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THE USE OF DISINFECTANTS IN LIVESTOCK FARMING
(Supplement to the evaluation method of non-agricultural pesticides of the Uniform System for Evaluation of Substances (USES)).

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TABLE OF CONTENTS

Page

SUMMARY

In 1993 an evaluation system for non-agricultural pesticides was presented (ESPE 2, Luttik et al.). This method was completely incorporated in the Uniform System for the Evaluation of Substances (USES 1, RIVM, VROM, WVC, 1994). USES 1 can be used as a tool in making rapid risk assessments and setting priorities for new and existing substances, plant protection products and biocides within the scope of the Dutch Chemical Substances Act and the Dutch Pesticides Act. In 1996 a second (national) version of USES (USES 2) will be presented. This report describes models for the use of disinfectants in livestock farming in addition to the existing models for the evaluation of non-agricultural pesticides. The models to be incorporated in USES 2 describe the following emission scenarios:

- disinfection of animal housing
- disinfection of footwear and animals' feet
- disinfection of milk extraction systems
- disinfection of means of transport
- disinfection of hatcheries.

SAMENVATTING

In 1993 werd een beoordelingsmethode voor niet landbouwbestrijdingsmiddelen gepresenteerd (ESPE 2, Luttik et al.). Deze beoordelingsmethode is ingebouwd in het Uniform Beoordelingsysteem voor Stoffen (UBS 1, RIVM, VROM, WVC, 1994). Het UBS kan worden gebruikt voor het maken van snelle risico analyses en voor het stellen van prioriteiten bij de beoordeling van nieuwe- en bestaande stoffen, gewasbeschermingsmiddelen en biociden in het kader van de Wet milieugevaarlijke stoffen en de Bestrijdingsmiddelenwet. In 1996 zal een tweede (nationale) versie van het UBS worden opgeleverd. In dit rapport worden modellen voor het gebruik van ontsmettingsmiddelen in de veeteelt beschreven in aanvulling op de reeds bestaande modellen voor de beoordeling van niet-landbouwbestrijdingsmiddelen.
De gepresenteerde modellen zullen in de tweede versie van het UBS worden geïmplementeerd en beschrijven de volgende emissie scenario's

- ontsmetting van dierverblijven;
- ontsmetting van schoeisel (van mensen) en klauwen van dieren;
- desinfectie van melkwininstallaties;
- onsmetting van transportmiddelen;
- desinfectie van kuikenbroederijen.

1. INTRODUCTION

When in 1990/1991 the national policy for agricultural pesticides was discussed in parliament, it was recognized that the arrears of the development of policy on non-agricultural pesticides should be made up. In 1994 a start was made with the preparation of a long-term policy plan (MJP-H) that will be proposed to parliament in 1996 and a status report was issued. Ahead of the MJP-H, policy options for so called focal points, i.e. specific groups of biocides, will be presented. Risk assessment is considered to be prerequisite for the definition of emission reduction strategies. Therefore, the development of tools for risk assessment of non-agricultural pesticides runs parallel to the described policy development.
The first step towards a full-scale evaluation system for pesticides (ESPE) was made in 1992 with the presentation of an evaluation system for agricultural pesticides (ESPE 1) by Emans *et al.* (1). In 1993 an evaluation system for non-agricultural pesticides was presented (ESPE 2) by Luttik *et al.* (2). The method for agricultural pesticides was completely incorporated in the Uniform System for the Evaluation of Substances, USES 1.0 (3). USES 1.0 is a tool that can be used for rapid, quantitative assessments of the general risks of substances. Risk assessment methods for various categories of substances were integrated, as much as was possible, into one assessment scheme. Uses 1.0 was developed through the elaboration of an action point of the Dutch National Environmental Policy Plan of 1989, in close consultation with other research Institutes and Industry, experts from the Ministry of Housing, Spatial Planning and the Environment, the Ministry of Welfare, Public Health and Cultural Affairs, and the National Institute of Public Health and Environmental Protection worked together on this project. Uses 1.0 can be applied to risk assessments and to set priorities for new substances, existing substances, plant protection products and biocides within the scope of the Dutch Chemical Substances Act and the Dutch Pesticide Act. The protection targets in USES 1.0 are: humans (exposed via the environment and via consumer products), micro-organisms in sewage treatment plants, the aquatic and terrestrial ecosystem, and top predators.
For the non-agricultural pesticides the following scenarios were incorporated in USES 1.0:
- biocides in the textile industry,
- biocides in the paper and cardboard industry,
- biocides in the process and cooling-water installations,
- preservatives in the metal industry,
- wood preservatives: creosote impregnation,
- wood preservatives: salt impregnation,
- wood preservatives: drenching and dipping,
- remedial timber treatment in buildings,
- leaching from impregnated wood to surface water,and
- antifoulings.

In the ESPE 2 report several open ends were still present, because methods for all routes were not available at that time. In 1995 the following scenarios were described by Luttik *et al.* (4):

- disinfectants for swimming water,
- leaching from impregnated wood to soil and ground water,
- household products used for fogging.

This report will provide models for the use of disinfectants in livestock farming:

- disinfection of animal housing facilities,
- disinfection of footwear and/or animals' feet,
- disinfection of milk-extraction systems,
- disinfection of means of transport, and
- disinfection of hatcheries.

The development of risk assessment methodologies for non-agricultural pesticides will continue in the coming year and is intended to result in a second national version of USES in 1996. Results of this work in the Netherlands will be submitted in current international discussions on this topic.

