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

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Abstract

Environmental risk limits for antimony

This report presents environmental risk limits (ERLs) for antimony in (ground)water, sediment, and soil. ERLs are advisory values that serve as a scientific background to set environmental quality standards in the Netherlands. The ERLs for antimony are based on the results of the European risk assessment for antimony, which was prepared under the former Existing Substances Regulation 793/93/EEC. The derivation of ERLs is in accordance with the methodology of the Water Framework Directive. Based on a comparison with Dutch monitoring data, it is expected that the newly derived ERLs will be exceeded in very few cases.

Keywords:
environmental risk limits; antimony

Rapport in het kort

Milieurisicogrenzen voor antimoon

Dit rapport geeft milieurisicogrenzen voor antimoon in (grond)water, sediment, en bodem. Milieurisicogrenzen zijn de technisch-wetenschappelijke advieswaarden voor de uiteindelijke milieukwaliteitsnormen in Nederland. De milieurisicogrenzen voor antimoon zijn gebaseerd op de uitkomsten van de EU risicobeoordeling voor antimoon, welke is opgesteld onder de voormalige Bestaande Stoffen Verordening 793/93/EEG. De afleiding van de milieurisicogrenzen sluit tevens aan bij de richtlijnen uit de Kaderrichtlijn Water. Op basis van een vergelijking met Nederlandse meetgegevens, wordt verwacht dat de nieuwe milieurisicogrenzen naar verwachting zeer zelden overschreden worden.

Trefwoorden:
milieurisicogrenzen; antimoon

Contents

Summary

Environmental risk limits (ERLs) are derived using ecotoxicological, physico-chemical, and human toxicological data. They represent environmental concentrations of a substance offering different levels of protection to man and ecosystems. It should be noted that the ERLs are scientifically derived values. They serve as advisory values for the Dutch Steering Committee for Substances, which is appointed to set Environmental Quality Standards (EQSs) based on these ERLs. ERLs should thus be considered as preliminary values that do not have an official status.

This report contains ERLs for antimony in water, groundwater, sediment and soil. The following ERLs are derived: Negligible Concentration (NC), Maximum Permissible Concentration (MPC), Maximum Acceptable Concentration for ecosystems (MAC$_{eco}$), and Serious Risk Concentration for ecosystems (SRC$_{eco}$). The risk limits are based on data presented in the Risk Assessment Report (RAR) for this compound, prepared under the former European Existing Substances Regulation (793/93/EEC). For antimony, no risk limits for the air compartment were derived, because (a)biotic effects due to the atmospheric release of antimony air are not considered likely according to the EU-RAR.

For the derivation of the MPC and MAC$_{eco}$ for water, the methodology used is in accordance with the Water Framework Directive (EC, 2011). For the other ERLs, the guidance developed for the project 'International and National Environmental Quality Standards for Substances in the Netherlands' was used (Van Vlaardingen and Verbruggen, 2007). An overview of the derived ERLs is given in Table 1.

Table 1. Derived MPC, NC, MAC$_{eco}$, and SRC$_{eco}$ values for antimony.

ERL	**unit**	**value**			
		MPC	NC	MAC$_{eco}$	SRC$_{eco}$
water [a]	mg.L^{-1}	5.6×10^{-3}	5.6×10^{-5}	0.2	9.6
drinking water [b]	mg.L^{-1}	2.1×10^{-2}	n.d.	n.d.	n.d.
marine	mg.L^{-1}	n.d.	n.d.	n.d.	n.d.
sediment	mg.kg$_{dwt}^{-1}$	14	3.1	n.d.	1.1×10^{2}
soil [c]	mg.kg$_{dwt}^{-1}$	1.0×10^{2}	4.0	n.d.	1.4×10^{3}
groundwater	mg.L^{-1}	2.1×10^{-2}	3.0×10^{-4}	n.d.	9.6
air	mg.m^{-3}	n.d.	n.d.	n.d.	n.d.

All values are based on dissolved concentrations.

a From the MPC$_{eco, water}$, MPC$_{sp, water}$ and MPC$_{hh food, water}$ the lowest one is selected as the 'overall' MPC$_{water}$.

b The MPC$_{dw, water}$ is presented as a separate value in this report.

c Expressed on the basis of Dutch standard soil.

n.d. = not derived.

1 Introduction

1.1 Project framework

In this report environmental risk limits (ERLs) for surface water (freshwater and marine), soil and groundwater are derived for antimony. The following ERLs are considered:

- Negligible Concentration (NC) – concentration at which effects to ecosystems are expected to be negligible and functional properties of ecosystems must be safeguarded fully. It defines a safety margin which should exclude combination toxicity. The NC is derived by dividing the MPC (see next bullet) by a factor of 100.
- Maximum Permissible Concentration (MPC) – concentration in an environmental compartment at which:
  1. no effect to be rated as negative is to be expected for ecosystems;
  2a no effect to be rated as negative is to be expected for humans (for non-carcinogenic substances);
  2b for humans no more than a probability of 10^{-6} over the whole life (one additional cancer incident in 10^6 persons taking up the substance concerned for 70 years) can be calculated (for carcinogenic substances) (Technical Guidance for deriving EQS, 2010).
- Maximum Acceptable Concentration (MAC_{eco}) – concentration protecting aquatic ecosystems for effects due to short-term exposure or concentration peaks.
- Serious Risk Concentration (SRC_{eco}) – concentration at which serious negative effects in an ecosystem may occur.

It should be noted that ERLs are scientifically derived values, based on (eco)toxicological, fate and physico-chemical data. They serve as advisory values for the Dutch Steering Committee for Substances, which is appointed to set the Environmental Quality Standards (EQSs) from these ERLs. ERLs should thus be considered as preliminary values that do not have an official status.

1.2 Production and use of antimony

The Risk Assessment Report (RAR) reports that antimony is used as flame-retardant in plastics, rubber, and textiles, as a catalyst in the PET industry, in paint pigments and ceramics and in glass (EC, 2008).

2 Methods

2.1 Data collection

The final Risk Assessment Report (RAR) of antimony European Commission, 2008 produced in the framework of the former Existing Substances Regulation (793/93/EEC) was used as the only source of physico-chemical and (eco)toxicity data. No additional search for and evaluation of data was performed for the ERL derivation. Only valid data combined in an aggregated data table are presented in the current report.
In the aggregated data table only one effect value per species is presented. When for a species several effect data are available, the geometric mean of multiple values for the same endpoint is calculated where possible. Subsequently, when several endpoints are available for one species, the lowest of these endpoints (per species) is reported in the aggregated data table.

2.2 Methodology for derivation of environmental risk limits

For the derivation of the MPC and MAC_{eco} for water, the methodology is in accordance with the Water Framework Directive and follows the recently published Technical Guidance for deriving Environmental Quality Standards (EC, 2011). For the other ERLs, the guidance developed for the project 'International and National Environmental Quality Standards for Substances in the Netherlands' was used (Van Vlaardingen and Verbruggen, 2007).

