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**TOWARDS INTEGRATED ENVIRONMENTAL  
QUALITY OBJECTIVES FOR SURFACE WATER,  
GROUND WATER, SEDIMENT AND SOIL FOR  
NINE TRACE METALS**

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This research was carried out on behalf of the Directorate for Environmental Protection, Directorate for Chemicals, External Safety, and Radiation Protection, in the frame of the project "Setting integrated environmental quality objectives" (Quality objectives and risks, project no. 679101).

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**PREFACE**

This report contains results of research carried out in the framework of the project 'Setting integrated environmental quality objectives'. The results have been discussed in the 'Setting integrated environmental quality objectives advisory group'. Members thereof are J.H.M. de Bruijn (Ministry of Housing, Physical Planning and the Environment), J.H. Canton (National Institute of Public Health and Environmental Protection), C.A.J. Denneman (Ministry of Housing, Physical Planning and the Environment), J.W. Everts (Ministry of Transport, Public Works and Water Management, Tidal Waters Division), M.P.M. Janssen (Institute for Forestry and Nature Research), P. Leeuwangh (Winand Staring Centre for Integrated Land, Soil and Water Research), E.J. van de Plassche (National Institute of Public Health and Environmental Protection), P.B.M. Stortelder (National Institute of Inland Water Management), J. Struijs (National Institute of Public Health and Environmental Protection), M. Vossen (National Institute of Inland Water Management), and J. van Wensem (Technical Soil Protection Committee).

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## SUMMARY

This report is the result of the second sub-project, called 'Exotic Metals' of the project "Setting integrated environmental quality objectives". These trace metals are antimony, barium, beryllium, cobalt, molybdenum, selenium, thallium, tin, and vanadium. The report is an integration of three activities, published in separate reports:

1. derivation of Maximum Permissible Concentrations (MPC's) and Negligible Concentrations (NC's) for water, sediment, and soil based on ecotoxicological data (including secondary poisoning for the routes: water → fish → fish-eating bird or mammal and soil → earthworm → worm-eating bird or mammal),
2. derivation of partition coefficients in order to apply the equilibrium partitioning method,
3. gathering information about background levels in soil, ground water, and surface water.

In this report the MPC's and NC's for the different compartments are harmonized using the equilibrium partitioning method. Also the harmonized MPC's and NC's are compared with the related background concentrations.

MPC's and NC's for surface water, ground water, sediment and soil could be derived for all nine trace metals. Only for the compartment water these MPC and NC values were based on ecotoxicological data. For soil and sediment no ecotoxicological data were available, except for cobalt for soil organisms. So MPC and NC values for soil and sediment for the other metals were derived using the equilibrium partitioning method. It has to be stated, however that the reliability of these MPC and NC values is limited caused by the high uncertainty in the derivation of partition coefficients for soil and sediment for these metals.

With respect to secondary poisoning only data were available for selenium and thallium for the aquatic route. Based on a global literature search (only reviews were used) it could be concluded that there will be no risk for secondary poisoning via this route for these metals.

A summary of the results of the comparison of MPC and NC values with the related background concentrations is presented in the table below. Because for sediment no data were available background concentrations in soil were used. These values can be used to set up environmental quality objectives (target and limit values). Care, however should be taken because the reliability of some of the values is limited. It should be stated that only the value for cobalt can be regarded as a harmonized value. The values presented in this table are however the best possible estimations taking into account the sometimes scarce information available.

From a comparison with the available actual concentrations it could be concluded that for several metals the MPC is exceeded in surface or ground water. For the metals for which measured data were available for sediment and/or suspended matter, i.e. antimony, cobalt and thallium, the background concentration in soil was exceeded.

A global literature search, based on reviews only, was carried out for 'deficiency levels' in surface water, because some of the exotic metals are essential elements. Only for molybdenum, selenium, cobalt and vanadium information was available. For molybdenum and selenium the negligible concentrations are lower than this level, while for cobalt the background concentration is lower than this level.

With respect to the setting of integrated environmental quality objectives for these metals the following remarks can be made:

- for many metals the derivation of background concentrations, partition coefficients and Maximum Permissible Concentrations was seriously hampered by the lack of reliable data. Considering the fact that most target values in soil and sediment will most probably be determined by the background concentration further research should be undertaken into these background concentrations and at obtaining more ecotoxicological data for sediment dwelling and soil organisms.
- for some metals negligible or background concentrations are lower than the 'deficiency levels' in surface water. Further research with respect to this subject is needed.
- data on the presence of the metals in surface water, sediment, soil and ground water were very scarce. It is, however necessary to have a systematic understanding of the actual concentrations and their spread in the environment.
- no harmonization has taken place with the compartment air. It is recognized however that transport via air can be an important route for metals. If harmonization with air is desired it is therefore first of all necessary to quantify these processes.

**Concentrations derived from the comparison of Maximum Permissible and Negligible Concentrations and background concentrations. Values for surface water and ground water in  $\mu\text{g/l}$ , for sediment and soil in  $\text{mg/kg}$  (concentrations in soil and sediment are derived for a standard soil containing 10% organic matter and 25% clay).**

	Surface water		Sediment		Ground water		Soil	
	MPC; B	NC; B	MPC; B	NC; B	MPC; B	NC; B	MPC; B	NC; B
antimony	6	<b>0.3</b>	16	<b>3</b>	6	<b>0.1</b>	<b>3</b>	<b>3</b>
barium	150	<b>75</b>	<b>155</b>	<b>155</b>	<b>200</b>	<b>200</b>	<b>155</b>	<b>155</b>
beryllium	0.2	<b>0.02</b>	<b>1.1</b>	<b>1.1</b>	0.2	<b>0.05</b>	<b>1.1</b>	<b>1.1</b>
cobalt	2.0	<b>0.2</b>	<b>9</b>	<b>9</b>	2.0	<b>0.6</b>	24	<b>9</b>
molybdenum	300	3	250	2.5	300	3	250	2.5
selenium	5	0.05	2	<b>0.7</b>	5	0.05	<b>0.7</b>	<b>0.7</b>
tin	20	0.2	22000	220	20	0.2	35	<b>19</b>
thallium	2	<b>0.04</b>	<b>(2)</b>	<b>(2)</b>	2	0.02	<b>(2)</b>	<b>(2)</b>
vanadium	4	<b>1</b>	<b>42</b>	<b>42</b>	4	<b>1</b>	<b>42</b>	<b>42</b>

- comparison is carried out as follows: if the MPC or NC is lower than the background concentration in the compartment considered the background concentration is presented in the table; if this is not the case the MPC or NC is presented,
- background concentrations printed in bold,
- background concentration in soil and sediment value for thallium is not a background concentration but value reported for the continental crest; for sediment background concentrations in soil were used.



## SAMENVATTING

Dit rapport is het resultaat van het tweede sub-project, getiteld 'Exotische Metalen' in het kader van het project Integrale Normstelling. Het betreft de volgende sporenmatalen: antimoon, barium, beryllium, cobalt, molybdeen, seleen, thallium, tin en vanadium. Het rapport is een integratie van de volgende activiteiten, gepubliceerd in afzonderlijke rapporten:

1. de afleiding van Maximaal Toelaatbare Risiconivo's (MTR's) en Verwaarloosbare Risiconivo's (VR's) voor water, sediment en bodem op basis van ecotoxicologische gegevens (inclusief doorvergiftiging voor de routes: water → vis → visetende vogel of zoogdier en bodem → regenworm → wormetende vogel of zoogdier),
2. de afleiding van partiticoëfficiënten om de evenwichtspartitiemethode te kunnen toepassen,
3. het verzamelen van informatie over achtergrondgehalten in bodem, grondwater en oppervlaktewater.

In dit rapport zijn de MTR en VR waarden voor de diverse compartimenten op elkaar afgestemd middels het toepassen van de evenwichtspartitiemethode. Daarnaast zijn de afgestemde MTR en VR waarden vergeleken met de achtergrondgehalten in het betreffende compartiment.

Voor alle sporenelementen konden MTR en VR waarden worden afgeleid voor oppervlaktewater, grondwater, bodem en sediment. Alleen voor het compartiment water zijn deze risiconivo's echter gebaseerd op ecotoxicologische gegevens. Voor bodem en sediment waren dergelijke gegevens alleen voor kobalt t.a.v. bodemorganismen beschikbaar. Dit betekent dat voor de andere metalen de MTR en VR waarden zijn afgeleid m.b.v. de evenwichtspartitiemethode. De betrouwbaarheid van deze waarden is echter gering gezien de grote onzekerheden bij de afleiding van partiticoëfficiënten voor bodem en sediment voor deze metalen.

Voor wat betreft het beoordelen van het risico voor doorvergiftiging waren alleen gegevens beschikbaar voor seleen en thallium voor de aquatische route. Gebaseerd op een globaal literatuuronderzoek, waarbij alleen gebruikt is gemaakt van reviews, kon geconcludeerd worden dat er geen risico bestaat voor doorvergiftiging via deze route voor deze twee metalen.

Een samenvatting van de resultaten van de vergelijking van de achtergrondgehalten met MTR en VR waarden is weergegeven in de onderstaande tabel. Omdat voor sediment geen achtergrondgehalten beschikbaar waren wegens het ontbreken van gegevens zijn de gehalten in bodem gebruikt. Deze waarden kunnen gebruikt worden voor het afleiden van milieukwaliteitsdoelstellingen (grens- en streefwaarden). Opgemerkt moet worden dat de betrouwbaarheid van de enkele waarden beperkt is en dat alleen de waarde voor kobalt beschouwd kan worden als een afgestemde waarde. De waarden uit de tabel moeten beschouwd worden als de best mogelijke schattingen voor deze metalen die gemaakt kunnen worden op grond van de (veelal beperkt) beschikbare informatie.

Uit de vergelijking van deze concentraties met actuele meetgegevens, voor zover aanwezig, kon geconcludeerd worden dat voor enkele metalen de MPC in oppervlakte- en grondwater wordt overschreden. Het achtergrondgehalte in de bodem werd overschreden voor alle metalen waarvoor gegevens beschikbaar waren voor sediment en/of gesuspendeerd materiaal, nl. antimoon, kobalt en thallium.

Een globaal literatuuronderzoek (alleen reviews zijn hierbij gebruikt) is uitgevoerd naar 'deficiëntienivo's' in oppervlaktewater, omdat sommige van deze metalen essentiële elementen zijn. Voor molybdeen en seleen zijn de VR waarden lager dan deze nivo's, terwijl voor kobalt het achtergrondgehalte lager is dan dit nivo.