2. THE USE OF DISINFECTANTS IN LIVESTOCK FARMING

2.1. Introduction

Disinfectants for livestock farming are used in many situations and, in 1990, a total of 7,230 tonnes disinfectants were used (5). They are employed to disinfect:

- Animal housing facilities,
- footwear,
- animals' feet,
- milk-extraction systems,
- means of transport, and
- hatcheries.

For all these applications an emission model for incorporation in USES II (Uniform System for the evaluation of Substances) has been developed. All models are based on literature research and, for all models, it is assumed that 25 percent of the disinfectants have reacted and are therefore no longer present in emissions (5).

2.2. Model description

2.2.1. Disinfection of animal housing facilities

Cleaning and disinfection of housing is common practice in poultry and pig houses. In these houses an 'all in' 'all out' system is used. Once all animals have left the building the walls and the floor are cleaned and often also disinfected with the help of a sprayer. In 1990 about 124 tonnes of disinfectants were used to disinfect houses, 14 tonnes for pigs and 110 tonnes for poultry (8). There are emissions, both to the air and to the manure storage system. Spreading of the manure leads to an (indirect) emission to the soil.

The quantity of active ingredient (a.i.) used for disinfection of an average housing ($Q_{a.i.}$) depends on the concentration of a.i. ($C_{a.i.}$), the quantity of disinfectant used per square meter ($Q_{disinfectant}$) and the surface (floor and walls) of the housing ($A_{housing}$):

$$Q_{a.i.}\ (g) = C_{a.i.}\ (g/l) * Q_{disinfectant}\ (l/m^2) * A_{housing}\ (m^2) \qquad [1]$$

With the following suggestions for default values (5):

$C_{a.i.}$ aldehydes pigs	= 2 g/l
$C_{a.i.}$ aldehydes poultry	= 40 g/l
$C_{a.i.}$ quats	= 0.5-2 g/l
$C_{a.i.}$ mixed	= 0.7-1.4 quats+5.25-10.5 aldehydes g/l
$C_{a.i.}$ chlorine compounds	= 0.2 g/l
$C_{a.i.}$ hydroxides	= 10.5 g/l
$C_{a.i.}$ unknown	= 40 g/l
$Q_{disinfectant}$ spray/fog	= 0.1-0.2 l/m2
$Q_{disinfectant}$ unknown	= 0.1-0.2 l/m2
$A_{housing}$ poultry (broilers)	= 4,000 m^2
$A_{housing}$ pigs (fattening)	= 390 m^2
$A_{housing}$ pigs (breeding)	= 210 m^2
$A_{housing}$ unknown	= 4,000 m^2

The emission to the manure storage system ($Edirect_{manure\ storage}$) depends on the quantity of a.i. used for disinfection of average housing ($Q_{a.i.}$) and the fraction released to the manure storage system ($F_{manure\ storage}$):

$$Edirect_{manure\ storage}\ (kg) = Q_{a.i.}\ (g) * F_{manure\ storage}\ (-) / 1{,}000 \qquad [2]$$

Where:

$F_{manure\ storage}$ spray = 0.65 (5)

$F_{manure\ storage}$ fog = 0.5 (5)

$F_{manure\ storage}$ unknown = 0.65

The concentration of the active ingredient in the manure storage system can be found if an average quantity of manure in the storage is taken as factor for dilution. E.g. for poultry, one broiler produces 10 kg manure/year (6). Thus an average poultry house (approx. 27,000 animals) produces an amount of manure of 10 * 27,000 = 270,000 kg manure/year. For this model a realistic estimation of half of this maximum amount of manure in the storage is taken as a default, assuming that most storage systems have the capacity to store the manure for about 6 months. If relevant: dilution due to cleaning etc. is assumed to be included in the default amount of slurry/manure in the manure storage system.

$$Cdirect_{manure\ storage}\ (kg/kg) = Edirect_{manure\ storage}\ (kg) / Q_{manure}\ (kg) \qquad [3]$$

Where:
Q_{manure} poultry (broilers) = 10*27,000/2 = 135,000 kg/storage period (6),
Q_{manure} pigs (fattening) = 1,250*260/2 = 163,000 kg/storage period (7),
Q_{manure} pigs (breeding) = 5,200*100/2 = 260,000 kg/storage period (7),
Q_{manure} unknown = 135,000 kg/storage period.

Although it is likely that the active ingredient is sometimes completely mineralised at the manure storage system (5) no reference has been found which provides a quantitative estimation for the fraction of disintegration in manure (F_{dis}). Therefore the default of F_{dis} (which stands for biodegradation inclusive hydrolysis and volatilisation together) is set on zero. For the calculation of the dose of a.i. to the soil due to manure spreading the original soil and ground water module of USES can be followed. In this context the application of sludge from an STP (Sewage Treatment Plant) should be interpreted as the application of manure ($Q_{application\ manure}$ with $Cdirect_{manure\ storage}$) and the number of days for the emission as the number of disinfection events ($N_{disinfection\ events}$) with the following default values:

$$C_{sludge}\ (kg/kg) = Cdirect_{manure\ storage}\ (kg/kg)\ * (1 - F_{dis}) \qquad [4]$$
$$APPL_{sludge}\ (kg/m^2) = Q_{application\ manure}\ (kg/m^2) \qquad [5]$$

Where:
$Q_{application\ manure}$ poultry (broilers) = 0.85 $kg/m^2/year$ (14)[1)]
$Q_{application\ manure}$ pigs (fattening) = 4.45 $kg/m^2/year$ (14)[1)]
$Q_{application\ manure}$ pigs (breeding) = 5.95 $kg/m^2/year$ (14)[1)]
$Q_{application\ manure}$ unknown = 0.85 $kg/m^2/year$

According to (5) in one year the following default numbers of disinfection events take place
$N_{disinfection\ events}$ poultry (broilers) = 5-6 d/year,
$N_{disinfection\ events}$ pigs (fattening) = 3 d/year,
$N_{disinfection\ events}$ pigs (breeding) = 2 d/year.

