveness of the regional Action Programme. Details of this are outlined in the next chapter 'Effect monitoring'.

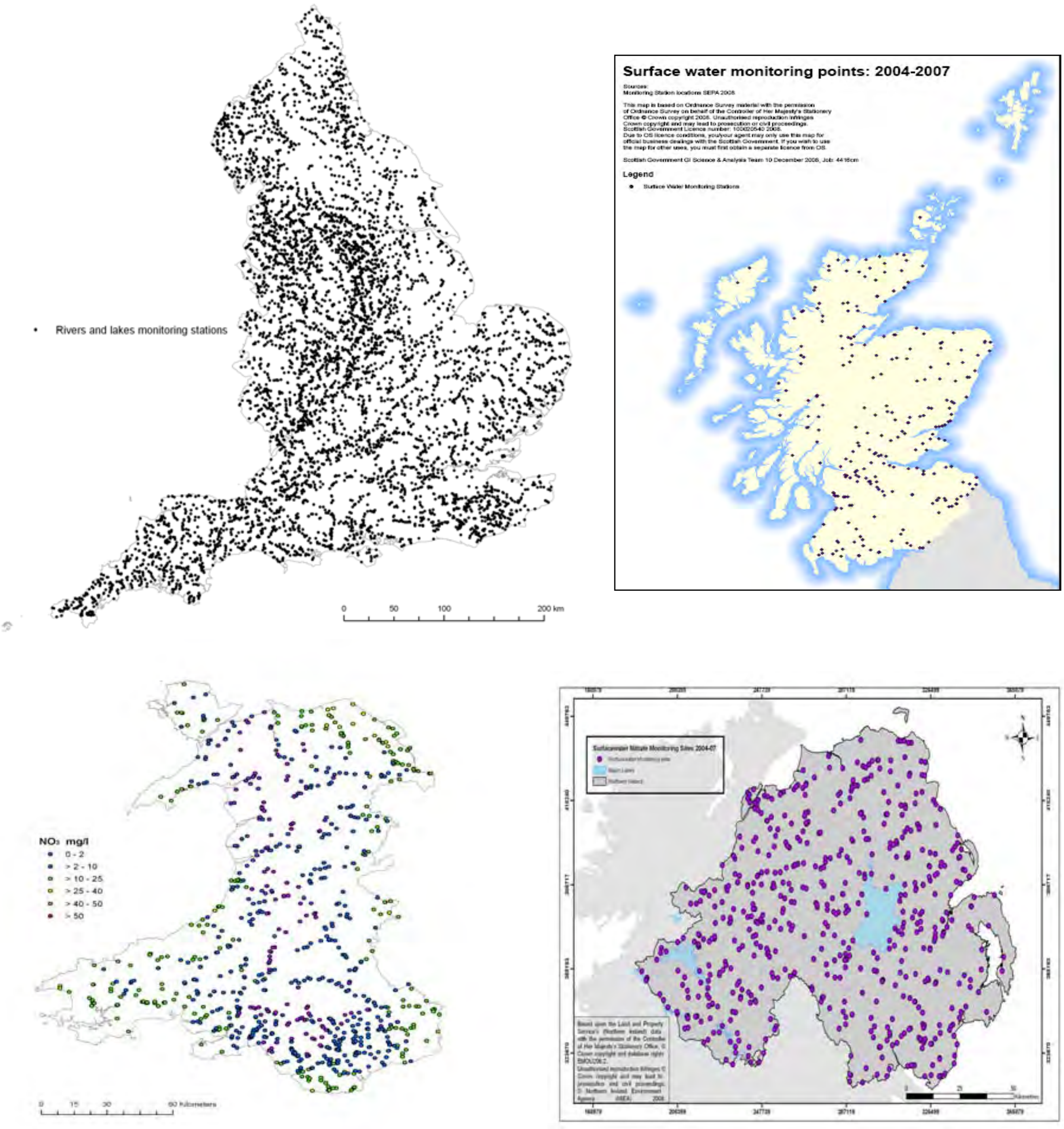


Figure 11 Maps of surface water monitoring stations across the UK: rivers and lakes (current monitoring period 2004-2007) (Defra, 2008c).

2 Effect monitoring

2.1 Strategy for effect monitoring

Out of all countries in the UK, the most well-established approach to effect monitoring is in England. Therefore, the chapter focuses upon the situation and experiences in England. Details of effect monitoring in the other countries are presented at the second MonNO$_3$ workshop (10-11 June 2009).

England has adopted a multi-strand approach to effect monitoring (Figure 12). This approach involved:

- Field measurements on commercial farms, to provide evidence of the size of nitrate losses and the effects of mitigation methods under 'real world' farming (rather than experimental plots).
- Use of field-scale and catchment-scale models (validated against the field data) to quantify the likely effectiveness of combinations of measures as applied to the NVZs.
- Use of other data and information to supplement assessments (for example, trends in water quality as monitored through the national networks; changes in agricultural practices as monitored through national surveys).

The effect monitoring project started in spring 2004, allowing five winters for measurement thus far (2004-2005, 2005-2006, 2006-2007, 2007-2008 and 2008-2009), and reports periodically to feed into the four-yearly review cycle of the Action Programme. Figure 12 summarises the overall approach of the project, a combination of field measurement and modelling (Lord et al., 2007).

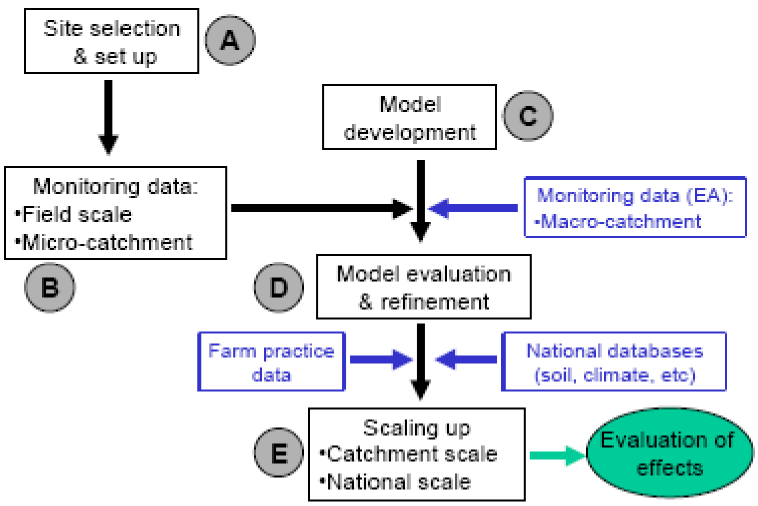


Figure 12 Schematic representation of the multi strand approach to effect monitoring (Lord et al., 2007).