Met betrekking tot het afleiden van milieukwaliteitsdoelstellingen voor deze metalen kunnen de volgende opmerkingen gemaakt worden:

- voor het afleiden van achtergrondgehalten, partiticoëfficiënten en Maximaal Toelaatbare Risiconivo's ontbreken voor veel metalen betrouwbare gegevens. Aangezien de streefwaarde in bodem en sediment meestal bepaald zal worden door het achtergrondgehalte verdient het aanbeveling om met name onderzoek te doen naar deze gehalten. Tevens dienen meer ecotoxicologische gegevens voor bodem- en sedimentorganismen beschikbaar te komen.
- voor sommige metalen waren de VR waarden of achtergrondgehalten lager dan de 'deficiëntienivo's' in oppervlaktewater. Verder onderzoek naar deze nivo's is nodig.
- gegevens over het voorkomen van deze metalen in sediment, bodem en oppervlakte en grondwater zijn nauwelijks beschikbaar. Het is echter noodzakelijk om een systematisch overzicht te hebben van de huidige concentraties in het milieu en de spreiding erin.
- geen afstemming heeft plaatsgevonden met het compartiment lucht. Transport via de lucht kan echter een belangrijke route zijn voor metalen. Indien afstemming met lucht gewenst is het noodzakelijk om deze processen te kwantificeren.

**Samenvatting van de vergelijking van Maximaal Toelaatbare en Verwaarloosbare Risiconivo's en achtergrondgehalten. De waarden voor oppervlaktewater en grondwater zijn weergegeven in  $\mu\text{g/l}$ , voor sediment en bodem in  $\text{mg/kg}$  (waarden voor bodem en sediment gebaseerd op een standaardbodem met 10% organische stof en 25% lutum).**

	Oppervlaktewater		Sediment		Grondwater		Bodem	
	MTR; B	VR; B	MTR; B	VR; B	MTR; B	VR; B	MTR; B	VR; B
antimoon	6	<b>0.3</b>	16	<b>3</b>	6	<b>0.1</b>	<b>3</b>	<b>3</b>
barium	150	<b>75</b>	<b>155</b>	<b>155</b>	<b>200</b>	<b>200</b>	<b>155</b>	<b>155</b>
beryllium	0.2	<b>0.02</b>	1.1	1.1	0.2	<b>0.05</b>	1.1	1.1
kobalt	2.0	<b>0.2</b>	<b>9</b>	<b>9</b>	2.0	<b>0.6</b>	24	<b>9</b>
molybdeen	300	3	250	2.5	300	3	250	2.5
seleen	5	0.05	2	<b>0.7</b>	5	0.05	<b>0.7</b>	<b>0.7</b>
tin	20	0.2	22000	220	20	0.2	35	<b>19</b>
thallium	2	<b>0.04</b>	<b>(2)</b>	<b>(2)</b>	2	0.02	<b>(2)</b>	<b>(2)</b>
vanadium	4	<b>1</b>	<b>42</b>	<b>42</b>	4	<b>1</b>	<b>42</b>	<b>42</b>

- de vergelijking is als volgt uitgevoerd: indien de MTR of VR waarde lager is dan het achtergrondgehalte in het betreffende compartiment is het achtergrondgehalte weergegeven; indien het omgekeerde het geval is de MTR of VR waarde weergegeven
- achtergrondgehalten zijn vet gedrukt,
- het achtergrondgehalte van thallium voor sediment en bodem is geen achtergrondgehalte maar een waarde gerapporteerd voor de continentale korst; voor sediment zijn de achtergrondgehalten in bodem gebruikt.

## 1. INTRODUCTION

In 1989 the Directorate-General for Environmental Protection started the project "Setting integrated environmental quality objectives". In this project action A-35 of the National Environmental Policy Plan is worked out [1]. Goal of this project is to derive integrated quality objectives for air, water and soil for a great number of compounds, based on the risk philosophy of the Ministry of Housing, Physical Planning and the Environment [2]. The project is carried out by the National Institute for Public Health and the Environmental Protection. The first sub-project "MILBOWA" resulted in the report "Desire for levels" [3]. In this report a methodology was proposed for deriving maximum permissible concentrations for several compounds like heavy metals, chlorophenols, pesticides and polycyclic aromatic hydrocarbons. Based on this report integrated environmental quality objectives for water and soil were proposed and accepted by the Minister of the Environment from the Netherlands [4].

The second sub-project (b-1) was called 'exotic metals'<sup>1</sup>. Goal of this project was to derive integrated quality objectives for surface water, ground water, sediment and soil for antimony, barium, beryllium, cobalt, molybdenum, selenium, thallium, tin, and vanadium. For deriving these quality objectives almost the same methods are used as described in "Desire for levels" [3]. Hence, Maximum Permissible Concentrations (MPC) and Negligible Concentrations (NC) for water, sediment and soil are determined using extrapolation methods based on toxicity data. Subsequently these MPC's and NC's for the different compartments are harmonized using the equilibrium partitioning method. Details on the methodological background can be found in reports by van de Meent et al. and Slooff [3,5]. Because metals are naturally occurring substances, specific attention has to be paid to the natural background concentrations that are present in surface water, ground water, sediment and soil. These background concentrations have to be compared with the harmonized MPC and NC values for the different compartments. In general the background concentration will be used as a target value if the NC is lower than this background concentration. It is possible that background concentrations are a factor in the selection of species in ecosystems, due to their toxic influence. For this reason target levels below the background concentration could be undesirable. This is also undesirable from a political point of view, because it is unreal to aim at the restoration of the 'natural' situation.

The compartment air was not taken into account for the following reasons:

- it was expected that there would be almost no toxicity data for the exotic metals in order to derive MPC and NC values,
- harmonization of MPC's and NC's for air with those for water, sediment and soil for metals is still problematic at the moment. A model for harmonization is being developed by the National Institute for Public Health and Environmental Protection.
- deriving and harmonizing MPC and NC values for air will be dealt with in the next sub-project (b-2) concerning several volatile organic compounds.

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<sup>1</sup> These metals are denoted 'exotic metals' because they were only relatively seldom subject of environmental studies. Although selenium and antimony are strictly speaking not metals but metalloids they are denoted trace metals throughout this report.

Summarizing, for project b-1 the following activities have taken place:

1. derivation of MPC's and NC's for water, sediment, and soil based on ecotoxicological data (including secondary poisoning),
2. derivation of partition coefficients in order to apply the equilibrium partitioning method,
3. gathering information on background levels in soil, ground water, and surface water,
4. harmonization of the MPC's and NC's for the different compartments using the equilibrium partitioning method,
5. comparison of the harmonized MPC's and NC's with background levels,
6. setting integrated environmental quality objectives (limit and target values).

A flow-diagram of the different steps in the procedure that leads to environmental quality objectives is given in Figure 1.1.

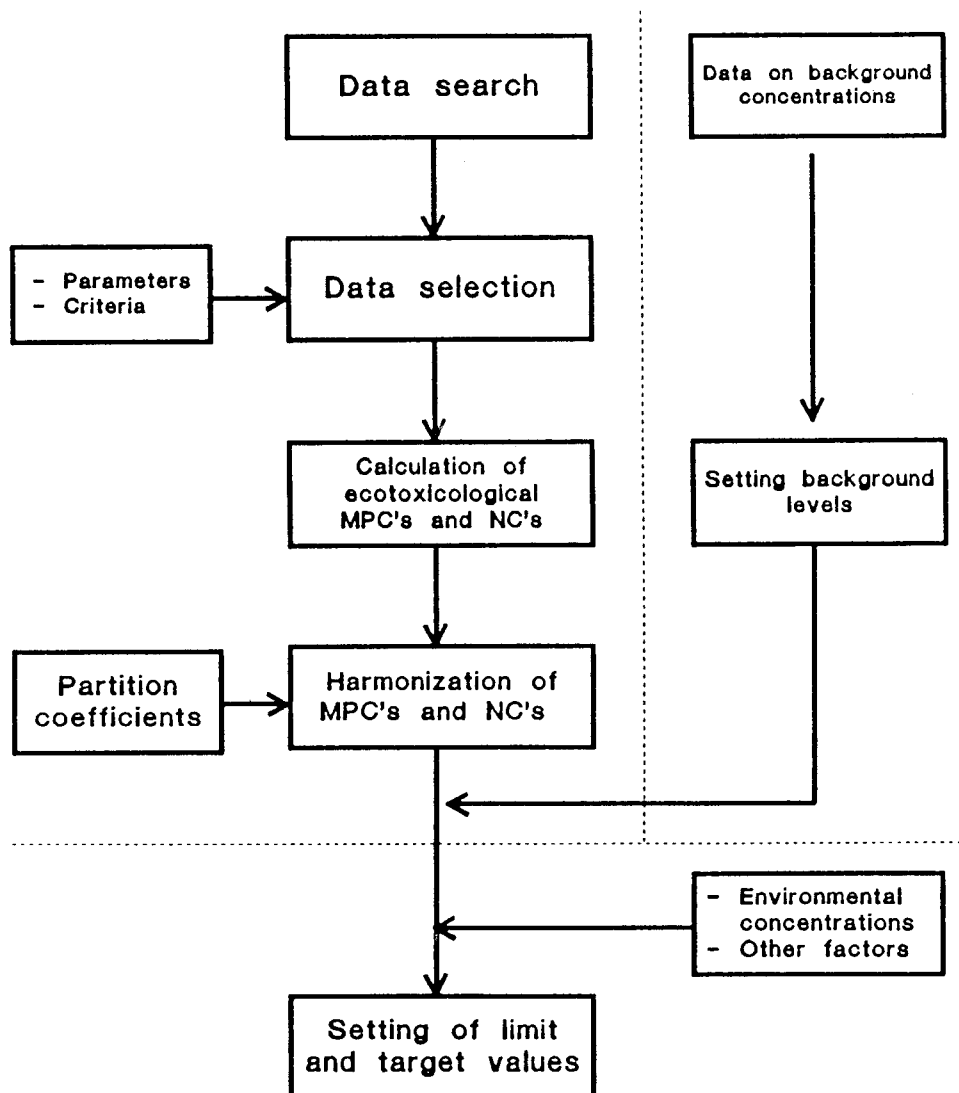


Figure 1.1: The process of setting integrated environmental quality objectives

It was decided by the National Institute of Public Health and Environmental Protection and the Ministry of Housing, Physical Planning and the Environment to publish separate reports about the first four aspects. The last step, setting limit and target values, will be the subject of a separate policy document that will include also environmental quality objectives for a group of volatile organic hydrocarbons and a group of pesticides (sub-projects b-2 and b3).