For a manure storage period of 6 months it is estimated that the (maximum) number of disinfection events will be:
$N_{disinfection\ events}$ poultry (broilers) = 3 d/storage period,
$N_{disinfection\ events}$ pigs (fattening) = 2 d/storage period,
$N_{disinfection\ events}$ pigs (breeding) = 2 d/storage period,
$N_{disinfection\ events}$ unknown = 3 d/storage period.

[1)]base year 1994. These values can be lower due to new legislation.

The dose can be calculated with the following formula:

$DOSE\ (kg/m^2) = C_{sludge}\ (kg/kg) * T_{emission}\ (d) / 365 * APPL_{sludge}\ (kg/m^2)$ [6]

Where:

$T_{emission}\ (d) = N_{disinfection\ events}\ (d)$ [7]

The emission to the air from average housing disinfection ($Edirect_{air}$) depends on the quantity of active ingredient used to disinfect average housing ($Q_{a.i.}$) and the emission fraction to the air (F_{air}):

$Edirect_{air}\ (kg) = Q_{a.i.}\ (g) * F_{air}\ (-) / 1{,}000$ [8]

Where (derived from reference 5) :

F_{air} spray = 0.1,

F_{air} fog = 0.25,

F_{air} unknown = 0.25.

To calculate the annual average air concentration the USES Air Module can be used with the following defaults for the number of emission days ($T_{emission}$).

$Cdirect_{air}\ (kg/m^3) = Edirect_{air}\ (kg) * T_{emission}\ (d) / 365 * Cstd_{air}\ (kg/m^3)$ [9]

Where:

$T_{emission}$ poultry (broilers) = 5 d (5)

$T_{emission}$ pigs (fattening) = 3 d (5)

$T_{emission}$ pigs (breeding) = 2 d (5)

$T_{emission}$ unknown = 5

In Table 1 a short description of the method is presented. When the application method is not known the worst case situation for both emissions (to air and to the manure storage) is taken as a default. In this particular case the total emission will be 90 percent of the used amount of disinfectant.

Table 1. Model description, parameters/variables and default values for the disinfection of animal housing facilities

Parameter/Variable (unit)	Symbol	Default	C/R/E/O
Input:			
Concentration of active ingredient (g/l)	$C_{a.i.}$	40	R/E
Quantity of disinfectant used (l/m^2)	$Q_{disinfectant}$	0.15	E
Surface of an average housing (m^2)	$A_{housing}$		E
- poultry (broilers) or unknown		4,000	
- pigs (fattening)		390	
- pigs (breeding)		210	
Fraction of the emission to the manure storage	$F_{manure\ storage}$		E
- spray or unknown		0,65	
- gas or fog		0,5	
Fraction of the emission to air	F_{air}		E
- gas, fog or unknown		0.25	
- spray		0.1	
Fraction of disintegration in the manure storage	F_{dis}	0	R/E
Quantity of manure in manure storage (kg)	Q_{manure}		E
- poultry (broilers) or unknown		135,000	
- pigs (fattening)		163,000	
- pigs (breeding)		260,000	
Application of manure to land (kg/m2/y)	$Q_{application\ manure}$		E
- manure from poultry (broilers) or unknown		0.85	
- manure from pigs (fattening)		4.45	
- manure from pigs (breeding)		5.95	
Number of disinfection events (d)	$N_{disinfection\ events}$		E
- poultry (broilers) or unknown		3	
- pigs (fattening)		2	
- pigs (breeding)		2	
Number of days for the emission (d)	$T_{emission}$		E
- poultry (broilers) or unknown		5	
- pigs (fattening)		3	
- pigs (breeding)		2	
Standard concentration in air at 100 meter from source for a source strength of 1 kg/s (kg/m^3)	$Cstd_{air}$	24.10^{-6}	C
Output:			
Output necessary for calculations in USES:			
- Direct emission to air from source (kg)	$Edirect_{air}$		
- Concentration of a.i. in sludge (kg/kg)	C_{sludge}		
- Number of days for the emission (d)	$T_{emission}$		
- Quantity of sludge applied to land (kg/m2/year)	$APPL_{sludge}$		
Annual average concentration in the air after direct emission (kg/m$_3$)	$Cdirect_{air}$		
Dosage of a.i. per square meter of pasture and/or arable land (kg/m^2)	DOSE		

Model Calculations:

$Q_{a.i.}$ = quantity of active ingredient used *(g)*
= $C_{a.i.}(g/l) * Q_{disinfectant}\ (l/m2) * A_{housing}\ (m2)$

$Edirect_{air}$ = direct emission to air from source *(kg)*
= $Q_{a.i.}\ (g) * F_{air}\ (-)\ /\ 1{,}000$

$Edirect_{manure\ storage}$ = direct emission to manure storage *(kg)*
= $Q_{a.i.}\ (g) * F_{manure\ storage}\ (-)\ /\ 1{,}000$

$Cdirect_{manure\ storage}$ = concentration of a.i. in manure storage *(kg/kg)*
= $E_{direct\ manure\ storage}\ (kg)\ /\ Q_{manure}\ (kg/year)$