The whole project is based around the linkage between field measurements and modelling (A-E, Figure 12) and is the prescribed approach presented in the EC's draft monitoring guidelines (EC, 2003). It is important to stress the need for both monitoring and modelling. Whereas field measurement data are essential to providing robust information on 'typical' nitrate losses under commercial agriculture, it is not feasible to monitor every field within the NVZs and modelling is required to bring in the understanding gained from the whole scientific knowledge base, and to scale up the results.

A network of measurement sites was set up (A, Figure 12) and is monitored (B, Figure 12). Sites were carefully chosen to represent the range of land uses and livestock systems soil types and climate within NVZs. The field measurements collected within the project were able to provide evidence from real commercial farms on the factors that affect nitrate loss, and the scale of nitrate loss from agricultural land under a range of conditions. Past experience with other schemes, for example, the Nitrate Sensitive Areas (NSAs) and the first round of NVZs, shows that such realistic evidence makes a valuable contribution to stakeholder discussion and facilitates change by providing a clear and readily understood evidence base. It extends the evidence provided by experimental data, and is demonstrably relevant to current farming conditions. Monitoring data also often provide evidence relating to issues not covered by experimental data (for example, there may be changes in management of certain crops such as set-aside, or new crops, or abnormal weather) (Lord et al., 2007).

Extending these measurements to build up a quantitative assessment of measures and to scale up to catchment and national effects, however, requires the use of robust nitrate leaching models (Figure 12). The models must be able to use farm management data (for example, fertiliser application rates, cropping and manure applications) to provide an estimate of likely leaching losses at the field and catchment scale.

An important component of the project was, therefore, to develop these models (C, Figure 12) and validate them against the field measurements collected in the project (D, Figure 12), as well as against other experimental data. The measurement data were crucial for evaluating model performance, including responsiveness to management or other factors (for example, if weather conditions are unusual), and the model's ability to deal with the full range of conditions on commercial farms (Lord et al., 2007).

The model system was then used to assess the effectiveness of the Action Programme measures by combining with farm practice, climate and soil data (E, Figure 12).

2.2 Detailed technical description of networks used for effect monitoring

Site Selection

Sites were established on a range of commercial farms to measure nitrate loss, and soil nitrate at risk of leaching. A network of sites was established on both surface and groundwater catchments (Figure 13).

A total of 203 fields were monitored on groundwater sites in eight locations and 125 fields on surface water sites in eight micro-catchments, ensuring measurements across a range of cropping systems and geoclimatic regions. The British Geological Survey (BGS) provided supporting information on the choice of groundwater aquifers used in the project.

The general following criteria were taken into consideration during site selection:
- representative spatial distribution across NVZ areas;
- representative range of land use (arable, grass; with and without manures; high and low N input systems);
- farmer co-operation;
- farm enterprises should be viable long term (as far as possible);
- rainfall range to represent main contrasts in NVZ areas.

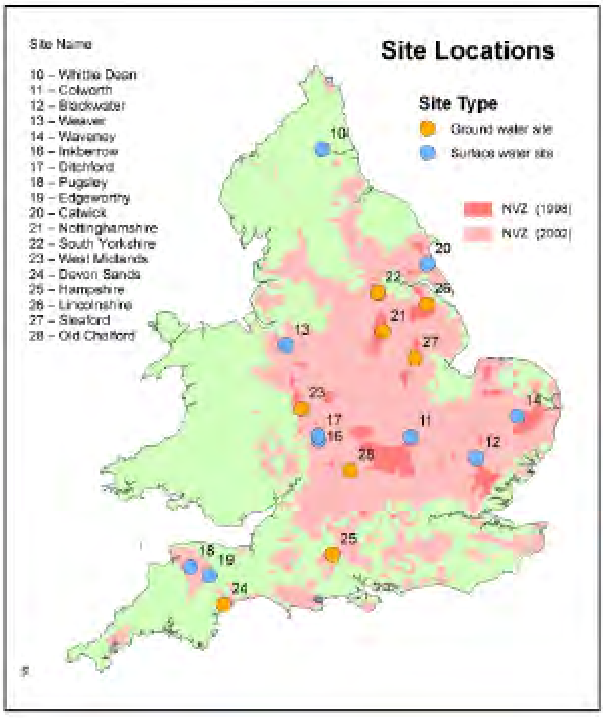


Figure 13 Location of nitrate vulnerable zones, and of groundwater and surface water monitoring areas within the effect monitoring project (Lord et al., 2007).

Field measurements

The main types of data collected from each monitoring site can be summarised thus:

- collection of permanent site details and weather data at each site;
- measurements of nitrate leaching and water flux at each site;
- measurement of late autumn soil mineral nitrogen (SMN), as an indicator of N at risk of leaching, and soil properties at each site;
- annual collection of field-level site management data to aid interpretation of the field measurements and as input data for the models to be validated against the field measurements.

SMN was measured in late autumn on all fields as an indicator of risk of nitrate loss arising from the management of that particular field. These measurements provided some insurance against problems with measurement of actual nitrate leaching (such as very dry winters). They also facilitated attribution of N loss in surface water catchments, where monitored drains sometimes represented flow from several fields.

On groundwater sites, nitrate leaching was also measured on about 100 fields each winter, using porous ceramic cups. Porous ceramic cups (Webster et al., 1993) have been shown to be appropriate for measurement of nitrate loss from the free draining soils (Figure 14) on the groundwater catchments (with the exception of the chalk sites: see Williams and Lord, 1997). The technique gives results for individual fields, which facilitates linking field management data to nitrate loss.

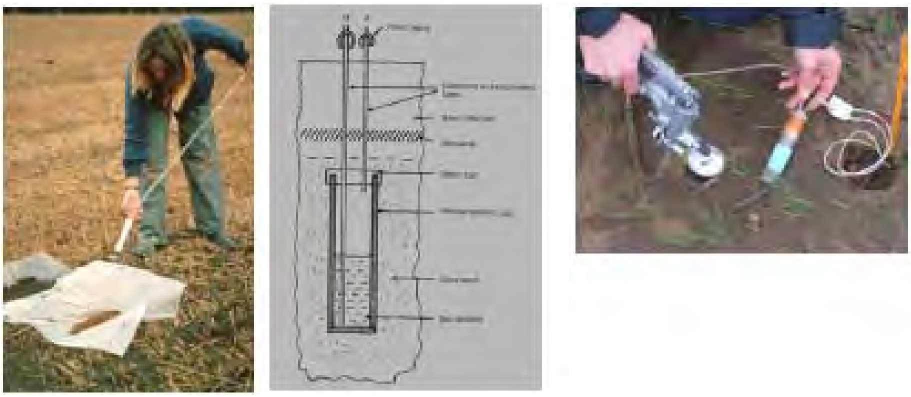


Figure 14 Examples of approaches to measure nitrate loss from free draining soils with porous ceramic cups (Lord et al., 2007).