This report deals with activities 4 and 5, mentioned above. First however, a short summary of the basic reports describing the first three activities is given in Chapters 2, 3 and 4 respectively. In Chapter 5 the results from the ecotoxicological effects assessment are compared with background concentrations and harmonization is carried out by application of the equilibrium partitioning method. Also values are proposed which can be used to set up environmental quality objectives (target and limit values). In Chapter 6 current environmental concentrations are given and compared to the proposed values. Finally in Chapter 7 the results are discussed in terms of the availability and reliability of the underlying information used.

## 2. DERIVING MAXIMUM PERMISSIBLE CONCENTRATIONS AND NEGLIGIBLE CONCENTRATIONS FOR WATER, SEDIMENT AND SOIL FROM TOXICITY DATA

### 2.1 Introduction

For deriving environmental quality objectives two risk limits have been defined in The Netherlands [2]:

- Maximum Permissible Concentration (MPC) defined as the concentration at which 95% of the species in an ecosystem is fully protected,
- Negligible Concentration (NC) defined as 1% of the MPC.

The MPC is determined using methods applied in ecotoxicological effects assessment [5]. These extrapolation methods use ecotoxicological data as input. Two different extrapolation methods are used. If 4 or more chronic NOEC's from different taxonomic groups are available Modification 0 of the method of Van Straalen and Denneman as developed by Aldenberg and Slob is used (refined effects assessment). The 95% protection level calculated with 50% confidence is regarded as the MPC. If less toxicity data are available the modified EPA method is applied (preliminary effects assessment). This method applies assessment factors based on the number and kind of data. The result of this method is called an indicative MPC.

Toxicity data were collected for aquatic (salt- as well as freshwater), terrestrial and sediment dwelling organisms by carrying out an extensive literature search. Since some of the 'exotic metals' are essential elements a limited literature search was carried out to determine at which waterborne concentration deficiency symptoms begin to occur, i.e. the 'deficiency level'. Toxicity data for marine and freshwater organisms were compared on the level of taxonomic group to see whether it was acceptable to apply extrapolation methods to the combined data sets. From this comparison it was concluded that for metals saltwater organisms are not more sensitive than freshwater organisms. For freshwater organisms, however, much more data were available than for saltwater organisms.

Also an attempt was made to take secondary poisoning into account for the routes water → fish → fish-eating bird or mammal and soil → earthworm → worm-eating bird or mammal. Therefore, the method of Romijn et al. was used in which MPC's for secondary poisoning are compared with the MPC's based on ecotoxicological data for aquatic or terrestrial organisms [6,7]. If the latter MPC's are higher than the former, secondary poisoning is considered as a critical pathway. Because it was expected that secondary poisoning would not occur for these metals it was decided to carry out a global literature search first.

### 2.2 MPC's and NC's for surface water

A survey of the selected reliable acute and chronic toxicity data is presented in appendix 1. For all metals enough toxicity data were available to make it possible to derive MPC's, although chronic data were scarce. Only for beryllium, cobalt and selenium 4 or more chronic

NOEC's were available, so Modification 0 could be applied. As was expected more data were available for freshwater than for saltwater organisms. For barium and beryllium no data for saltwater organisms were present at all. With respect to secondary poisoning only data were available for selenium and thallium. As the MPC's for secondary poisoning were higher than the MPC's based on toxicity data it was concluded that there will probably be no risk for secondary poisoning via the route water → fish → fish-eating mammal for both metals. In Table 2.1 the MPC's and NC's are presented together with the lowest NOEC available and the 'deficiency level'.

MPC's were compared with the lowest NOEC available and other toxicity data. It can be concluded that the MPC's for antimony, barium and molybdenum might be relatively low as compared to the toxicity data. It should be emphasized that these MPC's are calculated using the modified EPA method. Hence, high assessment factors are sometimes applied when few data are available. For antimony, however, some literature data of which the original papers could not be retrieved, showed that this metal was more toxic than could be concluded from the data already available.

**Table 2.1 Maximum permissible and negligible concentrations for surface water based on toxicity data for fresh- and saltwater organisms. The lowest L(E)C50, the lowest chronic NOEC's and the concentrations below which deficiency symptoms begin to occur ('deficiency level') are also presented (all in  $\mu\text{g/l}$ ).**

	MPC <sub>aq.</sub> ( $\mu\text{g/l}$ )	NC <sub>aq.</sub> ( $\mu\text{g/l}$ )	lowest L(E)C50 ( $\mu\text{g/l}$ )	lowest NOEC ( $\mu\text{g/l}$ )	'deficiency level' ( $\mu\text{g/l}$ )
antimony	6.2 <sup>1</sup>	0.062	6,200	23,000	-
barium	150 <sup>1</sup>	1.5	15,000	2,900	-
beryllium	0.16	0.0016	1,200	0.68	-
cobalt	2.0	0.020	300	5.0	5-40
molybdenum	290 <sup>1</sup>	2.9	29,000	27,000	10
selenium	5.3	0.053	260	0.9	1
thallium	1.6 <sup>1</sup>	0.016	160	30	-
tin	18 <sup>1</sup>	0.18	290	180	-
vanadium	3.5 <sup>1</sup>	0.035	3,500	41	0.5-10

<sup>1</sup> indicative MPC based on the modified EPA method

If the MPC's are compared with the deficiency levels it can be concluded that these concentrations lie in the same concentration range, except for molybdenum for which the MPC is a factor 29 higher. The NC's, however, are much lower than these deficiency levels. It should be stated however that no extensive literature search was carried out in order to determine these deficiency levels more exactly. Also both concentrations must be compared with background concentrations in surface water. This will be carried out in paragraph 5.2.

Because no toxicity data were available for ground water organisms the MPC and NC's for surface water from table 2.1 were used also as MPC and NC's for ground water.

### **2.3 MPC's and NC's for soil and sediment**

For sediment no MPC's could be calculated because no toxicity data were available for benthic organisms exposed via sediment. For soil only for cobalt an indicative MPC and NC of 24 and 0.24 mg/kg, respectively could be derived for a standard soil using the modified EPA method. For the other metals no toxicity data were available. The MPC for secondary poisoning via the route soil → earthworm → worm-eating bird or mammal could not be calculated because no data were available.



### 3 PARTITION COEFFICIENTS FOR SEDIMENT AND SOIL

#### 3.1 Introduction

To derive partition coefficients ( $K_p$ 's) for the nine trace metals a literature review with respect to adsorption experiments with soils and sediments was carried out by Bockting et al. [9]. A short summary of the report is included in this chapter.

For the derivation of  $K_p$ 's batch experiments were preferred, because other experimental techniques usually give no information whether an adsorption equilibrium is reached.

It should be kept in mind that  $K_p$ 's which must apply to a wide range of soils or sediments, differing considerably in their physical-chemical characteristics, can never be very accurate. It is estimated that a coefficient of variation of about 30 % applies to the logarithmic  $K_p$ 's presented in this Chapter.

#### 3.2 Soils

In batch experiments usually only the adsorbed metal content is determined to calculate the partition coefficient. Hence, in principle a correction should be made for the metal content that is unexchangeable bound in soils. The latter might be approximated with the background content, or a fraction thereof, of metals in soils assuming that the major fraction of the background content of soils is firmly bound. Because of the uncertainty in the  $K_p$ 's however this correction is not carried out.

Selected  $K_p$ 's for soils are presented in Table 3.1. Experimental data for barium, beryllium and tin were not available. Partitioning of these metals in soils was assumed to be comparable with calcium, magnesium and lead, respectively.

#### 3.3 Sediments

For sediments no studies were found in which adsorption was tested in batch experiments. Therefore,  $K_p$ 's for sediments were derived from measurements of the (total) metal content of riverine particulate matter and corresponding water samples (Table 3.1). Strictly speaking these  $K_p$ 's are not suitable for application of the EP method, because they do not necessarily relate to an equilibrium situation.

Since the adsorption of metals to sediments is lower than the adsorption to particulate matter, caused by the difference in organic matter and clay content, the  $K_p$ 's presented in Table 3.1 were derived from the  $K_p$ 's for particulate matter divided by a factor 1.5 [10].

The  $K_p$ 's for sediments are much higher than the soil  $K_p$ 's. The differences are attributed to divergent characteristics of the sorbent, deviating experimental techniques, the fact that the sediment  $K_p$ 's are based on total metal contents and to different physical-chemical conditions for adsorption. The pH of surface water is often higher than in soils were low pH's (3-5) are

often found. This relatively high pH may explain the high sediment  $K_p$ 's for cationic trace metals (but not for the metals that occur as oxyanions). Particle concentrations are obviously much lower in surface water than in soil. Several authors showed that low particle concentrations lead to high  $K_p$ 's [11,12]. The experiments with particulate matter found in literature were all conducted at low (environmental) metal concentrations in contrast with the relatively high aqueous concentrations in the batch experiments conducted with soil. Adsorption isotherms for trace metals normally show that  $K_p$ 's increase at low aqueous concentrations [11-14].

The  $K_p$ 's presented in Table 3.1 can be used to estimate the metal content of sediments corresponding with the MPC's for water. As stated above the  $K_p$ 's are based on total metal contents. Therefore, in contrast with soils, no estimation of the unexchangeable bound metal content should be added to this content.

### 3.4 Marine sediments

Physical-chemical conditions (pH, ionic strength, concentration of complex forming ions) for the adsorption of trace metals in seawater differ considerably from conditions in freshwater. Consequently,  $K_p$ 's for marine particulate matter or sediments might differ from those for freshwater. Examination of data for freshwater and marine particulate matter [15,16] showed that considerable differences occur indeed. Experimental results of Li et al. [17] showed that seawater  $K_p$ 's might either be lower or higher than freshwater  $K_p$ 's, depending on the metal regarded. This and the lack of data for partitioning of trace-metals in seawater makes it very difficult to propose well-founded  $K_p$ 's for marine sediments different from the ones for freshwater sediments. Because of these reasons for the moment the  $K_p$ 's for freshwater as shown in Table 3.1 were used.