2.2.1 Environmental risk limits for metals: the added risk approach

According to the guidance, the added risk approach is used for derivation of ERLs for metals in case other options for bioavailability correction, such as speciation models or biotic ligand modelling (BLM) cannot be used.
The added risk approach, which is modified from Struijs *et al.* (1997), is used to take natural background concentrations into account when calculating ERLs for naturally occurring elements. The approach starts by calculating a maximum permissible addition (MPA) on the basis of available data from laboratory toxicity tests (with added amounts of toxicants). This MPA is considered to be the maximum concentration that may be added to the background concentration (C_b), without causing deleterious effects. Hence, the MPC is the sum of C_b and MPA:

$$MPC = C_b + MPA$$

The background concentration and the MPA are independently derived values. The MPA is calculated using a similar approach as the MPC for substances having no natural background concentration, except for drinking water. The MPC for drinking water is always based on total concentration in water and the added risk approach is not applicable. This also holds for the MPC for secondary poisoning and human consumption of fish, since in the calculations of these value a bioaccumulation factor (BAF) is used in which the background concentrations are included.
The implicit assumption is that the background concentration has resulted in the biodiversity of ecosystems or serves to fulfil the need for micronutrients of species in the environment (Klepper *et al.*, 1998).

2.2.2 *Drinking water abstraction*

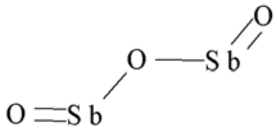
The INS-Guidance includes the MPC for surface waters intended for the abstraction of drinking water ($MPC_{dw,\ water}$) as one of the MPCs from which the lowest value should be selected as the general MPC_{water} (see INS-Guidance, Section 3.1.6 and 3.1.7). According to the current guidance (EC, 2011), drinking water abstraction is not guiding for the general MPC_{water} value, and protection of surface water for drinking water production is considered as a separate issue in the WFD-methodology. The $MPC_{dw,\ water}$ for surface is therefore presented as a separate value in this report.
The $MPC_{dw,\ water}$ is also used to derive the MPC_{gw}. For the derivation of the $MPC_{dw,\ water}$, a substance specific removal efficiency related to simple water treatment may be needed. Because there is no agreement as yet on how the removal fraction should be calculated, water treatment is not taken into account.

3 Substance information

3.1 Identity

Antimony is a metalloid that belongs to group 15, period 5 of the periodic table of the elements. Oxidation states of antimony include –3, 0, +3, and +5, where the two latter, i.e. +3 and +5, are the predominant environmental ones. Since diantimony trioxide is the subject of the EU-RAR on which the ERL derivation is based, data on this substance are included as well.

Table 2. Identification of diantimony trioxide and antimony.

Parameter	Name or number
Chemical name	diantimony trioxide
CAS number	1309-64-4
EC number	215-175-0
Molecular formula	Sb_2O_3
Molecular structure	
Chemical name	antimony
CAS number	7440-36-0
EC number	231-146-5
Molecular formula:	Sb

3.2 Physico-chemical properties

Table 3. Physico-chemical properties of diantimony trioxide and antimony.

Parameter	Unit	Value	Remark
Molecular weight	[g/mol]	291.52	Sb_2O_3
		121.76	Sb
Water solubility	[mg/L]	19.7	Sb_2O_3 distilled water, pH 5, 20°C
		25.6	Sb_2O_3 distilled water, pH 7, 20°C
		28.7	Sb_2O_3 distilled water, pH 9, 20°C
		2.76	Sb, reconstituted water, pH 8, 22.2°C
log K_{OW}	[-]	n.a.	
K_{OC}	[L/kg]		The mobility of antimony in soils depends on the form of antimony, the nature of the soil, and the environmental conditions in the soil.
Vapour pressure	[Pa]	133	574°C
Melting point	[°C]	655	
Boiling point	[°C]	1550	
Henry's law constant	[Pa.m^3.mol^{-1}]	n.a.	

n.a. = not applicable.

3.3 Behaviour in the environment

The speciation and physico-chemical state of antimony are important for its behaviour in the environment and availability to biota. For example, antimony incorporated in mineral lattices is inert and unlikely to be bioavailable.

The bioavailability of the organo-antimony forms is not well known. However, as mentioned by Farkasovska *et al.* (1999), methylated species of antimony are less toxic than the inorganic salts. It is therefore possible that they are less bioavailable, but this remains unconfirmed (Health Canada and Environment Canada, 2010).

Most analytical methods for antimony do not distinguish between the various forms of antimony. While the total amount of antimony may be known, the nature of the antimony compounds, the importance of adsorption, and other factors that may influence bioavailability are not. This information is apt to be site-specific (ATSDR, 1992).

There are uncertainties surrounding the thermodynamic data for antimony compounds, and as a consequence, the Eh-pH diagrams differ between different sources. Earlier diagrams suggest that antimony is immobile under oxidizing conditions, occurring as solid oxides (e.g. Brookins, 1988), but more recent diagrams show that in oxidizing conditions, $Sb(OH)_6^-$ is the most important species, confirming the relatively high mobility of antimony under oxidizing conditions (e.g. Filella et al*.*, 2002a; Filella et al*.*, 2002b, cited in EC, 2008).

3.3.1 Transformations in the environment

Antimony, being a natural element, cannot be degraded. However, it can be transformed between different binding/speciation forms and oxidation states. In the following sections, transformation processes in air, water, sediment and soil are briefly described for informative purposes based on the EU-RAR (EC, 2008).

3.3.1.1 Atmospheric transformation

Most of the antimony that is released to the atmosphere from anthropogenic sources results from metal smelting and refinement, combustion of coal, refuse and sludge incineration, and road traffic.

These activities may result in long-range transport of diantimony trioxide far from its source. The combustion/incineration processes transform antimony compounds to diantimony trioxide regardless of the pre-incinerated form of antimony. Further, there are indications that diantimony trioxide may dissolve in the atmosphere and that the trivalent form will oxidise to the pentavalent form (EC, 2008).

3.3.1.2 Aquatic transformation

Conclusions that can be drawn regarding the fate of antimony in water (EC, 2008):

i) in natural waters antimony exists almost exclusively in the dissolved phase in the two valency states +3 and +5. Both Sb(III) and Sb(V) ions hydrolyse easily, and Sb(III) is present as the neutral species $Sb(OH)_3$, and Sb(V) as the anion, $Sb(OH)_6^-$. According to thermodynamic calculations, antimony should almost exclusively be present as Sb(V) in oxic systems, and as Sb(III) in anoxic systems. Even though the dominant species in oxic waters is Sb(V), Sb(III) has been detected in concentrations much above what is predicted, and the reverse is true for Sb(V) in anoxic systems. The presence of these thermodynamically unfavourable species (i.e. Sb(III) in oxic waters, and Sb(V) in anoxic) requires a mechanism for the production and slow rates of conversion (i.e. kinetic stabilization), which however are not yet are fully understood,

ii) reports exist on both conservative (i.e. the concentration only changes with dilution or evaporation) behaviour, or a behaviour corresponding to mildly scavenged element with surface (atmospheric) input,

iii) in addition to the inorganic forms of antimony, there also exist methylated forms of trivalent and pentavalent antimony,

iv) interactions between the antimony species (anionic $Sb(OH)_6^-$ or the neutral $Sb(OH)_3$) present in natural waters and the predominately negatively charged natural organic matter may occur, but any firm conclusion on its importance is presently hard to make,

v) solubility of the diantimony trioxide is dependent on the conditions (Eh/pH), and the time factor. Studies on deposited antimony particles (most probably antimony oxides) in seawater indicated order of days to obtain complete dissolution.

3.3.1.3 Behaviour in sediment

Conclusions that can be drawn regarding the fate of antimony in sediment European Commission, 2008:

i) the adsorption of antimony in oxic sediments has been correlated with the presence of iron-, manganese-, and aluminium oxides,

ii) the decrease in bioavailable antimony in water by oxic sediments is not a permanent decrease, as the adsorption on the hydrous oxides is dependent on both pH and oxic condition (which may change). In addition, antimony may become bioavailable to organisms inhabiting the sediment through ingestion of the sediment,

iii) in anoxic systems, and in the presence of sulphur, depending on pH, antimony forms soluble or insoluble stibnite, SbS_2^- and $Sb_2S_3(s)$, respectively. This may result in a larger decrease in bioavailable antimony, as compared to the oxic part of the sediment.