Porous cups are not suitable for quantifying nitrate loss from clay soils, which are the dominant soils in many surface water catchments. Instead it was necessary to identify hydrological 'micro-catchments', and monitor individual drains or groups of fields within the micro-catchment using flow monitoring and automated water samplers (Figure 15). The 23 water sampling points were chosen such that activity in a field or collection of fields could be linked to the measured nitrate loss, and such that there was no significant point source (sewage) contribution. Where sampling stations represented more than one field, the SMN measurements and field management data were used to differentiate the likely contributions of individual fields to loss at that site.

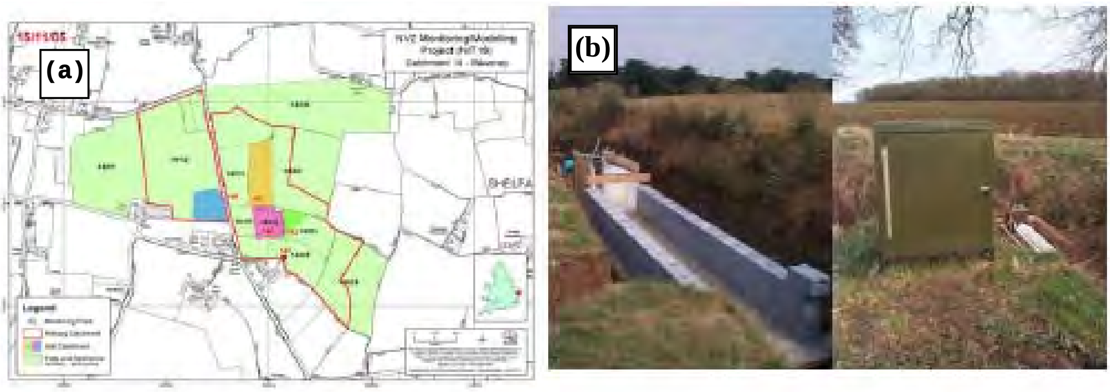


Figure 15 An example of the approach required at surface water 'micro-catchments':
(a) identification of a suitably hydrologically isolated collection of fields with selected monitoring points and
(b) construction of flumes to monitor flow (with accompanying automated water sampling) (Lord et al., 2007).

Data collection

A database was constructed including land use, land use management practices, and resulting nitrate loss which covers three winters of leaching data, and associated management information. Overall, about 300 fields were monitored each year (200 in groundwater areas and 100 in surface water areas). The land use management information collected included data at farm level (livestock numbers of different types and ages, and at field level (including land use, sowing date, harvest date, estimated yield, number of cuts of grass, primary cultivations, and the amounts, types and loadings of fertilisers and manures). Land use and land use management data were collected annually, and included additional information relating to the two years prior to the start of the project (to enable us to take into account the effect of previous land use on the risk of nitrate loss).

2.3 Data Interpretation

The effect monitoring project in England has provided:

- underpinning data on current field-scale nitrate losses from agricultural land under a range of systems that complements river and groundwater data collected via the national monitoring networks;
- a method of estimating present and future nitrate loss based on current and predicted farming practice;
- a method by which the effectiveness of individual measures can be assessed both at field scale, and in the catchment context;
- the framework for predicting the time scale over which changes in farming practice will result in changes in nitrate concentrations in ground and surface waters;
- expert opinion on the implications of the NVZ Action Programme for the risk of eutrophication of rivers and estuaries;
- a method by which the impact of other measures, or externally driven changes in agriculture or climate, can be predicted.

In 2006-2007, the data collected and the models developed under this project were used to review the effectiveness of the then current Action Programme (that means, the Action Programme that was introduced in 2002 and applied within NVZs covering 55% of England). The sections below outline how this was done.

Assessing the effectiveness of the Action Programme (2002) in England – monitoring data

The field measurement data showed that nitrate concentrations in leachate from typical agricultural land within NVZs often exceed 50 mg l^{-1}, especially under arable cropping or intensive dairying. Nitrate losses were elevated where manure was used; where fertiliser N inputs were high relative to crop N uptake; and in some intensively stocked grassland systems. Proper adjustment of fertiliser inputs to take account of the crop-available N supplied by manure is effective in reducing the additional losses. However, the data confirm that losses remain greater where manure is used in the rotation than where no manure is applied.

There was some evidence from the field measurements that further reductions in nitrate leaching from slurry (and, by inference, poultry manure) applications could be achieved by extending the closed period to cover all soil types, not just sandy and/or shallow soils.

In the surface water micro-catchments (drained clay soils), there was sometimes evidence of increased nitrate concentration in drainage water in the spring (normally, nitrate concentrations were decreasing at this time). This suggests new sources of nitrate were being leached, such as recently applied manure or fertiliser.

Where additional fertiliser N is applied to wheat to boost grain protein, there is an indication that this increases N loss, compared with fertilizing for yield only.

Nitrate losses from land were elevated where crop cover was nil or small for a long period prior to the winter – for example, after early harvested peas, and some rotational set-aside. In such situations, the only effective way to reduce nitrate leaching risk is to ensure green cover is established early enough in autumn to take up the high N supply – whether a commercial crop such as oilseed rape, or a purpose-sown cover crop.

Assessing the effectiveness of the Action Programme (2002) in England – modelling

The NIPPER model was used to explore the impacts of the Action Programme (2002) in two case study catchments (Meden and Taw). The purpose of these studies was to explore how measures that are highly effective at the field scale would translate to a larger scale.

The Meden and Taw catchments were chosen as being typical of contrasting elements of the NVZ area. The Meden is a groundwater catchment, partly on sandy soils to which the closed period for manure application applies, dominantly arable but with some intensive grass, and with a high livestock density. It is in the eastern half of the country, and in both climate and land use is representative of much of the NVZ area. The Taw catchment has much greater rainfall, and is a clay surface water catchment dominated by grassland.

Two measures were modelled which were considered, on the basis of preliminary modelling and data on current practice, to represent the main impact of the Action Programme (2002). These were:

- apply no more N than crop requires, taking account of all other sources of N;
- do not apply slurries or poultry manures during autumn on sandy or shallow soils.