**Table 3.1 Log  $K_p$ 's (l/kg) for sediments and soils<sup>1</sup>.**

	Sediment Geom. mean	Soil Geom. mean
antimony	3.41	1.93
barium	3.00	1.78 <sup>3</sup>
beryllium	2.78	1.58 <sup>4</sup>
cobalt	3.60	1.60
molybdenum	2.93	2.94
selenium	2.62	1.30
tin	6.09	3.28 <sup>5</sup>
thallium	3.00 <sup>2</sup>	2.20 <sup>6</sup>
vanadium	3.59	2.49

<sup>1</sup> The values are average values derived from concentration distributions for particulate matter in various rivers and lakes. It was assumed that  $K_p$ 's for sediments are roughly 1.5 times lower than for particulate matter [10]  
<sup>2</sup> no data available, estimation (more mobile than Zn), average Log  $K_p$  for Zn = 3.91 derived from [17,18,19]  
<sup>3</sup> no data available, adsorption of Ba is assumed to be comparable with Ca, data for Ca from [20]  
<sup>4</sup> no data available, adsorption of Be is assumed to be comparable with Mg, data for Mg from [20]  
<sup>5</sup> no data available, adsorption of Sn is assumed to be comparable with Pb, data for Pb from [13]  
<sup>6</sup> no data available, estimation (more mobile than Zn and Cu), data for Cu from [13]

#### 4. BACKGROUND CONCENTRATIONS IN SURFACE WATER, GROUND WATER AND SOIL

Background concentrations of the nine trace metals in surface water, ground water and soil in the Netherlands have been reported by De Bruijn and Denneman [21]. Only a short summary is given here. For further details on the data analysis reference is made to the original report. The results in that report are based only on data that were already available in data-bases and documents from the open literature. No specific chemical analyses have been carried out.

Background concentrations for surface water are derived using a so-called "clean-brooks model". In this model background concentrations are derived from measured concentrations of the metals in samples from brooks in relatively clean areas in the Northern European Lowland [22]. Data were obtained from international data bases and water quality management institutes. After a screening phase, particularly aiming at the detection of data from brooks that were not considered as clean, a statistical analysis was carried out to calculate geometric mean and 90 percentile values for the nine trace metals. However, the number of reliable suitable data appeared to be limited. For barium, molybdenum and vanadium enough data ( $n > 30$ ) were available from the Northern European Lowland data set to calculate reliable geometric mean and 90 percentile values that can be used as representative values for the Dutch situation. For beryllium, cobalt, antimony, selenium, tin and thallium data from the Northern European Lowland had to be combined with data from the international literature. Accordingly, the representativeness of these data for the Dutch situation is lower.

Because of the fact that concentrations in "clean brooks" can not be regarded as being free from anthropogenic influences (very likely by atmospheric deposition) [22], the geometric mean values instead of 90 percentile values can be regarded as being the most representative for the background concentrations in the Netherlands. Both values are given in Table 4.1. In Chapter 5 a discussion will be given on the consequences of choosing either of the data sets.

For soil, measured concentrations in soil samples from a large number of relatively unpolluted natural areas in the Netherlands are used. For barium, beryllium, cobalt, tin and vanadium enough data were available to calculate so-called "soil type correction factors" using the clay content (L) of the soil as the only variable. In this way allowance is made for the naturally occurring variation in the concentrations of these metals in soil. The soil type correction factors were set in such a way that approximately 90 % of the measured concentrations were below the reference-line as given in Table 4.1. For three metals data were so scarce that only one fixed background value could be established, whereas for thallium no data on concentrations in soil from the Netherlands were available. The only value for thallium which seems usable is 1.5 mg/kg reported by Zuurdeeg et al. for the continental crest [22]. The analytical method that was used appeared to be a very important factor for the final setting of the background concentrations. Particularly different methods of metal extraction from soil can lead to large differences in the final values. Standardisation of these methods should be given specific attention in the near future.

Background concentrations in ground water are mainly based on measured concentrations from the Dutch national ground water quality monitoring network. For most metals a sufficient number of data ( $n > 50$ ) were available to calculate a 90 percentile value. For tin and thallium only an upper-limit (approximately equal to the detection limit) can be given [24,25].

In the proceeding table a survey is given of the background concentrations that were finally selected from the data-bases and documents as reported by De Bruijn and Denneman [21].

**Table 4.1 Background concentrations in surface water, ground water and soil. Data for surface and ground water in  $\mu\text{g/l}$ , data for soil in  $\text{mg/kg}$ .**

	Surface water <sup>1</sup> geometric mean	Surface water 90-percentile	Ground water 90-percentile	Soil L = % clay
antimony	0.32	1.0	0.091	3
barium	76	121	197	30 + 5xL
beryllium	0.017	0.04	0.05	0.3 + 0.033xL
cobalt	0.22	1.8	0.63	2 + 0.28xL
molybdenum	1.4	6.8	0.69	0.5
selenium	0.042	0.24	0.024	0.7
tin	0.002	0.10	<2	4 + 0.6xL
thallium	0.04	0.13	<2	(1.5)
vanadium	0.96	3.7	1.22	12 + 1.2xL

<sup>1</sup> The background concentrations in surface water in the Netherlands are based on samples from brooks in relatively clean areas in the Northern European Lowland

## 5. DERIVATION OF COORDINATED MAXIMUM PERMISSIBLE AND NEGLIGIBLE CONCENTRATIONS FOR SURFACE WATER, GROUND WATER, SEDIMENT AND SOIL AND COMPARISON WITH BACKGROUND CONCENTRATIONS

### 5.1 Procedure

Maximum permissible and negligible concentrations for the aquatic compartment based on ecotoxicological data have been derived in Chapter 2. These  $MPC_{aq.}$  and  $NC_{aq.}$  values have to be compared to the natural background concentrations in the respective compartments. A discussion on the results of this comparison is given in paragraph 5.2.

In principle the ecotoxicological extrapolation methods that were used to derive MPC and NC values for surface water and ground water can also be applied to calculate MPC and NC values for sediment and soil. However, as was mentioned in Chapter 2, with the exception of cobalt, for the trace metals discussed in this report toxicity data for sediment or soil organisms are lacking. The calculation of the MPC and NC for soil and sediment is therefore carried out by means of the equilibrium partitioning method using the formula [5,23]:

$$MPC_{sed.} = MPC_{aq.} * K_p$$

where:

$K_p$  = partition coefficient between sediment and water (l/kg)

$MPC_{aq.}$  = maximum permissible concentration derived from toxicity data for aquatic organisms (mg/l)

$MPC_{sed.}$  = maximum permissible concentration in sediment based on ecotoxicological data (mg/kg dry sediment)

Similar equations can be set up for the negligible concentration in sediment ( $NC_{sed.}$ ) and for the MPC and NC in soil ( $MPC_{soil}$  and  $NC_{soil}$ ). Soil and sediment partition coefficients have been described in Chapter 3.

Since no toxicity data are available for soil and sediment dwelling organisms and the equilibrium partitioning method is used to calculate MPC and NC values for sediment and soil, coordination of these values to the values for surface water is meaningless. Only for cobalt coordination of the different  $MPC_{soil}$  and  $NC_{soil}$  values, based on toxicity data and based on the equilibrium partitioning method, can be carried out. The MPC and NC values for sediment and soil derived by equilibrium partitioning have to be compared however to the background concentrations in the respective compartments. The results of this comparison are given in paragraph 5.3 and 5.4.

## 5.2 Maximum Permissible and Negligible Concentrations in surface water and ground water and comparison with background concentrations

In Table 5.1 a survey of MPC<sub>aq.</sub> and NC<sub>aq.</sub> values is given together with the background concentrations in surface water (geometric mean and 90 percentile values) and in ground water. As stated in paragraph 2.2 MPC and NC values for surface water were used also as MPC and NC values for ground water. As can be seen from this table the MPC<sub>aq.</sub> calculated from the toxicological data is for all compounds higher than the background concentration in surface water as well as in ground water. Only for barium the ground water value slightly exceeds the MPC<sub>aq.</sub>. Except for tin, negligible concentrations are much lower than the 90-percentile background concentrations for surface water. For molybdenum, selenium and tin, however, the NC<sub>aq.</sub> is higher than the geometric mean value for surface water. A comparable situation where NC<sub>aq.</sub> values are lower than background concentrations was reported by van de Meent et al. for metals such as zinc, nickel, lead, copper and chromium [3]. It is very well possible that at naturally occurring concentrations of these metals risks to certain species are indeed not negligible. These concentrations may even be a very important factor in the selection of species in ecosystems and therefore may contribute to the natural variation in ecosystems. For the setting of limit or target values background concentrations have to be taken in consideration.

**Table 5.1 Maximum Permissible (MPC<sub>aq.</sub>) and Negligible Concentrations (NC<sub>aq.</sub>) based on ecotoxicological data for aquatic species and background concentrations for surface water and ground water (B<sub>sw</sub> and B<sub>gw</sub>, respectively) (in µg/l).**

	MPC <sub>aq.</sub> (µg/l)	NC <sub>aq.</sub> (µg/l)	B <sub>sw</sub> (µg/l) geom. mean	B <sub>sw</sub> (µg/l) 90-percentile	B <sub>gw</sub> (µg/l) 90-percentile
antimony	6.2	0.062	0.32	1.0	0.091
barium	150	1.5	76	121	197
beryllium	0.16	0.0016	0.017	0.04	0.05
cobalt	2.0	0.02	0.22	1.8	0.63
molybdenum	290	2.9	1.4	6.8	0.69
selenium	5.3	0.053	0.042	0.24	0.024
tin	18	0.18	0.002	0.10	<2
thallium	1.6	0.016	0.04	0.13	<2
vanadium	3.5	0.035	0.96	3.7	1.22

Abbreviations:

MPC <sub>aq.</sub> :	Maximum Permissible Concentration from ecotoxicological data
NC <sub>aq.</sub> :	Negligible Concentration from ecotoxicological data
B <sub>sw</sub> :	Background concentration in surface water
B <sub>gw</sub> :	Background concentration in ground water

From Table 5.1 it can also be seen that when instead of geometric mean values, 90-percentile values for surface water are used as background concentrations, the difference between the MPC<sub>aq.</sub> and the background concentration becomes very small for barium, cobalt and vanadium. In addition, relatively large differences arise between these 90-percentile values and the background concentrations in ground water: for molybdenum, antimony and selenium the surface water values are approximately a factor 10 higher. These results are contradictory

to the situation reported for other metals such as zinc, nickel and lead where background values in surface water were appreciably lower than ground water background values [4].

In Table 5.2 for every individual compound a summary is given of the relative differences between  $MPC_{aq}$  and  $NC_{aq}$  and the two reported background values in surface water (geometric mean ( $B_{sw,50}$ ) and 90 percentile ( $B_{sw,90}$ )). A similar exercise is carried out for ground water in Table 5.3. Where appropriate, values were rounded of.