3.3.1.4 Transformation in soil

In general, the knowledge on weathering reactions, mobility and adsorptive behaviour of antimony, its compounds and ions is relatively limited. However, the following conclusions can be drawn from the literature regarding the fate of antimony in soil European Commission, 2008:

i) the sorption and precipitation of $Ca[Sb(OH)_6]_2$ seem to be more important than the dissolution processes of Sb_2O_3 as regards the fate of antimony.

ii) the solubility of antimony compounds depends on the soil conditions (Eh/pH) and the time given to dissolve.

iii) the most important soil characteristic as regards the mobility of antimony in soil (and sediments), appears to be the presence of hydrous oxides of iron, manganese, and aluminium, to which antimony may adsorb. In addition, these hydrous oxides seem to oxidise dissolved trivalent antimonite ($Sb(OH)_3$) to the pentavalent antimonate ($Sb(OH)_6^-$).

iv) the largest effect of pH on sorption seems to be around 3 - 4, with decreasing sorption at higher pH-values. The effect of pH as such is probably less important as compared to the effect of the hydrous oxides. The effect of pH on antimony mobility seems to be via the hydrous oxides, via the influence on valence of antimony and the solubility of antimony compound, and via the increasing negative charge of the soil at increasing pH (and hence, weaker sorption of the negatively charged $Sb(OH)_6^-$).

v) due to the anionic character of the dissolved species ($Sb(OH)_6^-$), antimony is expected to have a low affinity for organic carbon. However, there exist results that indicate that the sorption of Sb(V) by humic acid in acid soils with high proportions of organic matter may be more important than previously suspected, although the strong Sb(V) scavenging potential of $Fe(OH)_3$ probably results in diminished role of organic matter binding in soils with high amounts of noncrystalline hydroxides.
vi) the cationic exchange reactions, which are the main sorption reactions on clay minerals, are not expected to be important for the anionic antimony.
vii) initial differences on sorption depending on type of antimony compound used diminish with time.
viii) the influence of the concentration of added antimony on sorption appears to be small
ix) a higher Sb porewater concentration can be achieved in transformation studies when using Sb_2O_3, as compared to when using $SbCl_3$. The limiting factor appears to be precipitation of $Ca[Sb(OH)_6]_2$.

From the above described processes, it appears that the environmental behaviour of antimony is complex, and that the factors that may influence speciation and bioavailability are only poorly understood. It is recognised that the added risk approach is a simplification which does not account for the processes that take place in reality. However, in the absence of agreed methods for this particular element, the added risk approach is considered as the only feasible method, in line with the WFD-guidance.

3.4 Bioconcentration and biomagnification

According to the EU-RAR, no fully reliable bioaccumulation studies are available and measured data from different aquatic organisms have been used to calculate tentative bioconcentration factors (BCF). For marine fish the calculated BCFs vary between 40 and 15000 L/kg whereas for freshwater fish the BCF values are lower; the highest being 14 L/kg. For invertebrates, tentative BCFs in the range of 4000-5000 L/kg have been calculated. As opposed to these values a study with caged specimens of *Hyallella azteca* indicates a BCF-value of approximately 0.06 L/kg. As there is a considerable uncertainty in these BCF-values the risk characterization for secondary poisoning in the EU-RAR was performed using both a BCF of 40 L/kg and a BCF of 15000 L/kg (EC, 2008).

For ERL-derivation of other elements (e.g. molybdenum and vanadium), Van Vlaardingen and Verbruggen (2009) used studies by Ikemoto *et al.* (2008) and Ravera *et al.* (2003) for the calculation of BAF values. These studies are used here to calculate BAFs for antimony as well.

<u>Ikemoto et al., 2008</u>
BAFs on dry weight basis are 219 L/kg_{dw} in phytoplankton, 31 - 94 L/kg_{dw} in crustaceans, and < LOD - 63 L/kg_{dw} in fish. Recalculated to a wet weight basis these values were 8 L/kg_{ww} in phytoplankton, 9 -20 L/kg_{ww} in crustaceans, and 2 - 31 L/kg_{ww} in fish.

Ravera et al., 2003
BAFs on dry weight basis are < LOD - 299 L/kg$_{dw}$ in aquatic plants and 130 - 260 L/kg$_{dw}$ in molluscs. Recalculated to a wet weight basis these values were < LOD - 30 L/kg$_{ww}$ for aquatic plants and 24 - 65 L/kg$_{ww}$ for molluscs.

In the Canadian "Screening Assessment for the Challenge Antimony trioxide" (Health Canada and Environment Canada, 2010) comparable BCF and BAF values were reported. Based on these BAF values, it can be concluded that a BCF value of 15000 L/kg for antimony is unrealistically high. Therefore, a worst-case BAF of 65 L/kg (the highest BCF value found in the study by Ravera, 2003) is considered most appropriate. This value is below 100 L/kg, and derivation of ERLs for secondary poisoning is not triggered. However, since secondary poisoning of antimony was assessed in the RAR, an MPA for this route will be derived. The value of 65 L/kg will be used in the calculations of the ERLs for secondary poisoning and human fish consumption.

3.4.1 *Human toxicological threshold limits and carcinogenicity*

Antimony salts as a group are classified with R20/22 and R51/53.
Antimony trioxide was found positive in vitro in bacterial mutation assays, a cytogenetic assay with human lymphocytes and a sister chromatid exchange assay. In vivo, chromosomal aberrations were observed, however no clastogenic effects were found (WHO, 2003; EFSA, 2004). For soluble antimony compounds positive results were found in some in vitro studies (trivalent and pentavalent antimony compounds) and also in some in vivo studies (only trivalent antimony compounds) (WHO 2003; De Boeck, 2003).
No oral carcinogenicity of antimony potassium tartrate was found in two lifetime studies in rats and mice (Kanisawa and Schroeder, 1969; Schroeder et al., 1970). However, the study design contained several crucial shortcomings and detailed histopathological examination appeared not to have been conducted (Lynch et al., 1999). Antimony trioxide inhalation in rats resulted in lung tumours in combination with direct lung damage due to chronic overload with insoluble particles (WHO, 2003). The data available indicate that these tumours are formed by a non-genotoxic mechanism (Van Engelen, 2006).
According to IARC (1989), antimony trioxide is possibly carcinogenic to humans (classified in group 2B) and antimony trisulfide is not classifiable as to its carcinogenicity to humans (classified in group 3) (Tiesjema and Baars, 2009).
Since antimony is not a genotoxic carcinogen, the threshold approach can be used.
Previously, US-EPA (1991) derived an RfD of 0.4 µg antimony/kg bw/day. This value was based on a reduced lifespan and altered plasma levels of glucose and cholesterol in a lifetime rat study with a LOAEL of 0.35 mg antimony/kg bw/day (5 ppm; Schroeder et al., 1970) and applying an uncertainty factor of 1000, for intra- and interspecies variation and the conversion of LOAEL to NOAEL.
OEHHA (1997) also used the rat study by Schroeder et al. (1970) as basis for the derivation of a drinking water guideline. They applied an uncertainty factor of 300 (100 for intra- and interspecies variation and a factor 3 for LOAEL to NOAEL conversion and a non-severe endpoint) to the LOAEL, which was put at 0.43 mg/kg bw/day, resulting in a Tolerable Daily Intake (TDI) of 1.4 µg antimony/kg bw/day.
WHO (2003) took the NOAEL of 6 mg antimony/kg bw/day, administered as antimony potassium tartrate, of the subchronic drinking water study in rats (Poon et al., 1998), which was suggested by Lynch et al. (1999) as most appropriate starting point for the derivation of a TDI. Applying an uncertainty

factor of 1000 (a factor of 10 each for intra- and interspecies variation and the use of a subchronic study) resulted in a TDI of 6 µg antimony/kg bw/day. EFSA (2004) adopted this TDI in its evaluation for use of antimony trioxide in food contact materials. RIVM (Van Engelen et al., 2006) also adopted this TDI as most appropriate limit value for the ingestion of antimony (Tiesjema and Baars, 2009), Since antimony is is classified as 'possibly carcinogenic to humans (Group 2B), an ERLfor human health via food (fish) consumption ($MPC_{hh\ food,\ water}$) should be derived. The TDI of 6 µg antimony/kg bw/day will be used for further calculations.