In order to explore the potential for minimising nitrate reduction at catchment scale, two further and far more severe measures were explored. It must be emphasisded that these were not part of the Action Programme (2002), but are purely indicative. The measures were:

- a 10% reduction in chemical fertiliser inputs;
- removal of all managed manure from the catchment.

Impact of Action Programme (2002): case study Meden catchment

The Action Programme (2002) requires that fertiliser inputs should not exceed crop requirement. Data from the BSFP (amongst others Goodlass and Allin, 2004) show that the main cause of non-compliance with recommendations is failure to reduce inputs to account for N supply from manures. Reducing inorganic fertiliser rates to account for the crop available N from manure applications resulted in a decrease in the average rate of fertiliser application across the catchment from 138 to 126 kg ha^{-1}. This change reduced modelled nitrate leaching in this catchment by 7% (Table 3). The actual impact of the measure may be less than this because farmers did already make some adjustment for manure N supply prior to the Action Programme (2002), but there may be gains in improved adjustment for factors other than manure, including previous cropping and soil type. There is considerable variation within the catchment in the effectiveness of this measure, which is due to the large variation in manure loadings within the catchment.

Introduction of a closed period, preventing autumn applications of slurry and poultry manure on sandy soils and adjusting inorganic fertiliser inputs to take account of the additional quantity of crop-available N (which reduced fertiliser rates to 118 kg ha^{-1}) reduced average nitrate concentrations in the catchment by a further 8% (Table 3). This last estimate is subject to some uncertainty, since farmers have some freedom to circumvent the closed period by moving manures onto different soil types, or applying them earlier in the autumn before the closed period begins.

Table 3 Modelled results for the Meden catchment.
Showing nitrogen leached per hectare of agricultural land and nitrate concentrations in drainage from agricultural land, along with the average effect of a mitigation measure across the whole catchment and the range of effect in the various sub-catchments (Lord et al., 2007).

Mitigation measures	N leached (kg ha^{-1})	Nitrate concentration (mg l^{-1})	Average reduction (%)	Range of reduction (%)
1. Baseline	58.4	147	-	-
2. Do not exceed crop N requirements	54.6	138	6.5	1.7-20
3. As 2 + closed period	49.6	125	15.0	1.9-23
4. 10% fertiliser reduction	54.1	137	7.4	4.0-11.7
5. Removed all manures	43.3	109	25.9	5.8-37.4

The calculation assumed that manures that could not be applied in early autumn were instead applied in winter. This is not an unreasonable assumption on these soils, which remain trafficable for most of the winter. As the closed period only affects sandy soils, it only alters the leaching across 65% of the catchment. On the sandy soils, the closed period actually reduced leaching by 10%. The fact that the closed period has such a large net effect for the catchment is a result of the fact that manure loadings from poultry are large and approximately two thirds of the poultry manure was applied in the autumn before implementation of the Action Programme (2002), so the timing of its application is impacted by the closed period.

The estimated total nitrate leaching reduction due to the current NVZ AP in this catchment is therefore about 15%, which still leaves nitrate concentrations in leachate from the agricultural land within the catchment significantly above 50 mg l^{-l} limit. The estimated reduction in nitrate loss due to the Action Programme (2002) for arable sandy soils with quantities of manure N more typical of the NVZ area (which is just under half of the application rate found within the Meden catchment) would thus be about 7%.

Impact of Action Programme (2002): case study Taw catchment
Reducing inorganic fertiliser rates to account for the crop-available N from manure applications resulted in a decrease in the average rate of fertiliser application across the catchment from 121 kg ha^{-1} down to 114 kg ha^{-1}. This

change reduced modelled nitrate leaching in this catchment by only 2% (Table 4).
The reason for the smaller change in the Taw catchment compared with the Meden catchment, despite a similar change in fertiliser rates, is that the increase in leaching per additional kg of fertiliser is generally less for grassland than for arable, at these levels of intensity of stocking. The actual impact of the measure may be less than this because farmers did already make some adjustment for manure N supply prior to the Action Programme (2002), and fertiliser inputs to grassland have fallen substantially already in recent years. There is some variation within the catchment, due to the poultry farming in the centre of the catchment providing greater amounts of manure.

Table 4 Modelled results for the Taw catchment.
Showing nitrogen leached per hectare of agricultural land and nitrate concentrations in drainage from agricultural land, along with the average effect of a mitigation measure across the whole catchment and the range of effect in the various sub-catchments (Lord et al., 2007).

Mitigation measures	N leached (kg ha^{-1})	Nitrate concentration (mg l^{-1})	Average reduction (%)	Range of reduction (%)
1. Baseline	23.0	29.3	-	-
2. Do not exceed crop N requirements	22.7	28.8	1.5	0.1-5.0
3. As 2 + closed period	-	-	-	-
4. 10% fertiliser reduction	22.4	28.5	2.7	0.5-5.4
5. Removed all manures	21.0	26.7	9.0	2.7-27.5

Modelling, as summarised above, sometimes shows large effects within the example catchments and sub-catchments. However, taking account of land use, soil types and livestock numbers across the whole NVZ area, our assessment suggests that the overall effect of the Action Programme (2002) is small: somewhere in the order of a 3% reduction in nitrate leaching loss.

Policy implications

As a result of the above assessment of the effectiveness of the Action Programme (2002) it was concluded that a revised and tightened set of measures needed to be introduced in England.

The evidence provided by the project proved useful in discussions with the agricultural industry (for example, explaining why a revised Action Programme was necessary; highlighting that agriculture can lead to significant losses of nitrate) and in identifying how the measures should/could be tightened. The models developed under the project were also used in the development of the revised Action Programme measures.

3 Discussion

This section describes the experiences, problems, bottlenecks encountered during the establishment of the ‘Effect Monitoring Networks’ and the solutions arising.

Monitoring of ground and surface water quality

The large network of monitoring stations for surface water quality is well established. One complication of interpreting the data is that many of the sites were set up to assess the impact of point sources (sewage treatment outflows) and therefore can give a somewhat biased picture of general river water quality. This is an even greater problem in relation to P status. Most stations measure oxidised N (nitrate plus nitrite); rather few measure organic N.

The groundwater monitoring network was originally focussed on control of drinking water quality. It has evolved in recent years to better represent the quality of the groundwater resource.

Assessment of impacts

The river and groundwater monitoring network is not adequate for assessing impacts of the Action Programme and other changes. Separation of impacts from background ‘noise’ and underlying trends is difficult; attribution of cause between different practices is unreliable at this scale; and in groundwater, typical response times in England are decades or more.

The text above briefly presents the approach we have taken to national and catchment-scale impact assessment. This depends on models, evaluated at field and farm scale, then applied to mapped statistical data on land use and management.