**Table 5.2 Concentrations derived from the comparison of Maximum Permissible ( $MPC_{aq}$ ) and Negligible Concentrations ( $NC_{aq}$ ) with background concentrations ( $B_{sw}$ ) in surface water (in  $\mu\text{g/l}$ ).**

	Considerations	$MPC_{aq}; B_{sw}$	$NC_{aq}; B_{sw}$
antimony	$MPC_{aq} \gg B_{sw,50}, MPC_{aq} > B_{sw,90}$ $NC_{aq} < B_{sw,50}, NC_{aq} \ll B_{sw,90}$	<b>6<sup>a</sup></b>	<b>0.3<sup>a</sup></b>
barium	$MPC_{aq} = 2 * B_{sw,50}, MPC_{aq} = B_{sw,90}$ $NC_{aq} \ll B_{sw,50} \& B_{sw,90}$	150	<b>75</b>
beryllium	$MPC_{aq} > B_{sw,50}, MPC_{aq} > B_{sw,90}$ $NC_{aq} \ll B_{sw,50} \& B_{sw,90}$	0.2	<b>0.02</b>
cobalt	$MPC_{aq} > B_{sw,50}, MPC_{aq} = B_{sw,90}$ $NC_{aq} \ll B_{sw,50} \& B_{sw,90}$	2.0	<b>0.2</b>
molybdenum	$MPC_{aq} \gg B_{sw,50} \& B_{sw,90}$ $NC_{aq} = 2 * B_{sw,50}, NC_{aq} = 0.4 * B_{sw,90}$	300	3
selenium	$MPC_{aq} \gg B_{sw,50} \& B_{sw,90}$ $NC_{aq} = B_{sw,50}, NC_{aq} < B_{sw,90}$	5	0.05
tin	$MPC_{aq} \gg B_{sw,50} \& B_{sw,90}$ $NC_{aq} \gg B_{sw,50}, NC_{aq} = 2 * B_{sw,90}$	20	0.2
thallium	$MPC_{aq} \gg B_{sw,50} \& B_{sw,90}$ $NC_{aq} = 0.4 * B_{sw,50}, NC_{aq} < B_{sw,90}$	2	<b>0.04</b>
vanadium	$MPC_{aq} > B_{sw,50}, MPC_{aq} = B_{sw,90}$ $NC_{aq} \ll B_{sw,50} \& B_{sw,90}$	4	<b>1</b>

Abbreviations: << and >>: value is more than a factor of 10 lower or higher

< or >: value is between 3 and 10 times lower or higher

\*: if the value presented is a geometric mean  $B_{sw}$  this value is printed bold

From Table 5.2 it can be seen that for almost all compounds  $MPC_{aq}$  values are higher than the geometric mean and 90 percentile background concentrations in surface water.  $NC_{aq}$  values for molybdenum, selenium and tin are higher than the geometric mean  $B_{sw}$  values whereas for the other compounds the opposite is true. Also for ground water the  $MPC_{aq}$  values are higher than the background concentrations, except for barium where both the  $MPC_{aq}$  and the  $NC_{aq}$  are lower than the  $B_{gw}$ . For tin, thallium, selenium and molybdenum the  $NC_{aq}$  values are higher than the background concentrations. However, care should be taken for tin and thallium because these  $NC_{aq}$  values are lower than the detection limit as reported by Stuijzand [24,25].

**Table 5.3 Concentrations derived from the comparison of Maximum Permissible (MPC<sub>aq.</sub>) and Negligible Concentrations (NC<sub>aq.</sub>) and background concentrations (B<sub>gw.</sub>) in ground water (in µg/l).**

	Considerations	MPC <sub>aq.</sub> ; B <sub>gw.</sub>	NC <sub>aq.</sub> ; B <sub>gw.</sub>
antimony	MPC <sub>aq.</sub> >> B <sub>gw.</sub> , NC <sub>aq.</sub> = 0.7 * B <sub>gw.</sub>	6 <sup>a</sup>	0.1 <sup>a</sup>
barium	MPC <sub>aq.</sub> = 0.75*B <sub>gw.</sub> , NC <sub>aq.</sub> << B <sub>gw.</sub>	<b>200</b>	<b>200</b>
beryllium	MPC <sub>aq.</sub> > B <sub>gw.</sub> , NC <sub>aq.</sub> << B <sub>gw.</sub>	0.2	<b>0.05</b>
cobalt	MPC <sub>aq.</sub> > B <sub>gw.</sub> , NC <sub>aq.</sub> << B <sub>gw.</sub>	2.0	<b>0.6</b>
molybdenum	MPC <sub>aq.</sub> >> B <sub>gw.</sub> , NC <sub>aq.</sub> > B <sub>gw.</sub>	300	3
selenium	MPC <sub>aq.</sub> >> B <sub>gw.</sub> , NC <sub>aq.</sub> = 2 * B <sub>gw.</sub>	5	0.05
tin	MPC <sub>aq.</sub> >> B <sub>gw.</sub> , NC <sub>aq.</sub> < B <sub>gw.</sub> (det.l.)	20	0.2 <sup>1</sup>
thallium	MPC <sub>aq.</sub> < B <sub>gw.</sub> (det.l.), NC <sub>aq.</sub> << B <sub>gw.</sub> (det.l.)	2	0.02 <sup>1</sup>
vanadium	MPC <sub>aq.</sub> > B <sub>gw.</sub> , NC <sub>aq.</sub> << B <sub>gw.</sub>	4	<b>1</b>

Abbreviations: << and >>: value is more than a factor of 10 lower or higher  
 < or >: value is between 3 and 10 times lower or higher

<sup>1</sup>: these NC values are below the detection limit

<sup>a</sup>: if the value presented is a B<sub>gw.</sub> this value is printed bold

### 5.3 Maximum Permissible and Negligible Concentrations for sediment and comparison with background concentrations

Maximum permissible and negligible concentrations in sediment are calculated using the partition coefficients from Chapter 3. The results are given in Table 5.4. For comparison, background concentrations for standard soil (B<sub>soil</sub>, 25 % clay, 10 % organic matter) are given also [21]. Unfortunately, no comparison can be made with measured background concentrations in sediment because these data are not available.

The results in Table 5.4 show that all negligible concentrations in sediment are far below the background concentrations in standard soil, except for tin where due to the very high partition coefficient, the MPC<sub>sed.</sub> and NC<sub>sed.</sub> values are relatively high. For molybdenum the NC<sub>sed.</sub> is somewhat higher than the background concentration in standard soil. For barium and cobalt the MPC is similar to B<sub>soil</sub>, for vanadium it is somewhat lower whereas for molybdenum, antimony and selenium MPC<sub>sed.</sub> is higher than B<sub>soil</sub>. The MPC<sub>sed.</sub> for thallium cannot be compared to a background concentration since the latter is not available. The value of 1.6 mg/kg, however, is approximately similar to the value of 1.5 mg/kg that was reported for the continental crest by Zuurdeeg et al. [22].



**Table 5.4 Maximum Permissible (MPC<sub>sed.</sub>) and Negligible Concentrations (NC<sub>sed.</sub>) for sediment based on ecotoxicological data and equilibrium partitioning (in mg/kg).**

	MPC <sub>aq.</sub> (µg/l)	NC <sub>aq.</sub> (µg/l)	LogK <sub>p</sub> sediment	MPC <sub>sed.</sub> (mg/kg)	NC <sub>sed.</sub> (mg/kg)	B <sub>soil</sub> (mg/kg)
antimony	6.2	0.062	3.41	16	0.16	3
barium	150	1.5	3.00	150	1.5	155
beryllium	0.16	0.0016	2.78	0.1	0.001	1.1
cobalt	2.0	0.02	3.60	8.0	0.08	9
molybdenum	290	2.9	2.93	250	2.5	0.5
selenium	5.3	0.053	2.62	2.2	0.022	0.7
tin	18	0.18	6.09	22000	220	19
thallium	1.6	0.016	3.00	1.6	0.016	-
vanadium	3.5	0.035	3.59	14	0.14	42

MPC<sub>aq.</sub>: Maximum Permissible Concentration based on aquatic toxicity data

NC<sub>aq.</sub>: Negligible Concentration based on aquatic toxicity data

K<sub>p</sub>: Partition coefficient for sediment

MPC<sub>sed.</sub>: Maximum Permissible Concentration in sediment based on aquatic toxicity data and partition coefficient for sediment

N<sub>sed.</sub>: Negligible Concentration based on aquatic toxicity data and partition coefficient for sediment

B<sub>soil</sub>: Background concentration in soil

In absence of background concentrations for sediment, the background concentrations in soil are used for the comparison with MPC<sub>sed.</sub> and NC<sub>sed.</sub> values. The results together with the considerations that lead to the proposed values are given in Table 5.5. The values are not rounded off because background concentrations are calculated for standard soil using the soil-type correction factors given in Chapter 4. Rounding off these values would induce also a change in these correction formulas. It has to be stated that for sediment this argument is not correct. When sediment assays are carried out the measured data are corrected and these corrected data are compared with the environmental quality objectives.

**Table 5.5 Concentrations derived from the comparison of Maximum Permissible (MPC<sub>sed.</sub>) and Negligible Concentrations (NC<sub>sed.</sub>) in sediment with background concentrations (B<sub>soil</sub>) in soil (in mg/kg).**

	Considerations	MPC <sub>sed.</sub> ; B <sub>soil</sub> (mg/kg)	NC <sub>sed.</sub> ; B <sub>soil</sub> (mg/kg)
antimony	MPC <sub>sed.</sub> > B <sub>soil</sub> , NC <sub>sed.</sub> << B <sub>soil</sub>	16 <sup>a</sup>	3 <sup>a</sup>
barium	MPC <sub>sed.</sub> = B <sub>soil</sub> , NC <sub>sed.</sub> << B <sub>soil</sub>	<b>155</b>	<b>155</b>
beryllium	MPC <sub>sed.</sub> < B <sub>soil</sub> , NC <sub>sed.</sub> << B <sub>soil</sub>	1.1	1.1
cobalt	MPC <sub>sed.</sub> = B <sub>soil</sub> , NC <sub>sed.</sub> << B <sub>soil</sub>	<b>9</b>	<b>9</b>
molybdenum	MPC <sub>sed.</sub> >> B <sub>soil</sub> , NC <sub>sed.</sub> > B <sub>soil</sub>	250	2.5
selenium	MPC <sub>sed.</sub> > B <sub>soil</sub> , NC <sub>sed.</sub> << B <sub>soil</sub>	2	<b>0.7</b>
tin	MPC <sub>sed.</sub> >> B <sub>soil</sub> , NC <sub>sed.</sub> >> B <sub>soil</sub>	22000	220
thallium	No B <sub>soil</sub> , MPC <sub>sed.</sub> ± cont. crest conc.	<b>(2)</b>	<b>(2)</b>
vanadium	MPC <sub>sed.</sub> = 0.33*B <sub>soil</sub> , NC <sub>sed.</sub> << B <sub>soil</sub>	<b>42</b>	<b>42</b>

Abbreviations: << and >>: value is more than a factor of 10 lower or higher

< or >: value is between 3 and 10 times lower or higher

<sup>a</sup>: if the value presented is a B<sub>soil</sub>, this value is printed bold

As can be seen from Table 5.5 all  $NC_{sed.}$  values are equal to the background concentrations in soil except for molybdenum and tin. For five metals, barium, beryllium, cobalt, thallium and vanadium the  $B_{soil}$  is higher than both the  $MPC_{sed.}$  and  $NC_{sed.}$  values. For selenium the difference between the  $MPC_{sed.}$  and the  $B_{soil}$  is very small. Only for molybdenum, antimony and tin the  $B_{soil}$  is much lower than the  $MPC_{sed.}$ .