$C_{sludge}\ (kg/kg) = Cdirect_{manure\ storage}\ (kg/kg) * (1 - F_{dis})$

$APPL_{sludge} = Q_{application\ manure}\ (kg/m^2)$

$T_{emission}\ (d)$ (in case of air) = $T_{emission}$ of input part of this table

$T_{emission}\ (d)$ (in case of manure) = $N_{disinfection\ events}$ of input part of this table

$DOSE\ (kg/m^2) = C_{sludge}\ (kg/kg) * T_{emission}\ (d)\ /\ 365 * APPL_{sludge}\ (kg/m^2)$

$Cdirect_{air}\ (kg/m^3) = Edirect_{air}\ (kg) * T_{emission}\ (d)\ /\ 365 * Cstd_{air}\ (kg/m^3)$

C=Constants; R=values from the test results in the notification; E=Expert estimations; O=Output.

2.2.2 Disinfection of footwear or animals' feet

Basins for disinfection of footwear (of farmworkers) are usually applied in housing facilities for poultry and pigs. To disinfect animal feet is only normal procedure for cows. To disinfect footwear about 157 tonnes were used in 1990 (12 tonnes for poultry and 145 tonnes for pigs) and for disinfection of feet about 4,800 ton (8).

To disinfect animal feet in most cases a basin of formaline is used. According to the Dutch Pesticides Act, no substances are permitted for this application. In practice however this is probably the main disinfectant used for livestock farming in the Netherlands and it is even advised by several organisations (8). So in this module the emissions from feet disinfection will be estimated in spite of legislation.

The quantity of active ingredient used to disinfect footwear or feet of animals ($Q_{a.i.}$) depends on the number of reservoirs ($N_{reservior s}$) the quantity of disinfectant in one reservoir ($Q_{disinfectant}$) and the concentration of a.i. ($C_{a.i.}$):

$$Q_{a.i}\ (g) = N_{reservoirs}\ (-)\ *\ Q_{disinfectant}\ (l/reservoir)\ *\ C_{a.i.}(g/l) \qquad [10]$$

With the following suggestions for default values (5):

$N_{reservoirs}$ pigs	= 1-3
$N_{reservoirs}$ poultry	= 1-2
$N_{reservoirs}$ cows	= 1
$N_{reservoirs}$ unknown	= 2
$C_{a.i.}$ aldehydes feet disinfection	= 2 g/l
$C_{a.i.}$ aldehydes footwear disinfection	= 40 g/l
$C_{a.i.}$ hydroxides	= 10.5 g/l
$C_{a.i.}$ chlorine compounds	= 0.2 g/l
$C_{a.i.}$ quats	= 0.5-2 g/l
$C_{a.i.}$ mixed	= 0.7-1.4 q+5.25-10.5a g/l
$C_{a.i.}$ unknown	= 40 g/l
$Q_{disinfectant}$ footwear pigs	= 10 l
$Q_{disinfectant}$ footwear poultry	= 10 l
$Q_{disinfectant}$ feet cows	= 1,000 l
$Q_{disinfectant}$ unknown	= 10 l

Although the remainder of pesticides should be considered as dangerous waste, it is sometimes poured directly to the ground but in common the destination of the remainder is the manure storage. In this scenario it is supposed that all emissions take place to the manure storage system according to reference (5) and (10)
The emission to the manure storage system ($Edirect_{manure\ storage}$) depends on the quantity of a.i. used for footwear or disinfection of feet ($Q_{a.i.}$) and the fraction released to the manure storage ($F_{manure\ storage}$):

$$Edirect_{manure\ storage}\ (kg) = Q_{a.i.}\ (g)\ *\ F_{manure\ storage}(-)\ /\ 1{,}000 \qquad [11]$$

Where:
$F_{manure\ storage}$ feet disinfection (cows)=0.25 (5)
$F_{manure\ storage}$ footwear disinfection =0.75 (5)
$F_{manure\ storage}$ unknown=0.75

The assesment can continue according to the modelling of the disinfection of animal housing.

$Cdirect_{manure\ storage}$ *(kg/kg)* = $Edirect_{manure\ storage}$ *(kg)* / Q_{manure} (kg) [12]

Where:

Q_{manure} poultry (broilers)= 10 * 27,000 / 2 =135,000 kg manure/storage period (6)
Q_{manure} pigs (fattening)= 1,250 * 260 / 2 =163,000 kg manure/storage period (7)
Q_{manure} pigs (breeding)= 5,200 * 100 / 2 =260,000 kg manure/ storage period (7)
Q_{manure} cows = (52 kg manure + 14.6 kg waste water/cow/day) * (175 days stalled)
40 cows = 466,000 kg including waste water (9)
Q_{manure} unknown = 163,000 kg manure/storage period

As was mentioned in the introduction of this chapter it is assumed that there is no disintegration of the active ingredient in the manure storage (worst case F_{dis}=0). Taking this into account the maximum emission-dose due to the spreading of manure on farmland can be found. For this purpose the original ground and soil-water module of USES can be followed. In this context the application of sludge from an STP (Sewage Treatment Plant) must be interpreted as the application of manure ($Q_{application\ manure}$ with $Cdirect_{manure\ storage}$) and the number of days for the emission as the number of disinfection events ($N_{disinfection\ events}$) with the following default values:

C_{sludge} *(kg/kg)* = $Cdirect_{manure\ storage}$ *(kg/kg)* * (1 - F_{dis}) [13]
$APPL_{sludge}$ *(kg/m²)* = $Q_{application\ manure}$*(kg/m²)* [14]

Where:

$Q_{application\ manure}$ poultry (broilers) = 0.85 kg/m²/year (14),
$Q_{application\ manure}$ pigs (fattening) = 4.45 kg/m²/year (14),
$Q_{application\ manure}$ pigs (breeding) = 5.95 kg/m²/year (14),
$Q_{application\ manure}$ cows = 9 kg/m²/year (14),
$Q_{application\ manure}$ unknown = 4.45 kg/m²/year.