Field scale measurement network

The network of field measurement sites on commercial farms, developed to provide ground truth data for models, has worked well over many years. It has proved to be useful in stakeholder engagement, by demonstrating unequivocally the scale of nitrate losses from commercial farms under typical current management. Soil mineral nitrogen (SMN) and nutrient balances are good indicators, but have proved to be more convincing when supported by direct measurements of nitrate concentrations leaving the land. The use of SMN to support direct measurements of leaching has been helpful in providing a larger number of sites; and in providing a form of insurance against very dry winters or factors affecting the reliability of leaching measurements. The detailed annual management data are an essential component for both data analysis and model evaluation.

The surface water measurement sites provide the opportunity to also address other pollutants, important both for understanding and to support the holistic mitigation policies being developed under the Water Framework Directive.

Models

The use of models to estimate impacts at catchment or national scale has evolved over the years, but is still an imperfect art. We have developed models which are responsive to the main environmental variables and management practices influencing nitrate loss. A greater challenge has proved to be translating this to catchment scale, where only statistical data are available. A mapped synthesis of agricultural census data with land cover information was developed to underpin catchment modelling across the whole country. Within individual catchments, we have linked these data to management survey data to generate land management scenarios representative of the range of activities in the catchment. These scenarios provided the inputs to the detailed model. However at national scale, somewhat simpler and more generic approaches have been used. These are based on estimating impacts on 'typical farms', and deriving coefficients which allow the change to be scaled up according to the mapped agricultural census data. There is still progress to be made in improving the transparency and robustness of the methods.

Agricultural information

Model estimates at catchment and/or national scale require land management data to link to the land use mapping. Interpretation of such data to provide 'before and after' scenarios for impact assessment has proved to be a significant potential source of uncertainty. The baseline data have been improved in recent years by adapting existing surveys to provide greater precision on questions of policy interest. Defra promotes a continuing essential dialogue between survey designers and data users for policy purposes. It remains the case that policymakers often request information which cannot be exactly deduced from the available survey data.

Evaluation

At field scale, we can demonstrate that the model responses correctly reflect measured data on impacts of management change, using both experimental data and the measurements from commercial farms. Catchment-scale estimates of current ('baseline') nitrate concentrations have also been shown to compare well with measured data. Predictions of impacts of the Action Programme have proved less easy to validate. This is because to date, within surface water catchments, the scale of impact expected is small relative to the natural variation in nitrate concentrations. In groundwater (where greater impacts are predicted) the depth of major aquifers in England is such that typical response times are decades or more.

4 References

BSFP (2001-2007). British Survey of Fertiliser Practice. Defra, York.

EC (2003) Draft guidelines for the monitoring required under the Nitrates Directive (91/676/EEC). Version 3, with annexes 1 through 3. European Commission, Directorate-General XI (Environment, Nuclear Safety and Civil Protection), Directorate D Environment.

Defra (2007) Nitrates in water – impact of the 2002 NVZ Action Programme. ADAS, UK

Defra (2008a) Request from Britain (England, Scotland and Wales) for derogation to the livestock manure limit of 170 kg N per hectare per year. Department for Environment, Food, and Rural Affairs, London, United Kingdom.

Defra (2008b) Transposition Note for the Nitrates Directive (91/676/EEC) and Public Participation Directive (2003/35/EC) in so far as it concerns the Action Programme established under the Nitrates Directive, http://www.opsi.gov.uk/si/si2008/em/uksiem_20082349_en.pdf.

Defra (2008c) Report on the state of implementation of the Nitrates Directive in the United Kingdom (England, Scotland, Wales and N. Ireland). Department for Environment, Food, and Rural Affairs, London, United Kingdom.

Environment Agency (2006) Percentage river length with high phosphate and nitrate levels in England; http://www.defra.gov.uk/wildlifecountryside/pdf/biodiversity/indicator/200810w5.pdf.

Goodlass, G. and Allin, R. (2004) British Survey of Fertiliser Practice: fertiliser use on farm crops for crop year 2003. The BSFP Authority, London.

Lord, E., Shepherd, M., Silgram, M., Goodlass, G., Gooday, R., Anthony, S.G., Davidson, P. and Hodgkinson, R. (2007) Investigating the effectiveness of NVZ Action Programme Measures: Development of a Strategy for England. Report for Defra Project No. NIT18. ADAS, UK.

OECD (2001). Environmental Indicators for Agriculture – Volume 3: Methods and Results.

Webster, C.P., Sherpherd, M.A., Goulding, K .W. and LORD, E.I. (1993) Comparison of methods for measuring the leaching of mineral nitrogen from arable 1and. Journal of Soil Science 44, 49-62.

Williams, J.R., Lord, E.I. (1997) The use of porous ceramic cup water samplers to measure solute leaching on chalk soils. Soil Use and Management 13 (3), pp. 156-162.

Williams, J.R., Chambers, B.J., Smith, K.A. and Ellis, S. (2000) Farm manure land application strategies to conserve nitrogen within farming systems. In: Agriculture and Waste: Management for a Sustainable Future (Petchey T; D'Arcy B; Frost A, eds), pp. 167-179. The Scottish Agricultural College, Edinburgh.

Appendix 1 Organisation

Organising Committee

Dico Fraters (chair)	RIVM, the Netherlands
Karel Kovar (secretary)	PBL, the Netherlands
Ruth Grant	DMU, Denmark
Lærke Thorling	GEUS, Denmark
Joan Reijs	LEI, the Netherlands

Chairs and rapporteurs

Chair plenary sessions

Brian Krongvang	DMU, Denmark

Chairs and rapporteurs parallel sessions

Simon Dawes	Defra, UK/England
Ralf Eppinger	VMM, Flemish region, Belgium
Ruth Grant	DMU, Denmark
Johannes Grath	UBA, Austria
Joan Reijs	LEI, the Netherlands
Lærke Thorling	GEUS, Denmark
Rüdiger Wolter	UBA, Germany
Manon Zwart	RIVM, the Netherlands