3.5 PNEC values derived in the EU-RAR

In the EU-RAR, predicted no effect concentrations (PNECs) were derived for various compartments (surface water, STP, sediment, marine water, marine sediment and soil) and secondary poisoning. In order to make a comparison between de PNEC values derived in the EU-RAR and the ERL values derived in this report, the PNEC values are listed in the table below.

Table 4. Antimony: EU-RAR PNEC values

Compartment	Value	Unit	Remarks
Surface water	0.113	mg Sb/L	AF 10 on lowest NOEC (1.13 mg Sb/L for *Pimephales promelas*)
STP	2.55	mg Sb/L	AF 10 on EC_{50} of test with nitrifying bacteria (25.5 mg Sb/L)
Sediment	11.2	mg Sb/kg_{dwt}	AF 10 on lowest NOEC (112 mg Sb/kg_{dwt} for *Chironomus riparius*)
Marine water	11.3	µg Sb/L	AF 100 on lowest NOEC (1.13 mg Sb/L for *Pimephales promelas*)
Marine sediment	2.24	mg Sb/kg_{dwt}	AF 50 on lowest NOEC (112 mg Sb/kg_{dwt} for *Chironomus riparius*)
Soil	37	mg Sb/kg_{dwt}	AF 10 on porewater concentration measured at NOEC (9.7 mg Sb/L)
Secondary poisoning	374.8	mg Sb/kg_{food}	Based on NOAEL of 1686 mg Sb/kg bw/day and AF 90

3.6 Trigger values

This section reports on the trigger values for ERL_{water} derivation (as demanded in WFD framework).

Table 5. Antimony: collected properties for comparison to MPC triggers.

Parameter	Value	Unit	Method/Source
Log $K_{p,susp-water}$	3.59	[-]	Van Vlaardingen *et al.*, 2005
BAF	65	[L/kg]	Section 3.1.4
Log K_{OW}	n.a.	[-]	
R-phrases	R20/22, R51/53 (Sb salts) 'possibly carcinogenic to humans (Group 2B)' (Sb_2O_3)	[-]	European Commission, 2008
A1 value	n.a.	[µg/L]	
DW standard	n.a.	[µg/L]	

- ○ Antimony has a log $K_{p,\ susp-water} > 3$; derivation of $MPC_{sediment}$ is triggered.
- ○ Antimony has a log $K_{p,\ susp-water} > 3$; expression of the MPC_{water} as $MPC_{water,\ total}$ $MPC_{water,\ susp}$ is required.
- ○ Antimony has a BCF < 100 L/kg; assessment of secondary poisoning is not triggered. However, since secondary poisoning of antimony was assessed in the RAR, an MPA for this route will be derived.
- ○ Antimony is classified as 'possibly carcinogenic to humans (Group 2B). Therefore, an MPC_{water} for human health via food (fish) consumption ($MPC_{hh\ food,\ water}$) should be derived.

3.7 Background concentrations for antimony

Antimony occurs naturally in a mineral form, embedded in rocks. Mining and extraction have to be employed in order to obtain antimony in a more pure form in which it can be further processed to eventually reach its applications. These anthropogenic activities but also geochemical, meteorological and biological processes lead to both local and global distribution of the elements over the different environmental compartments, resulting in background concentrations (Van Vlaardingen *et al.*, 2005). In Van Vlaardingen and Verbruggen (2009) background concentrations are reported (see Table 6) . For the marine environment, no background concentrations are available.

Table 6 Antimony: Background concentrations in the Netherlands

Compartment	Background concentration	Unit	Notes
Freshwater	0.29	µg/L	dissolved fraction
Groundwater	0.091	µg/L	dissolved fraction
Freshwater sediment	3	mg/kg	non-standardized sediment
Soil	3	mg/kg	non-standardized soil

4 Toxicity data and derivation of ERLs

4.1 Toxicity data and ERLs for water

4.1.1 *Aquatic toxicity data*

An overview of the selected freshwater toxicity data for antimony as reported in the EU-RAR is given in Table 7 and toxicity data for marine species are shown in Table 8. These studies are also included in the REACH dossier for antimony (ECHA, 2011).

Table 7. Antimony: selected freshwater toxicity data for ERL derivation.

Chronic Taxonomic group	**Valency**	**NOEC (mg Sb/L)**	**Acute Taxonomic group**	**Valency**	**$L(E)C_{50}$ (mg Sb/L)**
Bacteria			**Bacteria**		
Nitrifying bacteria	III	2.55	Nitrifying bacteria	III	27
Algae			**Algae**		
Pseudokirchneriella subcapitata	III	2.11	*Pseudokirchneriella subcapitata*	III	> solubility[b]
Macrophyta			**Macrophyta**		
Lemna minor	III	12.5	*Lemna minor*	III	> 25.5
Crustacea			**Crustacea**		
Daphnia magna	III	1.74	*Daphnia magna*	III	18.8
Pisces			*Gammarus pseudolimnaeus*	III	> 25.7
Pimephales promelas	III	1.13[a]	*Hyalella azteca*	III	21.6
			Cnidaria		
			Chlorohydra viridissima	III	1.77
			Hydra oligactis	III	1.95
			Annelida		
			Lumbriculus variegatus	III	> 25.7
			Mollusca		
			Physa heterostropha	III	14.2
			Insecta		
			Chironomus tentans	III	4.1
			Pycnopsyche sp.	III	> 25.7
			Pisces		
			Ictalurus punctatus	III	24.6
			Oncorhynchus mykiss	III	25.7[c]
			Pimephales promelas	III	14.4

[a] Most relevant endpoints: growth, length.

[b] The value of 36.6 mg Sb/L exceeds the water solubility.

[c] 45% mortality at highest test concentration.

Table 8. Antimony: selected toxicity data for marine species for ERL derivation.

Chronic Taxonomic group	**Valency**	**NOEC (mg Sb/L)**	**Acute Taxonomic group**	**Valency**	**$L(E)C_{50}$ (mg Sb/L)**
			Pisces		
			Pargus major	III	12.4
			Pargus major	V	6.9

4.1.2 *Treatment of fresh- and saltwater toxicity data*

According to the TGD and WFD guidance document, differences in iono- and osmoregulatory environments may cause differences in the toxicity of a substance, and especially of a metal, to freshwater and saltwater species, and it is important to check for such differences. Thus, data for metals should not be pooled, unless it can be demonstrated that there are no differences between the two datasets. In view of the limited data for marine species, a sound statistical comparison is not possible, and the datasets should be kept separated. Since the base set (acute toxicity data for algae, crustaceans and fish) for the saltwater compartment is incomplete, no ERLs can be derived for the marine water compartment.