#### 5.4. Maximum Permissible and Negligible Concentrations for soil and comparison with background concentrations

Similar to the calculations for sediment, Table 5.6 gives the results of the equilibrium partitioning calculations for soil using the partition coefficients for soil from Chapter 3. Because of the relatively low  $K_p$  values for soil for most of the compounds the derived  $MPC_{soil}$  and  $NC_{soil}$  are lower than the background concentrations in standard soil. Only for molybdenum both the  $MPC_{soil}$  and  $NC_{soil}$  are higher than  $B_{soil}$ , whereas for tin only the  $MPC_{soil}$  is higher than the background concentration. For molybdenum the situation is similar to the situation for sediment because of approximately similar  $K_p$  values for sediment and soil.

**Table 5.6 Maximum Permissible ( $MPC_{soil}$ ) and Negligible Concentrations ( $NC_{soil}$ ) for soil based on ecotoxicological data and equilibrium partitioning (in mg/kg).**

	$MPC_{aq.}$ ( $\mu\text{g/l}$ )	$NC_{aq.}$ ( $\mu\text{g/l}$ )	$\text{Log}K_p$ soil	$MPC_{soil}$ (mg/kg)	$NC_{soil}$ (mg/kg)	$B_{soil}$ (mg/kg)
antimony	6.2	0.062	1.93	0.53	0.0053	3
barium	150	1.5	1.78	9	0.09	155
beryllium	0.16	0.0016	1.58	0.006	0.00006	1.1
cobalt	2.0	0.02	1.60	0.08	0.0008	9
molybdenum	290	2.9	2.94	250	2.5	0.5
selenium	5.3	0.053	1.30	0.11	0.0011	0.7
tin	18	0.18	3.28	35	0.35	19
thallium	1.6	0.016	2.20	0.25	0.0025	-
vanadium	3.5	0.035	2.49	1.1	0.011	42

$MPC_{soil}$ : Maximum Permissible Concentration in soil based on aquatic toxicity data and partition coefficient for soil

$NC_{soil}$ : Negligible Concentration in soil based on aquatic toxicity data and partition coefficient for soil

For cobalt a  $MPC_{soil}$  of 24 mg/kg and a  $NC_{soil}$  of 0.24 mg/kg was derived from ecotoxicological data. These values should be preferred over the ones calculated by using the equilibrium partitioning method because they are based on ecotoxicological data for soil organisms. This  $MPC_{soil}$  is higher than the background concentration in soil, the  $NC_{soil}$ , however, is much lower.

Results of the comparison of  $MPC_{soil}$  and  $NC_{soil}$  values with the background concentrations in standard soil are given in Table 5.7. As can be seen from this table for almost all compounds the background concentration in the soil is higher than both the  $MPC_{soil}$  and the  $NC_{soil}$ .

**Table 5.7 Concentrations derived from the comparison of Maximum Permissible (MPC<sub>soil</sub>) and Negligible Concentrations (NC<sub>soil</sub>) with background concentrations (B<sub>soil</sub>) in soil (in mg/kg).**

	Considerations	MPC <sub>soil</sub> , B <sub>soil</sub> (mg/kg)	NC <sub>soil</sub> , B <sub>soil</sub> (mg/kg)
antimony	MPC <sub>soil</sub> < B <sub>soil</sub> , NC <sub>soil</sub> << B <sub>soil</sub>	<b>3<sup>a</sup></b>	<b>3<sup>a</sup></b>
barium	MPC <sub>soil</sub> & NC <sub>soil</sub> << B <sub>soil</sub>	<b>155</b>	<b>155</b>
beryllium	MPC <sub>soil</sub> & NC <sub>soil</sub> << B <sub>soil</sub>	<b>1.1</b>	<b>1.1</b>
cobalt	MPC <sub>soil</sub> & NC <sub>soil</sub> << B <sub>soil</sub>	24 <sup>b</sup>	<b>9</b>
molybdenum	MPC <sub>soil</sub> >> B <sub>soil</sub> , NC <sub>soil</sub> > B <sub>soil</sub>	250	2.5
selenium	MPC <sub>soil</sub> < B <sub>soil</sub> , NC <sub>soil</sub> << B <sub>soil</sub>	<b>0.7</b>	<b>0.7</b>
tin	MPC <sub>soil</sub> = 1.8*B <sub>soil</sub> , NC <sub>soil</sub> << B <sub>soil</sub>	35	<b>19</b>
thallium	No B <sub>soil</sub> , MPC <sub>soil</sub> < cont. crest conc.	<b>(2)</b>	<b>(2)</b>
vanadium	MPC <sub>soil</sub> & NC <sub>soil</sub> << B <sub>soil</sub>	<b>42</b>	<b>42</b>

Abbreviations: << and >>:value is more than a factor of 10 lower or higher  
< or >:value is between 3 and 10 times lower or higher.

<sup>a</sup>: if the value presented is a B<sub>soil</sub>, this value is printed bold

<sup>b</sup>: only value based on a MPC<sub>soil</sub> calculated from toxicity data for soil organisms

## 6. CURRENT ENVIRONMENTAL QUALITY OBJECTIVES AND ENVIRONMENTAL CONCENTRATIONS

In Table 6.1 current environmental quality objectives are given for the nine trace metals. As can be seen from the table very few quality objectives are in force at the moment.

**Table 6.1 Survey of current environmental quality objectives for nine trace metals<sup>1</sup>**

	ground water ( $\mu\text{g/l}$ ) <i>target value</i>	sediment ( $\text{mg/kg}$ ) <i>target value</i>	soil ( $\text{mg/kg}$ ) <i>target value</i>	drinking water ( $\mu\text{g/l}$ )
antimony			10	
barium	50	200	200	500
beryllium				
cobalt	20	20	20	
molybdenum	5	10	10	
selenium				10
tin	10	20	20	
thallium				
vanadium				

<sup>1</sup> From [26]

Quantitative data on environmental concentrations of the nine metals are scarce. No regular measurements in national measuring programmes are carried out. Hence, only a limited insight can be obtained whether concentrations in surface water, ground water, sediments or soil exceed the proposed maximum permissible or negligible concentrations. A summary of reported concentrations is given in Table 6.2. These differ from background concentrations in the sense that the latter are concentrations for 'relatively clean areas' only. Data for soil are missing. In the following the data presented in table 6.2 are compared with the concentrations presented in tables 5.2, 5.3 and 5.5.

From the data for surface water it can be seen that in the river Rhine the  $\text{MPC}_{\text{aq}}$  for barium, beryllium, cobalt, selenium and vanadium is exceeded. For antimony and beryllium the  $B_{\text{sw}}$  is exceeded. Maximum concentrations in ground water are for many metals higher than the  $\text{MPC}_{\text{aq}}$ . Care must be taken however to draw any conclusions from these observations since these high concentrations may well be the result of naturally occurring circumstances such as high chloride concentrations, low pH or specific redox conditions [24,25].

Very few data are available for sediment and suspended matter. Also, it has to be stated that reported concentrations in sediment and suspended matter presented in table 6.2 have not been corrected for organic matter and clay content. The concentrations in table 5.5, however refer to a standard soil containing 10% organic matter and 25% clay. This hampers a direct comparison of both values. For cobalt reported concentrations in sediment and suspended matter are much higher than or equal to the  $B_{\text{soil}}$ . For antimony concentrations in suspended matter are between the  $\text{MPC}_{\text{sed}}$  and the  $B_{\text{soil}}$  while for thallium they exceed the  $B_{\text{soil}}$ . It must be emphasized, however that the reliability of the  $B_{\text{soil}}$  for thallium is very low.

For antimony and vanadium concentrations in rain water slightly exceed the  $B_{sw}$  values for surface water, while for selenium the  $NC_{aq}$  is slightly exceeded. The number of data, however, is limited.

**Table 6.2 Summary of reported concentrations in surface water, ground water, sediment, suspended matter and rain water.**

	surface water ( $\mu\text{g/l}$ )	ground water ( $\mu\text{g/l}$ )	sediment <sup>1</sup> (mg/kg)	suspended matter <sup>1</sup> (mg/kg)	rain water ( $\mu\text{g/l}$ )
antimony	0.15-1.0 <sup>2</sup> 0.3 <sup>3</sup>	0.001-0.5 <sup>4</sup> <1.0-1.4 <sup>5</sup> 1.4 <sup>8</sup>		0.2-1.96 <sup>6</sup>	0.89 <sup>7</sup>
barium	175; 265 <sup>9</sup> 86 <sup>3</sup>	40-365 <sup>4</sup> 18-470 <sup>5</sup> 2600 <sup>8</sup>			3 <sup>7</sup>
beryllium	0.10; 0.21 <sup>9</sup> 0.01 <sup>3</sup>	<0.03 <sup>4</sup> 0.08-3.5 <sup>5</sup>			<0.02 <sup>7</sup>
cobalt	0.5-5.3 <sup>2</sup> 0.8 <sup>3</sup>	0.03-2 <sup>4</sup> <1-310 <sup>5</sup> 20 <sup>8</sup>	72 <sup>10</sup>	6-26 <sup>6</sup>	0.34 <sup>7</sup>
molybdenum	2 <sup>3</sup>	<0.1-2.2 <sup>4</sup> <1 <sup>5</sup> 2.2 <sup>8</sup>			<0.1 <sup>7</sup>
selenium	5; 8 <sup>9,11</sup> 0.2-2.0 <sup>2</sup> 0.35 <sup>3</sup>	0.01-0.12 <sup>4</sup> <0.5 <sup>5</sup> 0.18 <sup>8</sup> <2 <sup>4</sup>			<0.16 <sup>7</sup>
tin					
thallium			<5 <sup>10</sup>	<5-16 <sup>6</sup>	
vanadium	6 <sup>12</sup> 2.2-6.8 <sup>2</sup> 2 <sup>3</sup>	<0.1-4.5 <sup>4</sup> <1-12 <sup>5</sup> 3.5 <sup>8</sup>			2.0 <sup>7</sup>