Appendix 2 List of workshop participants

Country	Name	Surname	Organisation
Austria	Johannes	Grath	Federal Environmental Agency (UBA)
Austria	Harald	Loishandl-Weiß	Federal Environmental Agency (UBA)
Austria	Christian	Schilling	Federal Environmental Agency (UBA)
Belgium/Flanders	Ralf	Eppinger	Flemish Environment Agency (VMM)
Belgium/Flanders	Sofie	Ducheyne	Vlaamse Landmaatschappij (VLM)
Belgium/Flanders	Kor	Van Hoof	Flemish Environment Agency (VMM)
Belgium/Wallonia	Christophe	Vandenberghe	Gembloux Agricultural University
Belgium/Wallonia	Charles	Hendrickx	DG for Agricult., Natural Resources and Environment
Belgium/Wallonia	Aurore	Degré	Gembloux agricultural university (FUSAGx)
Czech Republic	Pavel	Rosendorf	T. G. Masyryk Water Research Institute
Czech Republic	Hana	Prchalova	T. G. Masyryk Water Research Institute
Czech Republic	Jan	Klir	Crop Research Institute
Denmark	Ruth	Grant	National Environmental Research Institute
Denmark	Lærke	Thorling	Geological survey of Denmark and Greenland
Denmark	Henriette	Hossy	Environmental Protection Agency
Denmark	Brian	Kronvang	National Environmental Research Institute
France	Philippe	Jannot	Ministère chargé de l'écologie
France	Valérie	Maquere	MAP/DGPAAT/Bureau des sols et de l'eau
France	Cécile	Gozler	Ministère chargé de l'écologie
Germany	Rüdiger	Wolter	Federal Environmental Agency (UBA)
Germany	Bernhard	Osterburg	Fed. Res. Inst. Rural Areas, Forestry & Fisheries
Germany	Björn	Tetzlaff	Research Cenre Jülich (FZ Juelich ICG-4)
Ireland	Donal	Daly	Environmental Protection Agency
Ireland	Patricia	Torpey	Dept of Agriculture, Fisheries & Food
Luxembourg	Claude	Neuberg	Administration de la Gestion de l'Eau
Netherlands	Dico	Fraters	National Institute for Public Health and the Environment
Netherlands	Manon	Zwart	
Netherlands	Leo	Boumans	
Netherlands	Karel	Kovar	National Environmental Assessment Agency
Netherlands	Joan	Reijs	Agricultural Economic Research Institute
Netherlands	Richard	Van Hoorn	Rijkswaterstaat - Centre for Water Managment
Slovakia	Katarina	Slivkova	Water Research Institute
Slovakia	Miroslav	Holubec	Water Research Institute
Slovakia	Andrea	Májovská	Slovak Hydrometeorological Institute
Sweden	Carina	Carlsson	Swedish Board of Agriculture
Sweden	Edward	Wirgén	Swedish Board of Agriculture
UK/England&Wales	Simon	Dawes	Dep. for Environment, Food and Rural Affairs
UK/England&Wales	Rob	Ward	Environment Agency
UK/England&Wales	Eunice	Lord	ADAS Consulting Ltd
UK/Scotland	Francis	Brewis	Water Air Soils and Flooding Div, Scottish Gov.
UK/Scotland	Vincent	Fitzsimons	Scottish Environmental Protection Agency
UK/Northern Ireland	Orla	Ruddle	Northern Ireland Environment Agency

Addresses

Austria
Johannes Grath
Federal Environmental Agency (Umweltbundesamt)
Spittelauer Lände 5
A-1090 Wien, Austria
Tel. +43 (1) 31304 3510
Fax +43 (1) 313043533
johannes.grath@umweltbundesamt.at

Harald Loishandl-Weiss
Federal Environmental Agency (Umweltbundesamt)
Spittelauer Lände 5
A-1090 Wien, Austria
Tel. +43 (1) 31304 3582
Fax +43 (1) 313043533
harald.loishandl-weisz@umweltbundesamt.at

Christian Schilling
Federal Environmental Agency (Umweltbundesamt)
Spittelauer Lände 5
A-1090 Wien, Austria
Tel. +43 (1) 31304 3575
Fax +43 (1) 313043533
christian.schilling@umweltbundesamt.at

Belgium / Flemish regio
Ralf Eppinger
Flemish Environment Agency (VMM)
Koning Albert II-laan 20
B-1000 Brussels, Belgium
Tel. +32 (0)2 553 2137
Fax +32 (0)2 553 2105
r.eppinger@vmm.be

Sofie Ducheyne
Vlaamse landmaatschappij (VLM)
Gulden-Vlieslaan 72
B-1060 Brussels, Belgium
Tel. +32 (0)2 543 7358
Fax +32 (0)2 543 7398
sofie.ducheyne@vlm.be

Kor Van Hoof
Flemish Environment Agency (VMM)
Alfons Van de Maelestraat 96
B-9320 Erembodegem, Belgium
Tel. +32 (0)53 726693
Fax +32 (0)53 726630
k.vanhoof@vmm.be

Belgium / Walloon region
Christophe Vandenberghe
Gembloux Agricultural University
Passage des Déportés
B-5030 Gembloux, Belgium
Tel. +32 81 622540
Fax +32 81 622529
vandenberghe.c@fsagx.ac.be

Charles Hendrickx
Directorate General for Agriculture, Natural Resources and Environment
Avenue Prince de Liège, 15
B-5100 Namur (Jambes), Belgium
Tel. +32 81 336407
Fax +32 81 336322
charles.hendrickx@spw.wallonie.be

Aurore Degré
Gembloux agricultural university (FUSAGx)
Hydrology and Hydraulic Eng.
Passage des Déportés, 2
B-5030 Gembloux, Belgium
Tel. +32 (0)81 622187
Fax +32 (0)81 622181
dege.a@fsagx.ac.be

The Czech Republic
Pavel Rosendorf
T.G. Masyryk Water Research Institute
Podbabska 2582/30
CZ-160 62 Prague 6, Czech Republic
Tel. +420 220 197 413
Fax +420 220 197 514
rosendorf@vuv.cz

Hana Prchalova
T.G. Masyryk Water Research Institute
Podbabska 2582/30
CZ-160 62 Prague 6, Czech Republic
Tel. +420 724 215 774
Fax +420 220 197 216
hana.prchalova@vuv.cz

Jan Klir
Crop Research Institute
Dmovska 507
CZ-161 06 Praha 6 Ruzyne, Czech Republic
Tel. +420 233 022 300
Fax -----
klir@vurv.cz

Denmark

Ruth Grant
National Environmental Research Institute (DMU)
Veijlsovej 25 (P.O. Box 315)
DK-8600 Silkeborg, Denmark
Tel. +45 8920 1464
Fax +45 8920 1414
rg@dmu.dk

Laerke Thorling
GEUS (geological survey of Denmark and Greenland)
Lyseng alle 1
DK-8270 Hojbjerg, Denmark
Tel. +45 3814 2082
Fax ----
lts@geus.dk

Henriette Hossy
Environmental Protection Agency
Strandgade 29
DK-1401 Kobenhavn, Denmark
Tel. +45 7254 4123
Fax ----
hehos@mst.dk