4.1.3 *Mesocosm studies*

No mesocosm studies were available in the EU-RAR for antimony.

4.1.4 *Derivation of MPC_{water} and NC_{water}*

4.1.4.1 Direct ecotoxicity - $MPC_{eco,\ water}$

As explained in section 2.2.1, the added risk approach is used to take natural background concentrations into account when calculating MPCs for naturally occurring substances. The MPC is the sum of the background concentration and the maximum permissible addition (MPA). The MPA is calculated using a similar approach as the MPC for substances having no natural background concentration.

The base-set (acute toxicity data for algae, *Daphnia* and fish) for the freshwater compartment is complete. Chronic NOEC values are available for five species from five taxonomic groups. The $MPA_{eco,\ water}$ is derived by applying an assessment factor of 10 on the lowest NOEC of 1.13 mg Sb/L for the fish *Pimephales promelas*. This value is also used for derivation of the PNEC in the REACH dossier (ECHA, 2011). This results in an $MPA_{eco,\ water}$ of 0.1 mg Sb/L. This value is added to the background concentration in order to determine the $MPC_{eco,\ water}$. The $MPC_{eco,\ water}$ is 0.1 mg Sb/L + 2.9×10^{-4} mg Sb/L = 0.1 mg Sb/L.

4.1.4.2 Secondary poisoning - $MPC_{sp,\ water}$

Except one, all reproduction and developmental toxicity studies available for diantimony trioxide are inhalation exposure studies. Even though the inhalation exposure studies reveal effects, they are not considered relevant for use in the assessment of secondary poisoning since this route refers to long-term dietary exposure via fish consumption. In the study performed with oral exposure of male rats and mice, no testicular toxicity was seen after repeated doses up to 1200 mg/ kg bw.

Though the effects on liver seen in the two repeated dose oral studies are not relevant on a population level, the lowest endpoint (a NOAEL of 1686 mg/kg bw/day for female rats from a 90 d repeated dose study) is used for the

derivation of a $PNEC_{oral}$ for secondary poisoning because this is the only available oral exposure study.
Using the conversion factor of 20 (rats >6 weeks) for the conversion of the NOAEL into a NOEC and an assessment factor of 90 as suggested in the WFD-guidance, the $MPC_{oral,\ min}$ is 374.8 mg Sb/kg food. This value is also used in the EU-RAR as $PNEC_{sec\ poisoning}$ for the assessment of secondary poisoning in the marine environment (European Commission, 2008). Based on the $MPC_{oral,\ min}$ and a BAF of 65 L/kg, the $MPC_{sp,\ water}$ becomes 5.8 mg Sb/L. Since background exposure is part of the BAF, this value refers to a MPC, including background concentrations.

4.1.4.3 Human fish consumption - $MPC_{hh\ food,\ water}$

Since diantimony trioxide is classified as 'possibly carcinogenic to humans (Group 2B)' by IARC (1991), a MPA for human fish consumption is derived. Using the TDI of 6 µg/kg_{bw}/day (section 3.1.5) as human toxicological threshold value (TL_{hh}) and a BAF of 65 L/kg, the $MPC_{hh\ food,\ water}$ becomes 5.6×10^{-3} mg Sb/L. Since background exposure is part of the BAF, this value refers to a MPC, including background concentrations.

4.1.4.4 Selection of the MPC_{water}

The following MPC-values were derived for antimony:

$MPC_{eco,\ water}$	0.1 mg Sb/L
$MPC_{sp,\ water}$	5.8 mg Sb/L
$MPC_{hh\ food,\ water}$	5.6×10^{-3} mg Sb/L

The lowest of these values is selected and the MPC_{water} is 5.6×10^{-3} mg Sb/L. This value refers to dissolved concentrations.

Since the log $K_{p\ susp\text{-}water}$ of antimony is > 3, the MPC_{water} has to be reported as the $MPC_{water,\ total}$. Based on calculations presented in Annex I, the $MPC_{water,\ total}$ becomes 1.2×10^{-2} mg Sb/L.

4.1.5 *Derivation of NC_{water}*

The negligible concentration (NC) for antimony is calculated by dividing the MPC by a factor of 100, and becomes 5.6×10^{-3} / 100) = 5.6×10^{-5} mg Sb/L = 0.056 µg Sb/L.
Since the log $K_{p\ susp\text{-}water}$ of antimony is > 3, the NC_{water} has to be reported as the $NC_{water,\ total}$. Based on calculations presented in Annex I, the $NC_{water,\ total}$ becomes 2.2×10^{-4} mg Sb/L.

4.1.6 *Derivation of $MPC_{dw,\ water}$*

No A1 value or DW standard is available for antimony. With the TDI of 6 µg/kg_{bw}/day, an $MPC_{dw,\ water,\ provisional}$ can be calculated with the following formula:

$$MPC_{dw,\ water,\ provisional} = 0.1 \times TL_{hh} \times BW / uptake_{dw}$$

In this formula the TL_{hh} is the TDI, BW is a body weight of 70 kg, and $uptake_{dw}$ is a daily water uptake of 2 L. As described in section 2.2.2, water treatment is currently not taken into account. Therefore the $MPC_{dw,\ water}$ = The $MPC_{dw,\ water,\ provisional}$ and becomes: 0.1 x 0.006 x 70 / 2 = 2.1×10^{-2} mg Sb/L.

4.1.7 Derivation of MAC$_{eco, water}$

4.1.7.1 Derivation of MAC$_{eco, water}$ using assessment factors

The most sensitive species reported is the green hydra *Chlorohydra viridissima* with an LC$_{50}$ of 1.77 mg Sb/L. Using an assessment factor of 100, the MAA$_{eco, water}$ becomes 1.8 x 10^{-2} mg Sb/L. Following the added risk approach, the MAC$_{eco, water}$ becomes 1.8 x 10^{-2} mg Sb/L + 2.9 x 10^{-4} mg Sb/L = 1.8 x 10^{-2} mg Sb/L.

4.1.7.2 Derivation of MAC$_{eco, water}$ using species sensitivity distribution (SSD).

Acute toxicity data are available for 15 species from nine taxonomic groups. Therefore, an SSD can be performed for antimony. Part of the data are unbound values (≥ highest concentration tested), causing difficulties in performing an SSD.

One way of solving the fitting problem, closest to parametric estimation for SSDs, and extrapolation based on it, is presented in the monograph of D.R. Helsel (2005): Nondetects and Data Analysis (Wiley).

In problems *without* nondetects, the likelihood of the parameters (say mu and sigma of a Normal distribution), is given by the product of PDF density values at each of the data points:

$$L(\mu,\sigma) = \prod_{i=1}^{n} PDF(x_i) = \varphi_{\mu,\sigma}(x_i)$$

with the Normal (Gaussian) densitiy function (PDF) evaluated at the i-th data point:

$$\varphi_{\mu,\sigma}(x_i)$$

The maximum likelihood estimate (MLE) of the parameters is the combination of parameter values that maximizes L.

For the Normal distribution it is well-known that the MLE can be easily calculated by the mean and standard deviation (n-based) of the data.