According to reference (5) in one year the following default numbers of disinfection events take place:

$N_{disinfection\ events}$ footwear disinfection (poultry or pigs) = 52-104 d/year
$N_{disinfection\ events}$ feet disinfection (cows) = 6-12 d/year

For the manure storage period of 6 months it is estimated that the (maximum) number of disinfection events will be:

$N_{disinfection\ events}$ footwear disinfection (poultry or pigs) = 52 d/storage period
$N_{disinfection\ events}$ feet disinfection (cows) = 6 d/storage period
$N_{disinfection\ events}$ unknown = 52 d/storage period

The dose can be calculated with the following formula:

$$DOSE\ (kg/m^2) = C_{sludge}\ (kg/kg) * T_{emission}\ (d) / 365 * APPL_{sludge}\ (kg/m^2) \qquad [15]$$

Where:

$T_{emission}$ *(d)* = $N_{disinfection\ events}$ *(d)*

No reference states an emission to the air from disinfection of footwear and consistent with those references the default emission to the air is set to zero. As has already been mentioned before, for the disinfection of feet often a basin of about 1,000 l formalin is placed in the pathway to the door of the housing (inside or outside). So with disinfection of feet there will be a certain emission to the air. The maximum emission fraction can be derived from reference (5): 1 - 0.25 (not available for emission) - 0.25 (estimated emission to manure storage) = 0.5.
For calculating the emissions to the air (only if the application method is not known) the quantity of active ingredient ($Q_{a.i.}$) has to be recalculated with the defaults for feet disinfection:

$N_{reservoirs}$ = 1 (5)
$Q_{disinfectant}$ feet disinfection (cows) = 1,000 l (5)
$C_{a.i.}$ aldehydes feet disinfection = 2 g/l (if concentration is unknown) (5)

The emission to the air ($Edirect_{air}$) depends on the quantity of active ingredient used for footwear or feet disinfection ($Q_{a.i.}$) and the emission fraction to the air (F_{air}):

$$Edirect_{air}\ (kg) = Q_{a.i.}(g) * F_{air}\ (-)/1,000 \qquad [17]$$

Where:

F_{air} footwear disinfection (poultry an pigs) = 0 (negligible)
F_{air} feet disinfection (cows) = 0.5 (worst case)
F_{air} unknown = 0.5 (worst case)

To calculate the annual average air concentration the USES Air Module can be used with the following defaults for the number of emission days ($T_{emission}$):

$$Cdirect_{air}\ (kg/m^3) = Edirect_{air}\ (kg) * T_{emission}\ (d) / 365 * Cstd_{air}\ (kg/m^3) \qquad [18]$$

Where:

$T_{emission\ air}$ = 12 (5)

A summary of the model for disinfection of footwear and animals' feet is presented in table 2.

Table 2. Parameters/variables and default values for the disinfection of footwear (of farm workers) and animals' feet

Parameter/Variable (unit)	Symbol	Default	C/R/E/O
Input:			
Concentration of active ingredient (g/l)	$C_{a.i.}$	40	R/E
Quantity of disinfectant used (l/reservoir)	$Q_{disinfectant}$		E
- footwear disinfection (pigs/poultry) or unknown		10	
- animal feet disinfection (cows)		1,000	
Number of reservoirs (-)	$N_{reservoirs}$		E
- footwear disinfection (pigs/poultry) or unknown		2	
- animal feet disinfection (cows)		1	
Fraction of the emission to the manure storage	$F_{manure\ storage}$		E
- footwear disinfection (pigs/poultry) or unknown		0,75	
- animal feet disinfection (cows)		0,25	
Fraction of the emission to air	F_{air}		E
- animal feet disinfection (worst case) or unknown		0.5	
- footwear disinfection (negligible)		0	
fraction of disintegration in the manure storage	F_{dis}	0	R/E
Quantity of manure in manure storage (kg)	Q_{manure}		E
- pigs (fattening) or unknown		163,000	
- pigs (breeding)		260,000	
- cows		466,000	
- poultry (broilers)		135,000	
Application of manure to land (kg/m2/y)	$Q_{application\ manure}$		E
- manure from pigs (fattening)		4.45	
- manure from pigs (breeding)		5.95	
- manure from poultry (broilers)		0.85	
- manure from cows		9	
Number of disinfection events (d)	$N_{disinfection\ events}$		E
- footwear disinfection (pigs/poultry) or unknown		52	
- animal feet disinfection (cows)		6	
Number of emission days (d)	$T_{emission}$	12	E
Standard concentration in air at 100 meter from source for a source strength of 1 kg/s (kg/m^3)	$Cstd_{air}$	24.10^{-6}	C
Output:			
Output necessary for calculations in USES:			
- Direct emission to air from source (kg)	$Edirect_{air}$		
- Concentration of a.i. in sludge (kg/kg)	C_{sludge}		
- Number of days for the emission (d)	$T_{emission}$		
- Quantity of sludge applied to land (kg/m2/year)	$APPL_{sludge}$		