<sup>1</sup> Concentrations are not corrected for organic matter and clay content

<sup>2</sup> Range of concentrations from samples taken from the Maas (at Eysden and Keizersveer), Rijn (at Lobith and Hagestein), IJsselmeer and Haringvliet

<sup>3</sup> Mean concentrations of samples taken from the Rijn at Vuren in 1980-1983 [24]

<sup>4</sup> Concentrations in ground water with anthropogenic contamination (by surface water of the Rhine) [24,25]

<sup>5</sup> Concentrations in ground water with anthropogenic contamination (by agricultural use) [24,25]

<sup>6</sup> Range of concentrations from samples taken from the Rijn, tributaries of the Rijn, Maas, Schelde and IJsselmeer [28]

<sup>7</sup> From Stuyfzand [24,25]

<sup>8</sup> Highest values found in the National Ground Water Quality Monitoring Network in the Netherlands (data from 1982)

<sup>9</sup> Mean and maximum concentration in Rijn water at Lobith in 1989 [27]

<sup>10</sup> Samples taken at Dintelsas; mean of duplicates [28]

<sup>11</sup> Mean and maximum concentration in Rijn water at Lobith in 1988 [27]

<sup>12</sup> Mean value for the Rijn in 1988 [27]

## 7. DISCUSSION.

### 7.1 Availability of data

From the preceding chapters it can be concluded that relatively few data are available that can be applied to set up reliable environmental quality criteria for the individual compartments. Although effects data for aquatic organisms were available for all trace metals, only for three metals the number of chronic toxicity data was high enough to calculate a  $MPC_{aq}$  using the refined effects assessment procedure. Hence, for the six other compounds, the modified EPA method had to be used leading to sometimes large differences between the  $MPC_{aq}$  and the (very few) chronic NOEC values present. For all metals, however, more than four acute toxicity data were available although these were not always distributed among different taxonomic classes.

As was mentioned in Chapter 2, toxicity data for soil and sediment organisms are fully lacking, except for cobalt where one single chronic value was found. Data for parameters like respiration or nitrification were available for several metals, but these studies were not reliable enough to use them for effect assessment. In general however the no effect levels of these studies are high [8].

A relative small number of data for the partition coefficients in soil could be obtained. For barium, beryllium tin and thallium no data were found at all and the  $K_p$  values had to be estimated from data for "comparable" metals such as calcium, magnesium, lead or zinc. In case of sediment, partition coefficients could be derived from concentration distributions in particulate matter in various lakes and rivers. Only for thallium no data were available and a  $K_p$  value had to be estimated from the  $K_p$  value for zinc.

Background concentrations in ground water and soil could be retrieved for most of the compounds. In case of ground water values for thallium and tin were missing. In soil no measured values were found for thallium, whereas for molybdenum and selenium values were very close to or below the detection limit. Measured background concentrations in surface water in the Netherlands are not available since no clean surface water was found. Consequently, background concentrations had to be derived from concentrations in clean surface waters from 'comparable' areas. The representativeness of these data for the Dutch situation is of course less. No background concentrations could be derived for sediment due to lack of data.

Only a few data were available on actual measured concentrations in the environment. Most data concerned concentrations in surface, ground and rain water. Almost no data were present for sediment and suspended matter, and no data at all were available for soil.

### 7.2 Reliability of the MPC and NC values and background concentrations

Because of the sometimes relatively large uncertainties that exist in the data that were used in Chapter 5, it is very difficult to give a qualitative judgement of the reliability or correctness of these values. Some general remarks, however, can be made here.

The MPC values for surface water were also used for ground water, because no toxicity data were available for ground water organisms. MPC values for surface water differ in their reliability due to the different number of toxicological data available. For antimony, barium and molybdenum the calculated  $MPC_{aq}$  is considerably lower than the lowest NOEC value due to the high assessment factors that had to be applied. It should be emphasized, however, that sometimes only one chronic value from one taxonomic group is available to make the comparison with. The  $MPC_{aq}$  may therefore seem to be on the "safe" side, its correctness, however, cannot be assessed properly. For beryllium, cobalt and selenium a relatively high number of chronic data from different taxonomic groups was available leading to relatively good estimations of the MPC for the aquatic ecosystem.

The NC values for water are for most compounds lower than the related background concentrations for surface and ground water. For barium, beryllium, cobalt, antimony and vanadium the background concentration for ground water is relatively reliable whereas for these five compounds and for thallium the background concentration for surface water is somewhat less reliable. For molybdenum, selenium and tin the  $NC_{aq}$  for both surface water and ground water were higher than the related background concentrations. These  $NC_{aq}$  values are based on ecotoxicological data and therefore have the same reliability as the  $MPC_{aq}$ .

A different situation exists for sediment and soil where no toxicological data are available and partition coefficients are to be used to derive ecotoxicological MPC and NC values. From the comparison of the MPC and NC values with background concentrations in soil it was shown that the latter values are in many cases higher than both the MPC and the NC value. As was mentioned in section 5.4, for all compounds, except for molybdenum (MPC and NC) and tin (MPC) the  $B_{soil}$  is higher than MPC and NC values. The reliability of  $B_{soil}$  for barium, beryllium, cobalt, antimony, tin and vanadium is good. For selenium the reliability is less but acceptable while for thallium the reliability is very low.

For sediment background concentrations in soil were for several metals higher than the  $MPC_{sed.}$  and  $NC_{sed.}$  values. For molybdenum, antimony, selenium and tin the  $MPC_{sed.}$  is higher than the background concentrations in soil. The  $MPC_{sed.}$  is determined by the equilibrium calculation and therefore depends both on  $MPC_{aq.}$  and on the  $K_p$  for sediment. For selenium both a reliable  $K_p$  value and a reliable  $MPC_{aq.}$  was obtained. For molybdenum and antimony also reliable  $K_p$  values were obtained, their  $MPC_{aq.}$  values, however, may be somewhat low. Finally for tin the  $MPC_{aq.}$  value seems reliable, the  $K_p$  value, however, had to be estimated from the  $K_p$  value for lead.

### 7.3 Coordination of background concentrations, MPC and NC values

After the definition of the MPC and NC values for the different compartments coordination of these values can be effected using the equilibrium partitioning method. However, in paragraph 5.1 it was mentioned already that because of the lack of toxicological data for sediment and soil organisms and thus a lack of ecotoxicological MPC and NC values, the MPC and NC values for these compartments are coordinated to the values for the aquatic

compartments inherently.

It should be stated however that if e.g. a target value for these trace metals is derived from measured background concentrations in individual compartments coordination has not inherently taken place. In principle there should be a relationship between the background concentration of a metal in soil and ground water and between the concentration in sediment and surface water. For the metals of this report this latter relationship cannot be validated since background concentrations in sediment are not available. The relationship between  $B_{gw}$  and  $B_{soil}$  can be investigated by multiplying  $B_{gw}$  with the partition coefficient for soil and comparing the result with the measured  $B_{soil}$  data. The results of this comparison are given in Table 7.1. From this comparison it can be concluded that when the partition coefficients for soil are used the calculated background concentrations in soil deviate strongly from measured data. Only for molybdenum the calculated value is in agreement with the measured one, for all others metals the measured values are much higher. Although it is unlikely that in all field situations full equilibrium exists between concentrations in ground water and soil, the differences in Table 7.1 are so large that it seems more presumable that they are caused by the relatively low soil/water partition coefficients that were used. If instead of  $K_p$  values for soil the  $K_p$  values for sediment are used the differences between calculated and measured values are much smaller (see Table 7.1). However, substantial deviations (more than a factor of 10) still remain for metals such as beryllium, antimony and selenium.

From these comparisons it can be concluded that at the moment coordination of e.g. target values that are based on background concentrations is not possible due to the uncertainties in the partition coefficients that have to be applied. On the other hand it needs to be mentioned that in natural situations ground water and soil may be at a non-equilibrium situation. So coordination of the quality objectives is therefore not desirable if the target value is set equal to the background concentration.

**Table 7.1 Comparison of calculated background concentrations in soil from background concentrations in ground water and soil/water partition coefficients with measured background concentrations in soil.**

	$B_{gw}$ ( $\mu\text{g/l}$ ) 90-percentile	$\log K_p$ soil	$K_p * B_{gw}$ soil	$\log K_p$ sediment	$K_p * B_{gw}$ sediment	Measured $B_{soil}$
antimony	0.091	1.93	0.008	3.41	0.2	3
barium	197	1.78	11.9	3.00	197	155
beryllium	0.05	1.58	0.002	2.78	0.03	1.1
cobalt	0.63	1.60	0.025	3.60	2.5	9
molybdenum	0.69	2.94	0.6	2.93	0.6	0.5
selenium	0.024	1.30	0.0005	2.62	0.01	0.7
tin	<2	3.28	<sup>1</sup>	6.09	<sub>3</sub>	19
thallium	<2	2.20	<sub>2</sub>	3.00	<sub>4</sub>	<sub>2</sub>
vanadium	1.22	2.49	0.4	3.59	5	42

<sup>1</sup> If the 90-percentile value for surface water is used (0.1  $\mu\text{g/l}$ ) a background concentration of 0.2 mg/kg is calculated

<sup>2</sup> If the geometric mean value for surface water is used (0.04  $\mu\text{g/l}$ ) a background concentration of 0.006 mg/kg is calculated which is much lower than the value for the continental crest (2 mg/kg)

<sup>3</sup> If the 90-percentile value for surface water is used (0.1  $\mu\text{g/l}$ ) a background concentration of 123 mg/kg is calculated

<sup>4</sup> If the geometric mean value for surface water is used (0.04  $\mu\text{g/l}$ ) a background concentration of 0.04 mg/kg is calculated which is much lower than the value for the continental crest (2 mg/kg)



Comparison of the background concentrations in soil with the  $MPC_{soil}$  and  $NC_{soil}$  showed that only for molybdenum the  $NC_{soil}$  is higher than the background concentration. If target values in soil are derived for the exotic metals it can be considered to use the background concentration for molybdenum in order to be consistent and because the difference between both values is only a factor 5. The same argument can be used if target values are set for sediment for molybdenum.