When there are non-detects, the likelihood is split into three parts, for smaller-thans, non-range data, and greater-thans:

$$L^*(\mu,\sigma) = \prod_{h=1}^{n_<} \phi_{\mu,\sigma}(x_h) \prod_{i=1}^{n_=} \varphi_{\mu,\sigma}(x_i) \prod_{j=1}^{n_>} \left[1 - \phi_{\mu,\sigma}(x_j)\right]$$

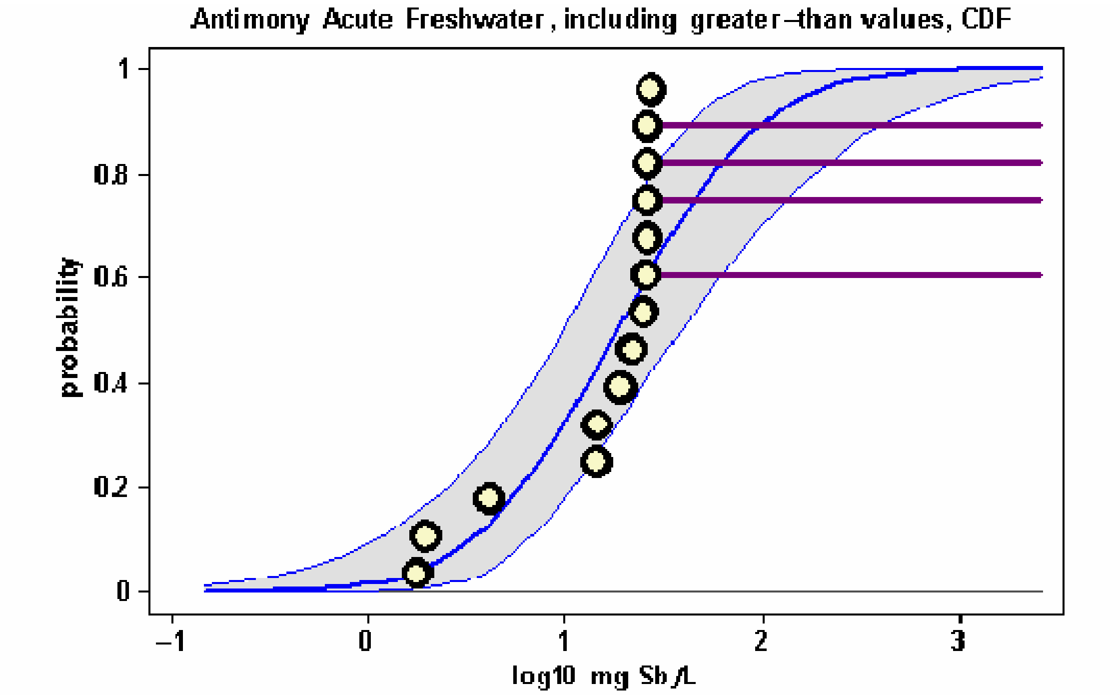
Here, the Normal cumulative distribution function (CDF), for the smaller-thans, is

$$\phi_{\mu,\sigma}(x_h)$$

and

1-$\phi_{\mu,\sigma}(x_j)$

is the complementary CDF (= CCDF) for the greater-thans.



This methodology results in a HC_5 of 2.02 mg Sb/L (95% confidence intervals 0.53, 4.39 mg Sb/L). When the SSD was performed without unbound values, the HC_5 would have been 1.72 mg Sb/L.
In order to extrapolate from the 50% effect level (L(E)C50 values) to the no-effect level and to account for the other uncertainties (as is done by using the AF 1-5 on the chronic HC_5), an assessment factor of 10 is used on the HC_5 for the derivation of the $MAA_{eco,\ water}$. Thus, the $MAA_{eco,\ water}$ is 0.2 mg Sb/L.
Following the added risk approach, the $MAC_{eco,\ water}$ becomes 0.2 mg Sb/L + 2.9 x 10^{-4} mg Sb/L = 0.2 mg Sb/L.

4.1.7.3 Selection of the $MAC_{eco,\ water}$

The MAC value based on the SSD is selected as the $MAC_{eco,\ water}$. Thus, the $MAC_{eco,\ water}$ is 0.2 mg Sb/L.
Since the log $K_{p\ susp\text{-}water}$ of antimony is > 3, the $MAC_{eco\ water}$ has to be reported as the $MAC_{eco\ water,\ total}$. Based on calculations presented in Annex I, the $MAC_{eco\ water,\ total}$ becomes 4.3 x 10^{-1} mg Sb/L.

4.1.8 Derivation of $SRC_{eco,\ water}$

The base-set (acute toxicity data for algae, *Daphnia* and fish) is complete. Chronic NOEC values are available for five species from five taxonomic groups. Therefore, the $SRA_{eco,\ water}$ is calculated as geometric mean of all available NOEC values, and the $SRA_{eco,\ water}$ becomes 9.6 mg Sb/L. The $SRC_{eco,\ water}$ is calculated by the $SRA_{eco,\ water}$ plus the background concentration. The $SRC_{eco,\ water}$ becomes 9.6 mg Sb/L + 2.9 x 10^{-4} mg Sb/L = 9.6 mg Sb/L.
Since the log $K_{p\ susp\text{-}water}$ of antimony is > 3, the $SRC_{eco\ water}$ has to be reported as the $SRC_{eco\ water,\ total}$. Based on calculations presented in Annex I, the $SRC_{eco\ water,\ total}$ becomes 2.1 x 10^{1} mg Sb/L.

4.2 Toxicity data and derivation of ERLs for sediment

4.2.1 Sediment toxicity data

An overview of the selected freshwater sediment toxicity data for antimony as reported in the RAR is given in Table 9. These data are also included in the REACH dossier (ECHA, 2011). No marine sediment toxicity data were available. Based on the characteristics of the substance, normalisation for binding to organic matter is not applicable.

Table 9. Antimony: selected freshwater sediment toxicity data for ERL derivation.

Chronic Taxonomic group	**Valency**	**NOEC/EC10 (mg Sb/kg$_{dwt}$)**	**Acute Taxonomic group**	**L(E)C50 (mg Sb/kg$_{dwt}$)**
Crustacea				
Hyalella azteca	III	124		
Insecta				
Chironomus riparius	III	≥ 636		
Oligochaeta				
Lumbriculus variegatus	III	112[a]		

a Endpoint growth

4.2.2 Derivation of MPC$_{sediment}$

Data from three chronic tests are available. Therefore, the MPA$_{sediment}$ is derived using an assessment factor of 10 on the lowest NOEC value (112 mg Sb/kg$_{dwt}$ for *Lumbriculus variegatus*). Thus, the MPA$_{sediment}$ becomes 11 mg Sb/kg$_{dwt}$. According to the added risk approach, the MPC$_{sediment}$ is calculated by adding the background concentration (3 mg/kg; Van Vlaardingen and Verbruggen, 2009). Therefore, the MPC$_{sediment}$ becomes 14 mg Sb/kg$_{dwt}$.
When the MPC$_{sediment}$ is calculated from the MPA$_{eco, water}$ using the equilibrium partitioning method (EqP) , it becomes 22 mg Sb/kg$_{dwt}$. This value is comparable to the MPC$_{sediment}$ of 14 mg Sb/kg$_{dwt}$ based on experimental studies, with sediment organisms and preference is given to this value.

4.2.3 Derivation of NC$_{sediment}$

The negligible concentration for antimony was calculated by dividing the MPA by a factor 100 plus the background concentration.
The NC$_{sediment}$ becomes (11 mg Sb/kg$_{dwt}$ / 100) + 3 mg Sb/kg$_{dwt}$ = 3.1 mg Sb/kg$_{dwt}$.

4.2.4 Derivation of SRC$_{eco, sediment}$

Data from three chronic tests are available. Therefore, the SRA$_{eco, sediment}$ is calculated as the geometric mean of the NOEC values, and the SRA$_{eco, sediment}$ is 1.1×10^2 mg Sb/kg$_{dwt}$.
The SRC$_{eco, sediment}$ is calculated by the SRA$_{eco, sediment}$ plus the background concentration and becomes 1.1×10^2 mg Sb/kg$_{dwt}$.