Annual average concentration in the air after direct emission (kg/m_3)	$Cdirect_{air}$
Dosage of a.i. per square meter of pasture and/or arable land (kg/m^2)	DOSE

Model calculations:

$Q_{a.i.}$ = quantity of active ingredient used *(g)*
$= N_{reservoirs}\ (-) * C_{a.i.}\ (g/l) * Q_{disinfectant}\ (l)$

$Edirect_{air}$ = direct emission to air from source *(kg)*
$= Q_{a.i.}\ (g) * F_{air}\ (-) / 1{,}000$

$Edirect_{manure\ storage}$ = direct emission to manure storage *(kg)*
$= Q_{a.i.}\ (g) * F_{manure\ storage}\ (-) / 1{,}000$

$Cdirect_{manure\ storage}$ = concentration of a.i. in manure storage *(kg/kg)*
$= E_{direct\ manure\ storage}\ (kg) / Q_{manure}\ (kg/year)$

$C_{sludge}\ (kg/kg) = Cdirect_{manure\ storage}\ (kg/kg) * (1 - F_{dis})$

$APPL_{sludge} = Q_{application\ manure}\ (kg/m^2)$

$T_{emission}\ (d)$ (in case of air) = $T_{emission}$ of input part of this table

$T_{emission}\ (d)$ (in case of manure) = $N_{disinfection\ events}$ of input part of this table

$DOSE\ (kg/m^2) = C_{sludge}\ (kg/kg) * T_{emission}\ (d) / 365 * APPL_{sludge}\ (kg/m^2)$

$Cdirect_{air}\ (kg/m^3) = Edirect_{air}\ (kg) * T_{emission}\ (d) / 365 * Cstd_{air}\ (kg/m^3)$

C=Constants; R=values from the test results in the notification; E=Expert estimations; O=Output.

2.2.3 Disinfection of milk extraction systems

Clearly disinfection of milk extraction systems is only relevant for dairy. In 1990 about 2,120 tonnes of disinfectants were used, most mixtures of hydroxides and chlorine compounds (8). At the moment only about 30% of the farmhouses in the Netherlands have a connection with the sewer (10). For this model it is supposed that all active ingredient available for emission is emitted to the manure store in consistence with reference (5). Regarding the binding capacities of chloride with organic material it is expected that the surplus of disinfectant is inactivated in relatively short time (8). But like the other models it is supposed that there is no disintegration/inactivation of the disinfectant in the manure storage system.

The quantity of active ingredient ($Q_{a.i.}$) depends on the concentration of active ingredient ($C_{a.i.}$) and the amount of disinfectant used for cleaning of the milk installation (V_{inst}) but also on the amount of disinfectant used for cleaning of the milk storage-tank (V_{tank}):

$$Q_{a.i} \text{ (g)} = C_{a.i.} \text{ (g/l)} * V_{inst} \text{ (l/day)} + C_{a.i.} \text{ (g/l)} * V_{tank} \text{ (l/day)} \quad [19]$$

Where :

$C_{a.i.}$ hydroxides = 0.62 g/l (5)

$C_{a.i.}$ chlorine compounds = 0.19 g/l (5)

V_{inst} = 130 (2 * 65) l/d (5)

V_{tank} = 45 l/d (5)

The emission to the manure storage system ($Edirect_{manure\ storage}$) depends on the quantity of a.i. used for disinfection of milk extraction systems ($Q_{a.i.}$) and the fraction released to the manure storage ($F_{manure\ storage}$):

$$Edirect_{manure\ storage}\ (kg) = Q_{a.i.}\ (g) * F_{manure\ storage}\ (-) / 1{,}000 \quad [20]$$

Where:

$F_{manure\ storage}$ = 0.75 (5)

The assessment can continue according to the model for the disinfection of animal houses.

$$Cdirect_{manure\ storage}\ (kg/kg) = Edirect_{manure\ storage}\ (kg) / Q_{manure}\ (kg) \quad [21]$$

Where:

Q_{manure}cows = (52 kg manure + 14.6 kg waste water/cow/day) * (175 days stalled) * 40 cows = 466,000 kg/storage period (9)

$C_{sludge}\ (kg/kg)\ =\ Cdirect_{manure\ storage}\ (kg/kg)\ *\ (1 - F_{dis})$ [22]

$APPL_{sludge}\ (kg/m^2)\ = Q_{application\ manure}\ (kg/m^2)$ [23]

Where:
$Q_{application\ manure}$ cows = 9 kg/m^2/year (14)

The dose can be calculated with the following formula:

$DOSE\ (kg/m^2) = C_{sludge}\ (kg/kg)\ *\ T_{emission}\ (d)/365\ *\ APPL_{sludge}\ (kg/m^2)$ [25]

$N_{disinfection\ events}\ (d) = T_{emission}\ (d)$ [24]

Where:
$T_{emission}\ (d) = N_{disinfection\ events}\ (d) = 150$

The number of disinfection events is not equal to a real number of days but it is derived from a combination of the amount of days when the milk installation is cleaned (twice a day) and when the milktank is cleaned (once in 3 days): ((365 * 65 * 2) + ((365 / 3) * 45)) / (130 + 45) = 302 days in one year. With this mathematical trick the real amount of disinfectant in one year can be calculated. For the manure storage period of 6 months this means about 150 days.

A summary of the model for disinfection of milk extraction systems is given in table 3.