With respect to sediment the difference between the  $B_{soil}$  and the  $NC_{sed.}$  for tin is considerable. The high  $MPC_{sed.}$ , and thus also the high  $NC_{sed.}$ , is caused by the high partition coefficient and the low toxicity of tin to aquatic organisms. The  $K_p$  is derived from batch experiments with particulate matter and from measured dissolved and particulate tin in several rivers [9]. The  $MPC_{aq.}$  for tin is derived with the modified EPA method. Although it can be concluded that data were scarce to derive the  $K_p$  and  $MPC_{aq.}$  values, the  $MPC_{sed.}$  might be correct because it is known that tin is a relatively immobile metal and that metallic tin and inorganic tin compounds are generally nontoxic. If target values are derived it might be considered, however to use the background concentration in soil. If the  $NC_{sed.}$  is used the 'stand still principle' should of course be applied.

The geometric mean instead of the 90 percentile  $B_{sw}$  values were used for the comparison of background concentrations in surface water with  $MPC_{aq.}$  and  $NC_{aq.}$  values. Although it was recognized that for the other compartments the 90 percentile was used this procedure was followed due to reasons given in Chapter 4.

## 8. CONCLUSIONS

Maximum Permissible and Negligible Concentrations for surface water, ground water, sediment and soil could be derived for all nine trace metals that are subject of this report. Only for the compartment water however these MPC and NC values were based on ecotoxicological data. For the compartments soil and sediment no ecotoxicological data were available, except for cobalt. So MPC and NC values for soil and sediment were derived using the equilibrium partitioning method. This means that coordination of the MPC and NC values for the different compartments could not take place, except for cobalt.

The MPC and NC values were also compared with background concentrations in the related compartments. Because no data were available for sediment background concentrations in soil were used. A summary of the results of the comparison is given in Table 8.1. These values can be used to set up general environmental quality objectives (target and limit values). Care, however, should be taken because the reliability of some of the values is limited. They are however, the best possible estimations taking into account the sometimes scarce information available.

**Table 8.1 Summary of the comparison of Maximum Permissible and Negligible Concentrations and background concentrations. Values for surface water and ground water in  $\mu\text{g/l}$ , for sediment and soil in  $\text{mg/kg}$  (concentrations for soil and sediment are derived for a standard soil containing 10% organic matter and 25% clay).**

	Surface water		Sediment		Ground water		Soil	
	MPC; B	NC; B	MPC; B	NC; B	MPC; B	NC; B	MPC; B	NC; B
antimony	6	<b>0.3</b>	16	<b>3</b>	6	<b>0.1</b>	<b>3</b>	<b>3</b>
barium	150	<b>75</b>	<b>155</b>	<b>155</b>	<b>200</b>	<b>200</b>	<b>155</b>	<b>155</b>
beryllium	0.2	<b>0.02</b>	<b>1.1</b>	<b>1.1</b>	0.2	<b>0.05</b>	<b>1.1</b>	<b>1.1</b>
cobalt	2.0	<b>0.2</b>	<b>9</b>	<b>9</b>	2.0	<b>0.6</b>	24	<b>9</b>
molybdenum	300	3	250	2.5	300	3	250	2.5
selenium	5	0.05	2	<b>0.7</b>	5	0.05	<b>0.7</b>	<b>0.7</b>
tin	20	0.2	22000	220	20	0.2	35	<b>19</b>
thallium	2	<b>0.04</b>	<b>(2)</b>	<b>(2)</b>	2	0.02	<b>(2)</b>	<b>(2)</b>
vanadium	4	<b>1</b>	<b>42</b>	<b>42</b>	4	<b>1</b>	<b>42</b>	<b>42</b>

background concentrations printed in bold (soil and sediment value for thallium is not a background concentration but value reported for the continental crest)

From the comparison of these concentrations with actual measured concentration in the environment it can be concluded that for several metals the  $\text{MPC}_{\text{aq}}$  is exceeded in surface or ground water. For all metals for which measured data were available for sediment and suspended matter the  $\text{B}_{\text{soil}}$  was exceeded.

With respect to the setting of integrated environmental quality objectives for the 'exotic metals' the following remarks can be made:

- for many metals the derivation of background concentrations, partition coefficients and

Maximum Permissible Concentrations was seriously hampered by the lack of reliable data. Especially for the compartments soil and sediment this is problematic if quality objectives are derived. First of all no reliable partition coefficients are available. As stated in Chapter 3 a coefficient of c. 30% applies to the logarithmic  $K_p$ 's. Secondly, almost no toxicity data were available for soil and sediment dwelling organisms. Thirdly, only for 5 metals soil type correction factors could be derived, and no data on measured concentrations were available at all to derive background concentrations in sediment. Considering the fact that most target values in soil and sediment will be determined by the background concentration further research should be undertaken into these background concentrations and at obtaining more ecotoxicological data for soil organisms.

- data on the presence of the metals in surface water, sediment, soil and ground water were very scarce. When determining limit and target values it is, however necessary to have a systematic understanding of the actual concentrations and their spread in the environment to obtain an insight to which extent these quality objectives will be exceeded.
- no coordination has taken place with the compartment air. It is recognized however that transport via air can be an important route for metals, e.g. contamination of the soil due to deposition. If coordination with air is desired it is therefore first of all necessary to quantify these processes.

## 9. REFERENCES

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**APPENDIX 1. SURVEY OF ACUTE AND CHRONIC TOXICITY DATA FOR THE AQUATIC ENVIRONMENT.**

A survey of acute and chronic toxicity data for freshwater and saltwater organisms is presented in table 1 and 2, respectively. The data are presented as if they are used as input data for the extrapolation methods. This means that acute as well as chronic toxicity data are weighted over the species:

- if for a single species several NOEC or L(E)C50 values are derived for different effect parameters the lowest is selected,
- if for a single species several NOEC or L(E)C50 values are derived for the same effect parameter a geometric mean is calculated.

Legend:

F/S freshwater and saltwater organism

Sb antimony

Ba barium

Be beryllium

Co cobalt

Mo molybdenum

Se selenium

Sn tin

Tl thallium

V vanadium

Table 1. Survey of acute fresh and saltwater toxicity data: L(E)C50 in mg/l (F = freshwater organisms; S = saltwater organisms)

taxonomic group	F/ S	Sb	Ba	Be	Co	Mo	Se	Tl	Sn	V
fish	F	1,100	570	1.9 3.9 6.1	4.8	1,000	1.8 2.1 6.5 10 11 13 16 16 28 30 110	0.86 140		11 120
	S	6.2				2,600	1.6 4.4 7.4	21		28
crustaceans	F	420	15 200	1.2 1.8	1.3 2.0 4.0 16 39	2,700	0.53 0.60 1.8	0.42	42 50	3.5 12
	S				4.5 170	250 1,100 1,900	1.2 1.5 4.6 4.8 33			
green algae	F							3.0	7.0 23	
	S				0.3 24			0.16	0.29 0.32	
protozoa	F				28					
oligochaete	F									31
amphibians	F			10 12						
mollusca	S					1,900	0.26 1.9 2.9			
worms	F	680		10	140	29	7.7			
cumaceans	S						6.1			
plants	F		26				2.4			
insects	F				57		3.1 11.9			



Table 2. Survey of chronic fresh and saltwater toxicity data: NOEC in mg/l (F = freshwater organisms; S = saltwater organisms)

taxonomic group	F/ S	Sb	Ba	Be	Co	Mo	Se	Tl	Sn	V
fish	F			0.08	1.1		0.015	0.03	7.8	0.041
	S				45		0.47			1.0
crustaceans	F		2.9		0.005		0.03 0.05 0.16 0.2		0.18	1.0
	S				0.45 110		0.14			
green algae	F		17	0.001	0.058 0.5	27	0.005 0.05 0.2 0.26 1.3		0.26	
	S						0.01 0.079 0.1 0.25 0.79 0.79 0.79 2.5 7.9 10			0.1 0.2 0.3
blue algae	F	23		0.015	0.5		0.079 1.0 4.7 5.0			
protozoa	F	120		0.002 0.0085 0.26			0.0009 0.031 0.059			
insects	F						0.3			
bacteria	F			0.00068			5.6			

**APPENDIX 2. DEFINITIONS.**

Background concentration	concentration of a naturally occurring compound in a relatively unpolluted area (not influenced by anthropogenic deposits).
Batch experiment	experiments involving the shaking of soil, sediment or particulate matter with an aqueous solution containing the adsorbent. After a certain equilibration period the suspension is centrifugated or filtered and the aqueous concentration of the adsorbent is determined. The adsorbed fraction is calculated from the decrease of the aqueous concentration. An adsorption isotherm is derived by using 4 to 5 initial concentrations.
Deficiency level	concentration of an essential element below which organisms begin to show deficiency symptoms.
Equilibrium Partitioning Method	method based on the assumption that there is a thermodynamical equilibrium between the concentration of a substance in water (surface water or pore water) and the concentration in the non-aqueous media in contact with it (suspended particles, sediment, soil or organisms). Using this method quality objectives can be derived for sediment and soil from toxicity data for aquatic organisms in the absence of toxicity data for soil or sediment dwelling organisms.
Maximum Permissible Concentration (MPC)	the maximum permissible level is reached if the concentration of a substance equals that at which 95% of the species in an ecosystem are protected.

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Modification 0	statistical extrapolation method, being a modification developed by Aldenberg and Slob of the method of Van Straalen and Denneman. The method assumes a logistic distribution of the sensitivity of species and calculates a 95% protection level. This level calculated with 50% confidence is set equal to the MPC.
Modified EPA method	extrapolation method using assessment factors of 10, 100 or 1,000 on toxicity data. The size of the assessment factor applied depends on the number and kind (acute or chronic) of toxicity data. The result of this method is called an indicative MPC.
Negligible Concentration (NC)	1% of the MPC. The safety factor of 100 is used because of the possibility of combined toxicity and the uncertainty in the calculation of the MPC itself.
No Observed Effect Concentration (NOEC)	highest test concentration showing no significant adverse effects compared to the control.
Partition Coefficient ( $K_p$ )	quotient between the adsorbed concentration ( $C_s$ ) and the aqueous equilibrium concentration ( $C_e$ ).
Soil type correction factors	relation between measured concentrations in soil and variables as organic matter and clay content. These factors are set in such a way that c. 90% of the measured concentrations are below the reference line.
Standard Soil	reference soil defined as a soil with a clay content of 25% and an organic matter content of 10%.