4.3 Toxicity data and derivation of ERLs for soil

4.3.1 Soil toxicity data

An overview of the selected soil toxicity data for antimony is given in Table 10. These endpoints are also included in the REACH dossier (ECHA, 2011). Based on the characteristics of the substance, normalisation for binding to organic matter is not applicable.

Table 10. Antimony: selected soil toxicity data for ERL derivation.

Chronic		**Acute**	
Taxonomic group	**NOEC/EC10 (mg Sb/kg$_{dwt}$)**	**Taxonomic group**	**L(E)C50 (mg Sb/kg$_{dwt}$)**
Bacteria			
Native micro-organisms[a]	2930		
Macrophyta			
Hordeum vulgare	999		
Insecta			
Folsomia candida	999		

a nitrification

4.3.2 Derivation of MPC$_{soil}$

4.3.2.1 Direct ecotoxicity - MPC$_{eco, soil}$

Data from three chronic tests are available. Therefore, the MPA$_{soil}$ is calculated using an assessment factor of 10 on the lowest NOEC value, resulting in an MPA$_{soil}$ of 1.0 x 10^2 mg Sb/kg$_{dwt}$. The MPC$_{soil}$ is calculated by adding the background concentration of 3.0 mg Sb/kg$_{dwt}$ and becomes 1.0 x 10^2 mg Sb/kg$_{dwt}$.

4.3.2.2 Secondary poisoning - MPC$_{sp, soil}$

In the RAR, a BSAF value of 1 kg/kg$_{dwt}$ is reported for earthworms. Using the dry to fresh weight ratio of 0.16 kg/kg Jager, 1998, the bioaccumulation value was converted to a BSAF$_{earthworm}$ of 0.16 kg/kg$_{ww}$. Based on this value and the MPC$_{oral}$ of 374.8 mg Sb/kg food, the MPC$_{sp, soil}$ is calculated. The MPC$_{sp, soil}$ is 1.6 x 10^3 mg Sb/kg$_{dwt}$.

4.3.2.3 Human consumption of vegetables, meat and milk - MPC$_{human, soil}$

The formulas to derive an MPC$_{human, soil}$ are all log K$_{ow}$-driven. Since a log K$_{ow}$ is not relevant to antimony, the MPC$_{human, soil}$ cannot be derived.

4.3.2.4 Selection of the MPC$_{soil}$

The lowest value is selected as the MPC$_{soil}$. The MPC$_{soil}$ is 1.0 x 10^2 mg Sb/kg$_{dwt}$.

4.3.3 Derivation of NC$_{soil}$

The negligible concentration (NC) for antimony based on direct ecotoxicity is calculated by dividing the MPA$_{eco, soil}$ by a factor of 100, and adding the background concentration. The NC$_{eco, soil}$ becomes (1.0 x 10^2 mg Sb/kg$_{dwt}$ / 100) + 3.0 mg Sb/kg$_{dwt}$ = 4.0 mg Sb/kg$_{dwt}$. The NC$_{sp, soil}$ is 1.6 x 10^3 mg Sb/kg$_{dwt}$ / 100 =
16 mg Sb/kg$_{dwt}$. The lowest of these is selected as the final NC$_{soil}$. The NC$_{soil}$ is 4.0 mg Sb/kg$_{dwt}$.

4.3.4 *Derivation of $SRC_{eco, soil}$*

Data from three chronic tests are available. Therefore, the $SRA_{eco, soil}$ is based on the geometric mean of the NOEC values. Thus, the $SRA_{eco, soil}$ is 1.4 x 10^3 mg Sb/kg $_{dwt}$. The $SRC_{eco, soil}$ is calculated by the $SRA_{eco, sediment}$ plus the background concentration and becomes 1.4 x 10^3 mg Sb/kg_{dwt}.

4.4 Derivation of ERLs for groundwater

4.4.1 *Derivation of MPC_{gw}*

4.4.1.1 Direct ecotoxicity - $MPC_{eco, gw}$

Since groundwater-specific ecotoxicity data are absent, the surface water $MPA_{eco, water}$ of 0.1 mg Sb/L is taken as a substitute for the $MPA_{eco, gw}$. The $MPC_{eco, gw}$ is derived by adding the background concentration (9.1 x 10^{-5} mg Sb/L) to the $MPA_{eco, gw}$. The $MPC_{eco, gw}$ is 0.1 mg Sb/L.

4.4.1.2 Groundwater used for drinking water - $MPC_{human, gw}$

The $MPC_{human, gw}$ is set equal to the $MPC_{dw, water}$. Therefore, the $MPC_{human, gw}$ is 2.1 x 10^{-2} mg Sb/L.

4.4.1.3 Selection of the MPC_{gw}

The lowest MPC for groundwater is the $MPC_{human, gw}$. Therefore, the MPC_{gw} is 2.1 x 10^{-2} mg Sb/L.

4.4.2 *Derivation of NC_{gw}*

The negligible concentration (NC) for antimony for direct ecotoxicity is calculated by dividing the $MPA_{eco, gw}$ by a factor of 100, and adding the background concentration. The $NC_{eco, gw}$ becomes (21 x 10^{-3} mg Sb/L / 100) + 9.1 x 10^{-5} mg Sb/L = 3.0 x 10^{-4} mg Sb/L. The $NC_{human, gw}$ is 21 x 10^{-3} mg Sb/L / 100 = 2.1 mg Sb/L. The lowest of these is selected as the final NC_{gw}. The NC_{gw} is 3.0 x 10^{-4} mg Sb/L = 0.3 µg Sb/L.

4.4.3 *Derivation of $SRC_{eco, gw}$*

The $SRA_{eco, gw}$ is set equal to the $SRA_{eco, water}$ of 9.6 mg Sb/L. The $SRC_{eco, gw}$ is calculated by the $SRA_{eco, gw}$ plus the background concentration.
The $SRC_{eco, gw}$ becomes 9.6 mg Sb/L + 9.1 x 10^{-5} mg Sb/L = 9.6 mg Sb/L.

4.5 Derivation of ERLs for air

No data are available on atmospheric toxicity of antimony. Therefore, no ERLs for air can be derived. In the EU-RAR is stated that "Neither biotic nor abiotic effects are considered likely due to the atmospheric release of antimony resulting from production and use of products containing diantimony trioxide, nor are any effects considered likely due to releases of antimony from unintentional sources."

4.6 Comparison of derived ERLs for water with monitoring data

The RIWA (Dutch Association of River Water companies) reports monitoring data for antimony. The Dutch Ministry of Transport, Public Works and Water Management presents monitoring data for antimony on their website (www.waterbase.nl). Concentrations measured in the period 2005-2009 in the Netherlands ranged from < 0.5 µg/L to 13.2 µg/L (n = 1881). Only the highest measured concentration exceeds the MPC_{water} for antimony. Therefore, it can be concluded that the new MPCs for antimony in water will only seldom be exceeded in the Netherlands.

5 Conclusions

In this report, the risk limits Negligible Concentration (NC), Maximum Permissible Concentration (MPC), Maximum Acceptable Concentration for ecosystems (MAC_{eco}), and Serious Risk Concentration for ecosystems (SRC_{eco}) are derived for antimony in water, groundwater, sediment and soil.

The ERLs that were obtained are summarised in the table below.

Table 11. Derived MPC, NC, MAC_{eco}, and SRC_{eco} values for antimony.