Table 3. Parameters/variables and default values for the disinfection of milk extraction systems

Parameter/Variable (unit)	Symbol	Default	C/R/E/O
Input:			
Concentration of active ingredient (g/l)	$C_{a.i.}$	0.62	R/E
Amount of disinfectant used for cleaning of the milk installation (l/d)	V_{inst}	130	E
Amount of disinfectant used for cleaning of the milk storage tank (l)	V_{tank}	45	E
Fraction of the emission to the manure storage (-)	$F_{manure\ storage}$	0,75	E
Fraction of disintegration in the manure storage	F_{dis}	0	R/E
Quantity of manure in manure storage (kg)	Q_{manure}	466,000	E
Application of manure to land (kg/m2/y)	$Q_{application\ manure}$	9	E
Number of disinfection events (d)	$N_{disinfection\ events}$	150	E

Output:

Output necessary for calculations in USES:

Concentration of a.i. in sludge (kg/kg)	C_{sludge}
Number of days for the emission (d)	$T_{emission}$
Quantity of sludge applied to land (kg/m2/year)	$APPL_{sludge}$
Dosage of a.i. per square meter of pasture and/or arable land (kg/m^2)	DOSE

Model calculations:

$Q_{a.i.}$ = quantity of active ingredient used *(g)*
= $C_{a.i.}(g/l) * V_{inst}(l) + C_{a.i.}(g/l) * V_{tank}(l)$

$Edirect_{manure\ storage}$ = direct emission to manure storage *(kg)*
= $Q_{a.i.}(g) * F_{manure\ storage}(-) / 1,000$

$Cdirect_{manure\ storage}$ = concentration of a.i. in manure storage *(kg/kg)*
= $E_{direct\ manure\ storage}(kg) / Q_{manure}(kg/year)$

$C_{sludge}(kg/kg) = Cdirect_{manure\ storage}(kg/kg) * (1 - F_{dis})$

$APPL_{sludge} = Q_{application\ manure}(kg/m^2)$

$T_{emission} = N_{disinfection\ events}(d)$

$DOSE\ (kg/m^2) = C_{sludge}(kg/kg) * T_{emission}(d) / 365 * APPL_{sludge}(kg/m^2)$

C=Constants; R=values from the test results in the notification; E=Expert estimations; O=Output.

2.2.4 Disinfection of means of transport

Disinfection of means of transport is relevant for pigs and poultry. Pigs are transported in transport vehicles only, poultry is transported in special boxes on the transport vehicle. In 1990 about 22 tonnes of disinfectant were used (8). Although there is legislation which prescribes disinfection of means of transport at pig farms in common there is no disinfection of transport vehicles at farms at all (8). On few occasions there is a basin of disinfectant where the cars passes the frontier of the 'dirty road' to the 'clean road'. In this case only the tyres of the vehicle are disinfected but in most cases disinfection of the whole vehicle occurs only at slaughterhouses or export places for pigs. At these locations there is a severe risk of infection and cleaning and disinfection is required. Afterwards there is an inspection of the car and only if found sufficiently disinfected the transport vehicle gets an endorsement and can leave.

For this modelling the present situation is taken as a guide. This means that only the most important aspect of disinfection of means of transport is described: disinfection at the slaughterhouse (5). After use in most cases the surplus of disinfectant is discharged to the sewer and goes to the local Sewage Treatment Plant often after on-site treatment (11). On a few occasions the waste-water is discharged into the surface-water directly after treatment in an industrial (biological) waste water treatment plant.
For this modelling the "worst case" assumption has been made that the total amount of active ingredient that is available for emission is discharged (untreated) to the local STP.

The quantity of active ingredient ($Q_{a.i.}$) depends on the concentration of active ingredient ($C_{a.i.}$), the amount of disinfectant used for cleaning a square meter or a box ($Q_{disinfectant}$) and the number of square meters or boxes to be cleaned ($A_{boxes/transport}$):

$$Q_{a.i.}\ (g) = C_{a.i}\ (g/l) * Q_{disinfectant}\ (l/box\ or\ l/m^2) * A_{boxes/transport}\ (-\ or\ m^2) \qquad [26]$$

With the following suggestions for default values (5):

$C_{a.i.}$chlorine compounds	= 0.2 g/l
$C_{a.i.}$hydroxides	= 10.5 g/l
$C_{a.i.}$unknown	= 10.5 g/l

$Q_{disinfectant}$poultry	= 2 l/box
$Q_{disinfectant}$pigs	= 0.2 l/m^2
$Q_{disinfectant}$unknown	= 2 l

$A_{boxes/transport}$poultry	= 2,550 boxes (d), (51,000 animals in one day / 20 animals in one box = 2,550 boxes/d (12))
$A_{boxes/transport}$pigs	= 12,500 (m^2/d) (25,000 animals in one day * 0,5 m^2/animal = 12,500 m^2/d (12))
$A_{boxes/transport}$unknown	= 2,550 boxes/d

All active ingredient available for emission is assumed to go to the STP.

$$Edirect_{water}\ (kg) = Q_{a.i}\ (g) * F_{water}(-)/1{,}000 \qquad [27]$$

Where:
F_{water}= 0.75 (5)

The number of emission days in one year is estimated at 260 days:

$$T_{emission}=260\ d/year\ (12) \qquad [28]$$

A summary of the model for disinfection of means of transport at the slaughterhouse is presented in table 4.