Brian Kronvang
National Environmental Research Institute (DMU)
Veijlsovej 25 (P.O. Box 315)
DK-8600 Silkeborg, Denmark
Tel. +45 8920 1400
Fax +45 8920 1414
bkr@dmu.dk

France

Philippe Jannot
Ministère chargé de l'écologie
20 avenue de Ségur
F-75007 Paris, France
Tel. +33 (0)1 4219 1288
Fax +33 (0)1 4219 1222
philippe.jannot@developpement-durable.gouv.fr

Valérie Maquere
MAP/DGPAAT/Bureau des sols et de l'eau
3 rue Barbet de Jouy
F-75007 Paris, France
Tel. +33(0)1 4955 5719
Fax +33(0)1 4955 5063
valerie.maquere@agriculture.gouv.fr

Cécile Gozler
Ministère chargé de l'écologie
20 avenue de Ségur
F-75007 Paris, France
Tel. +33 (0)1 4219 1261
Fax +33 (0)1 4219 1334
cecile.gozler@developpement-durable.gouv.fr

Germany

Rüdiger Wolter
Umweltbundesamt (Federal Environment Agency)
Wörlitzer Platz 1
D-06844 Dessau, Germany
Tel. +49 (0)340 2103 2212
Fax +49 (0)340 2104 2212
ruediger.wolter@uba.de

Bernhard Osterburg
Federal Research Institute for Rural Areas, Forestry and Fisheries
Bundesallee 50
D-38116 Braunschweig, Germany
Tel. +49 (0)531 596 5211
Fax +49 (0)531 596 5599
bernhard.osterburg@vti.bund.de

Björn Tetzlaff
Research Cenre Jülich (FZ Juelich ICG-4)
D-52425 Jülich, Germany
Tel. +49 2461 61 3648
Fax +49 2461 61 2518
b.tetzlaff@fz-juelich.de

Republic of Ireland

Donal Daly
Environmental Protection Agency
Richview, Clonskeagh
14 Dublin, Ireland
Tel. +353 (0)1 268 0186
Fax +353 (0)1 268 0199
d.daly@epa.ie

Patricia Torpey
Dept of Agriculture, Fisheries and Food
Government Buildings, Convent Road
Roscommon, Ireland
Tel. +353 (0)90 6630199
Fax ----
patricia.torpey@agriculture.gov.ie

Luxembourg
Claude Neuberg
Administration de la Gestion de l'Eau
51, rue de Merl
L-2146 Luxembourg, Luxembourg
Tel. +352 26 028648
Fax +352 26 028660
claude.neuberg@eau.etat.lu

The Netherlands
Dico Fraters
National Institute for Public Health and the Environment
PO Box 1 (visit: A. van Leeuwenhoeklaan 9)
NL-3720 BA Bilthoven, Netherlands
Tel. +31 30 274 4039
Fax +31 30 228 7531
dico.fraters@rivm.nl

Manon Zwart
National Institute for Public Health and the Environment
PO Box 1 (visit: A. van Leeuwenhoeklaan 9)
NL-3720 BA Bilthoven, Netherlands
Tel. +31 30 274 3625
Fax +31 30 228 7531
manon.zwart@rivm.nl

Leo Boumans
National Institute for Public Health and the Environment
PO Box 1 (visit: A. van Leeuwenhoeklaan 9)
NL-3720 BA Bilthoven, Netherlands
Tel. +31 30 274 3341
Fax +31 30 228 7531
leo.boumans@rivm.nl

Karel Kovar
National Environment Assessment Agency
PO Box 303
NL-3720 AH Bilthoven, Netherlands
Tel. +31 30 274 3360
Fax +31 30 2744435
karel.kovar@pbl.nl

Joan Reijs
Agricultural Economic Research Institute
PO Box 29703
NL-2502 LS Den Haag, Netherlands
Tel. +31 70 335 8326
Fax ----
joan.reijs@wur.nl

Richard van Hoorn
Rijkswaterstaat – Centre for Water Management
PO Box 17
NL-8200 AA Lelystad, Netherlands
Tel. +31 (0)6 11532396
Fax ----
richard.van.hoorn@rws.nl

The Slovak Republic

Katarina Slivkova
Water Research Institute
Nábr. am.gen. L. Svobodu 5
SK-812 49 Bratislava, Slovakia
Tel. +421 2 59343 439
Fax +421 3 5441 1941
slivkova@vuvh.sk

Miroslav Holubec
Water Research Institute
Nábr. am.gen. L. Svobodu 5
SK-812 49 Bratislava, Slovakia
Tel. +421 2 59343 439
Fax +421 3 5441 1941
holubec@vuvh.sk

Andrea Májovská
Slovak Hydrometeorological Institute
Jeséniová 15
SK-833 15 Bratislava, Slovakia
Tel. +421 2 59 415415
Fax +421 2 54 773 602
andrea.majovska@shmu.sk

Sweden

Carina Carlsson
Swedish Board of Agriculture
SE-551 82 Jönköping, Sweden
Tel. +46 (0)36 156052
Fax ----
carina.carlsson-ross@sjv.se

Edward Wirgén
Swedish Board of Agriculture
SE-551 82 Jönköping, Sweden
Tel. +46 (0)36 156052
Fax +46 (0)36 710517
edward.wirgen@sjv.se

UK / England and Wales

Simon Dawes
Department of Environment, Food and Rural Affairs (DEFRA)
Area 2A, Ergon House, Horseferry Road
SW1P 2AL London, UK/England and Wales
Tel. +44 (0)20 7238 5494
Fax +44 (0)20 7238 5106
simon.dawes@defra.gsi.gov.uk

Rob Ward
Environment Agency
Olton Court, 10 Warwick Road, Olton
B92 7HX Solihull, UK/England and Wales
Tel. +44 (0)121 708 4657
Fax ----
rob.ward@environment-agency.gov.uk

Eunice Lord
ADAS Consulting Ltd
Woodthorne, Wergs Road
WV6 8TQ Wolverhampton, UK/England and Wales
Tel. +44 (0) 1384 878191
Fax +44 (0) 1902 693178
eunice.lord@adas.co.uk

UK / Scotland

Francis Brewis
Water Air Soils and Flooding Division, Scottish Government
1-H, Victoria Quay
EH8 8BU Edinburgh, UK/Scotland
Tel. +44 (0)131 244 0231
Fax +44 (0)131 244 0259/0195
francis.brewis@scotland.gsi.gov.uk