ERL	**unit**	**value**			
		MPC	NC	MAC_{eco}	SRC_{eco}
water [a]	$mg.L^{-1}$	5.6×10^{-3}	5.6×10^{-5}	0.2	9.6
drinking water [b]	$mg.L^{-1}$	2.1×10^{-2}	n.d.	n.d.	n.d.
marine	$mg.L^{-1}$	n.d.	n.d.	n.d.	n.d.
sediment	$mg.kg_{dwt}^{-1}$	14	3.1	n.d.	1.1×10^{2}
soil [c]	$mg.kg_{dwt}^{-1}$	1.0×10^{2}	4.0	n.d.	1.4×10^{3}
groundwater	$mg.L^{-1}$	2.1×10^{-2}	3.0×10^{-4}	n.d.	9.6
air	$mg.m^{-3}$	n.d.	n.d.	n.d.	n.d.

All values are based on dissolved concentrations.

a From the MPCeco, water, MPCsp, water and MPChf food, water the lowest one is selected as the ‘overall’ MPCwater.

b The MPCdw, water is presented as a separate value in this report.

c Expressed on the basis of Dutch standard soil.

n.d. = not derived.

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List of abbreviations

BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
EC_x	Concentration at which x% effect is observed
ERL	Environmental Risk Limit
EU	European Union
INS	International and National Environmental Quality Standards for Substances in the Netherlands
MAC_{eco}	Maximum Acceptable Concentration for ecosystems
$MAC_{eco,\ water}$	Maximum Acceptable Concentration for ecosystems in freshwater
$MAC_{eco,\ marine}$	Maximum Acceptable Concentration for ecosystems in the marine compartment
MPC	Maximum Permissible Concentration
MPC_{water}	Maximum Permissible Concentration in freshwater
MPC_{marine}	Maximum Permissible Concentration in the marine compartment
$MPC_{eco,\ water}$	Maximum Permissible Concentration in freshwater based on ecotoxicological data
$MPC_{eco,\ marine}$	Maximum Permissible Concentration in the marine compartment based on ecotoxicological data
$MPC_{sp,\ water}$	Maximum Permissible Concentration in freshwater based on secondary poisoning
$MPC_{sp,\ marine}$	Maximum Permissible Concentration in the marine compartment based on secondary poisoning
$MPC_{hhfood,\ water}$	Maximum Permissible Concentration in freshwater based on consumption of fish and shellfish by humans
$MPC_{hhfood,\ marine}$	Maximum Permissible Concentration in the marine compartment based on consumption of fish and shellfish by humans
$MPC_{dw,\ water}$	Maximum Permissible Concentration in freshwater based on abstraction of drinking water
NC	Negligible Concentration
NC_{water}	Negligible Concentration in freshwater
NC_{marine}	Negligible Concentration in the marine compartment
NOEC	No Observed Effect Concentration

Annex I Calculations

Conversion of $\mathbf{MPC_{water}}$ to $\mathbf{MPC_{water,\ total}}$

The MPC_{water} is converted to $MPC_{water,\ total}$ using the following equations:

$MPC_{water,\ total} = MPC_{water} \times (1 + K_{p,\ susp\text{-}water} \times 10^{-6} \times C_{susp,\ Dutch\ standard})$
$MPC_{water,\ total} = 5.6 \times 10^{-3}$ mg Sb/L x (1 + ($10^{\wedge 3.59}$) x 10^{-6} x 30) =
1.2×10^{-2} mg Sb/L

Conversion of $\mathbf{NC_{water}}$ to $\mathbf{NC_{water,\ total}}$

The NC_{water} is converted to $NC_{water,\ total}$ using the following equations:

$NC_{water,\ total} = NC_{water} \times (1 + K_{p,\ susp\text{-}water} \times 10^{-6} \times C_{susp,\ Dutch\ standard})$
$NC_{water,\ total} = 5.6 \times 10^{-5}$ mg Sb/L x (1 + ($10^{\wedge 3.59}$) x 10^{-6} x 30) =
1.2×10^{-4} mg Sb/L

Conversion of $\mathbf{NC_{water}}$ to $\mathbf{NC_{water,\ total}}$

The NC_{water} is converted to $NC_{water,\ total}$ using the following equations:

$NC_{water,\ total} = NC_{water} \times (1 + K_{p,\ susp\text{-}water} \times 10^{-6} \times C_{susp,\ Dutch\ standard})$
$NC_{water,\ total} = 5.6 \times 10^{-5}$ mg Sb/L x (1 + ($10^{\wedge 3.59}$) x 10^{-6} x 30) =
1.2×10^{-4} mg Sb/L

Conversion of $\mathbf{MAC_{eco,\ water}}$ to $\mathbf{MAC_{eco,\ water,\ total}}$

The $MAC_{eco,\ water}$ is converted to $MAC_{eco,\ water,\ total}$ using the following equations:

$MAC_{eco,\ water,\ total} = MAC_{water} \times (1 + K_{p,\ susp\text{-}water} \times 10^{-6} \times C_{susp,\ Dutch\ standard})$
$MPA_{water,\ total} = 0.2$ mg Sb/L x (1 + ($10^{\wedge 3.59}$) x 10^{-6} x 30) =
4.3×10^{-1} mg Sb/L

The background concentration is converted via the same formula:

$C_{b,\ water\ total} = C_b \times (1 + K_{p,\ susp\text{-}water} \times 10^{-6} \times C_{susp,\ Dutch\ standard})$
$C_{b,\ water\ total} = 2.9 \times 10^{-4}$ mg Sb/L x (1 + ($10^{\wedge 3.59}$) x 10^{-6} x 30) =
6.3×10^{-4} mg Sb/L

The $MAC_{eco,\ water,\ total}$ becomes 4.3×10^{-1} mg Sb/L + 6.3×10^{-4} mg Sb/L =
4.3×10^{-1} mg Sb/L.

Conversion of $\mathrm{SRC}_{\mathrm{eco,\ water}}$ to $\mathrm{SRC}_{\mathrm{eco,\ water,\ total}}$

The $\mathrm{SRC}_{\mathrm{eco,\ water}}$ is converted to $\mathrm{SRC}_{\mathrm{eco,\ water,\ total}}$ using the following equations:

$\mathrm{SRC}_{\mathrm{eco,\ water,\ total}} = \mathrm{SRC}_{\mathrm{water}} \times (1 + K_{\mathrm{p,\ susp\text{-}water}} \times 10^{-6} \times C_{\mathrm{susp,\ Dutch\ standard}})$
$\mathrm{SRC}_{\mathrm{water,\ total}} = 9.6$ mg Sb/L $\times (1 + (10^{\wedge 3.59}) \times 10^{-6} \times 30) =$
2.1×10^{1} mg Sb/L

The background concentration is converted via the same formula:

$C_{\mathrm{b,\ water\ total}} = C_{\mathrm{b}} \times (1 + K_{\mathrm{p,\ susp\text{-}water}} \times 10^{-6} \times C_{\mathrm{susp,\ Dutch\ standard}})$
$C_{\mathrm{b,\ water\ total}} = 2.9 \times 10^{-4}$ mg Sb/L $\times (1 + (10^{\wedge 3.59}) \times 10^{-6} \times 30) =$
6.3×10^{-4} mg Sb/L

The $\mathrm{SRC}_{\mathrm{eco,\ water,\ total}}$ becomes 2.1×10^{1} mg Sb/L + 6.3×10^{-4} mg Sb/L =
2.1×10^{1} mg Sb/L.

Dit is een uitgave van:

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