Table 4. Parameters/variables and default values for the disinfection of means of transport at the slaughterhouse

Parameter/Variable (unit)	Symbol	Default	C/R/E/O
Input:			
Concentration of active ingredient (g/l)	$C_{a.i.}$	10.5	R/E
Quantity of disinfectant used (l/box or l/m²)	$Q_{disinfectant}$		E
- poultry or unknown (l/box)		2	
- pigs (l/m²)		0,2	
Amount of boxes or square metres transport (- or m²)	$A_{boxes/transport}$		E
- poultry or unknown (boxes)		2,550	
- pigs (m²)		12,500	
Fraction of a.i. to waste water	F_{water}	0.75	E
Number of emission days	$T_{emission}$	260	E
Output:			
Output necessary for calculations in USES:			
- Number of days for the emission *(d)*	$T_{emission}$		
- Direct emission to water *(kg/day)*	$Edirect_{water}$		

Model calculations:

$Q_{a.i.}$ = quantity of active ingredient used *(g)*
$= C_{a.i}\ (g/l) * Q_{disinfectant}\ (l/box\ or\ l/m^2) * A_{boxes/transport}\ (-\ or\ m^2)$

$Edirect_{water}\ (kg) = Q_{a.i}\ (g) * F_{water}\ (-) / 1{,}000$

$T_{emission} = 260\ (days)$

C=Constants; R=values from the test results in the notification; E=Expert estimations; O=Output.

2.2.5 Disinfection of hatcheries

For disinfection at the hatchery about 13 tonnes of disinfectants were used in the year 1990 [5]. In most cases formaldehyde is used. Disinfection can take place four times: disinfection of the eggs both before and during the brooding, disinfection of the chicks (and eggshells) and also with the cleaning of the rooms of the hatchery. There are emissions to the waste water and to the air [8]. The waste water is discharged into the sewer or to the surface water [8]. For this modelling it is assumed that all disinfectants are emitted to the sewer and channelled to the local STP. For worst case modelling the STP can be bypassed. In 1994 there were 72 hatcheries which hatched about 700 million eggs [13] which means an average of 9.7 million eggs per hachery in one year.

The quantity of active ingredient ($Q_{a.i.}$) used for these 1 to 4 disinfections depends on the quantity of disinfectant used per cubic metre ($Q_{disinfectant}$) * (Total amount of eggs disinfected (N_{eggs}) / Amount of eggs per cubic metre (A_{eggs})):

$$Q_{a.i.}\ (g) = \sum_{n=1}^{4} (Q_{disinfectant\ n}\ (g/m^3) * (N_{eggs\ n}\ (eggs/day) / A_{eggs\ n}\ (eggs/m^3))) \quad (29)$$

With the following suggestions for default values (derived from reference 5):

$Q_{disinfectant\ n}$ formaline = 1.2 g/m^3
$Q_{disinfectant\ n}$ paraformaldehyde or unknown=6.3 g/m^3

$N_{eggs\ n}$ = 37,000 eggs/day

$A_{eggs\ 1}$=1,160 eggs/m^3
$A_{eggs\ 2}$=1,410 eggs/m^3
$A_{eggs\ 3}$=1,410 eggs/m^3
$A_{eggs\ 4}$=1,410 eggs/m^3

The estimated emission fraction to the air is 0.25 and therefore the emission fraction to waste water is estimated 0.5 in consistence with reference (5).

$$Edirect_{water}\ (kg) = Q_{a.i}\ (g) * F_{water}(-) / 1{,}000 \quad [30]$$

Where:
F_{water}=0.5

$$Edirect_{air}(kg) = Q_{a.i.}\ (g) * F_{air}(-)\ /\ 1{,}000 \qquad [31]$$

Where:

$F_{air}=0.25$

The default number of emission days is estimated at 260 days:

$$T_{emission}\ (days) = 260 \qquad [32]$$

In table 5 a summary of the approach for disinfection of hatcheries is given.

Table 5. Parameters/variables and default values for the disinfection of hatcheries

Parameter/Variable (unit)	Symbol	Default	C/R/E/O
Input:			
Quantity of disinfectant used per cubic metre (g/m^3)	$Q_{disinfectant}$	6.3	R/E
Total amount of eggs disinfected (eggs/day)	N_{eggs}	37,000	E
Amount of eggs per cubic metre (eggs/m^3)	A_{eggs}		E
- first disinfection of the eggs ($A_{eggs\ 1}$)			1,160
- other disinfections ($A_{eggs\ 2}$, $A_{eggs\ 3}$, $A_{eggs\ 4}$)			1,410
Fraction of a.i. to waste water (-)	F_{water}	0.5	E
Fraction of a.i. to air (-)	F_{air}	0.25	E
Number of emission days (days/year)	$T_{emission}$	260	E
Output:			
Outpu necessary for calculations in USES:			
Direct emission to water from source (kg/day)	$Edirect_{water}$		
Direct emission to air from source (kg/day)	$Edirect_{air}$		
Number of emission days *(days/year)*	$T_{emission}$		

Model calculations:

$$Q_{a.i.}\ (g) = \sum_{n=1}^{4} (Q_{disinfectant\ n}(g/m^3) * (N_{eggs\ n}(eggs/day)\ /\ A_{eggs\ n}(eggs/m^3)))$$

$$Edirect_{water}\ (kg) = Q_{a.i.}\ (g) * F_{water}\ (-)\ /\ 1{,}000$$

$$Edirect_{air}\ (kg) = Q_{a.i.}\ (g) * F_{air}\ (-)\ /\ 1{,}000$$

$$T_{emission}\ (days/year) = 260$$

C=Constants; R=values from the test results in the notification; E=Expert estimations; O=Output.

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