Vincent Fitzsimons
Scottish Environmental Protection Agency
Clearwater House, Heriot Watt research park, Avenue North
EH4 4AP Riccarton, UK/Scotland
Tel. +44 (0)131 273 2783
Fax ----
vincent.fitzsimons@sepa.org.uk

UK / Northern Ireland

Orla Ruddle
Northern Ireland Environment Agency
17 Antrim Road
BT28 3AL Lisburn, Co Down, UK/Northern Ireland
Tel. +44 28 9262 3144
Fax +44 28 9267 6054
orla.ruddle@doeni.gov.uk

Appendix 3 Workshop programme

Second MonNO$_3$ workshop programme (version per 25 May 2009)

Tuesday, 9 June 2009

From 15:00	Check-in
15:00-17:00	Meeting of the Organizing Committee, Workshop Chair and Discussion Leaders
17:00-18:00	Welcome reception in the Bar of Radisson SAS
19:00-21:00	Welcome dinner in the Radisson SAS

Wednesday, 10 June 2009

07:00-08:30	Breakfast
08:30-09:00	Opening session second MonNO$_3$ workshop
09:00-12:30	Introduction session - Plenary
09:00-10:30	Introduction of delegations, statements (4 slides) (9 presentations; 8 minutes each)
10:30-11:00	Coffee and tea break
11:30-12:10	Introduction of delegations, statements (4 slides) (7 presentations; 8 minutes each)
12:10-12:30	Wrap-up and introduction of discussion topics
12:30-14:00	Lunch
14:00-17:30	Discussion session 1 Pros and cons of different effect monitoring approaches
14:00-14:40	Plenary, introduction of theme
14:40-16:30	Parallel, working group sessions (4 groups)
16:30-17:30	Plenary, account of working group discussions
17:30-18:30	Poster session (with drinks and snacks)
19:00-22:00	Dinner and special event

Thursday, 11 June 2009

07:00-08:30	Breakfast
08:30-12:00	Discussion session 2 Can monitoring data from national networks be used to underpin new policy (e.g. fertilisation standards) or can data be used to show that no new measures are needed?
08:30-09:10	Plenary, introduction of theme
09:10-11:00	Parallel, working group sessions (4 groups)
11:00-12:00	Plenary, account of working group discussions
12:00-13:30	Lunch
13:30-17:00	Discussion session 3 Can existing networks be used/are special networks needed to monitoring for NVZ designation and/or underpinning of derogation?
13:30-14:10	Plenary, introduction of theme
14:10-16:00	Parallel, working group sessions (4 groups)
16:00-17:00	Plenary, account of working group discussions
17:00-17:30	Closing session second MonNO$_3$ workshop
18:00-20:00	Dinner in the Radisson SAS
20:00-	Optional: Visit to Amsterdam

Friday, 12 June 2009

07.00-08.30	Breakfast
08.30-12.00	Check-out
08.30-12.00	Meeting of Organising Committee, Workshop Chair and Discussion Leaders
12:00-13:30	Lunch of OC, WC and DL

Appendix 4 Discussion groups' composition

Names of discussion chair and rapporteur are in italics

Composition of discussion groups for discussion session 1

Group 1	Group 2	Group 3	Group 4
Johannes Grath	*Ralf Eppinger*	*Ruth Grant*	*Manon Zwart*
Rüdiger Wolter	*Simon Dawes*	*Lærke Thorling*	*Joan Reijs*
Philippe Jannot	Pavel Rosendorf	Richard Van Hoorn	Rob Ward
Francis Brewis	Dico Fraters	Christophe Vandenberghe	Jan Klir
Leo Boumans	Lea Mrafkova	Vincent Fitzsimons	Patricia Torpey
Hana Prchalova	Björn Tetzlaff	Carina Carlsson	Orla Ruddle
Sofie Ducheyne	Christian Schilling	Eunice Lord	Aurore Degré
Claude Neuberg	Henriette Hossy	Valérie Maquere	Cécile Gozler
Lucia Šulvová	Edward Wirgén	Harald Loishandl-Weiß	Miroslav Holubec
		Donal Daly	Kor Van Hoof

Composition of discussion groups for discussion session 2

Group 1	Group 2	Group 3	Group 4
Johannes Grath	*Ralf Eppinger*	*Ruth Grant*	*Manon Zwart*
Rüdiger Wolter	*Simon Dawes*	*Lærke Thorling*	*Joan Reijs*
Vincent Fitzsimons	Richard Van Hoorn	Björn Tetzlaff	Henriette Hossy
Miroslav Holubec	Jan Klir	Orla Ruddle	Eunice Lord
Pavel Rosendorf	Bernhard Osterburg	Leo Boumans	Valérie Maquere
Dico Fraters	Patricia Torpey	Aurore Degré	Claude Neuberg
Kor Van Hoof	Philippe Jannot	Hana Prchalova	Harald Loishandl-Weiß
Rob Ward	Francis Brewis	Sofie Ducheyne	Lucia Šulvová
Carina Carlsson	Lea Mrafkova	Christian Schilling	Edward Wirgén
	Christophe Vandenberghe	Cécile Gozler	Donal Daly

Composition of discussion groups for discussion session 3

Group 1	Group 2	Group 3	Group 4
Johannes Grath	*Ralf Eppinger*	*Ruth Grant*	*Manon Zwart*
Rüdiger Wolter	*Simon Dawes*	*Lærke Thorling*	*Joan Reijs*
Richard Van Hoorn	Vincent Fitzsimons	Pavel Rosendorf	Carina Carlsson
Jan Klir	Miroslav Holubec	Dico Fraters	Francis Brewis
Bernhard Osterburg	Patricia Torpey	Kor Van Hoof	Lea Mrafkova
Björn Tetzlaff	Leo Boumans	Rob Ward	Christophe Vandenberghe
Orla Ruddle	Aurore Degré	Philippe Jannot	Hana Prchalova
Henriette Hossy	Claude Neuberg	Lucia Šulvová	Sofie Ducheyne
Eunice Lord	Harald Loishandl-Weiß	Edward Wirgén	Christian Schilling
Valérie Maquere		Donal Daly	Cécile Gozler

Appendix 5 Photo impression of workshop

Plenary session

Parallel sessions

Parallel sessions

B. Fraters et al.

Rapport 680717019/2011

Dit is een uitgave van:

Rijksinstituut voor Volksgezondheid en Milieu
Postbus 1 | 3720 BA Bilthoven
www.rivm.nl

NATIONAL ENVIRONMENTAL RESEARCH INSTITUTE
AARHUS UNIVERSITY

GEUS
GEOLOGICAL SURVEY OF DENMARK AND GREENLAND

LEI
WAGENINGEN UR

juni 2011

002402