

Protection of the drinking water function of surface waters under the EU Water Framework Directive

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Summary

Background

The general objective of the European Water Framework Directive (WFD) is to achieve a good ecological status (or good ecological potential) and a good chemical status of surface waters and ground water. Another objective is to lower the purification level used for drinking water production on the long term. Surface water destined for drinking water production must be of such a quality that simple purification can produce safe drinking water. However, a good ecological status does not ensure that simple purification will produce 100% reliable drinking water from surface water. Surface water as a source for drinking water is assigned different requirements to than surface water as ecosystem carrier. These different requirements mean that quality standards related to drinking water production can be stronger or weaker than the standards that would be set on surface water quality from an ecological viewpoint.

Simple purification

The Dutch water supply companies define 'simple purification' of surface water as follows: simple physical processing (coagulation, aeration, rapid filtration) and disinfection (using chlorine, ozone or UV). Application of active carbon, membrane filtration, etc., do not fall within this definition. In the current report the performance of a simple purification procedure was studied for 100 compounds: the 33 priority compounds specified in the WFD and 67 other compounds for which the current ecological standards in The Netherlands (maximum allowable risk, called MTR in this report) are less strict than those for drinking water (as defined in the Dutch Water Supply Act). We determined whether the ecological standards for these compounds in surface water provide adequate protection for drinking water production, taking a simple purification procedure into account.

The performance of a simple purification procedure for heavy metals was determined on the basis of data from purification station Cornelis Biemond in Nieuwegein (coagulation, precipitation and rapid filtration). The purification performance for organic micro-pollutants was theoretically estimated on the basis of compound properties (Koc and Henry constant), from which the degree of adsorption and volatilization in a simple purification process were estimated. This approach was validated with groundwater purification data.

Potential problem compounds

The desired standards for surface water as a source of drinking water were derived by combining the performance of a simple purification procedure with current drinking water standards (EU Guideline 98/83, Water Supply Act). This was done for all of the 100 compounds in this study. The derived standards were compared with the concept 'guidance values' for priority compounds in water bodies with drinking water abstraction (DWA), and with the MTR values for non-priority compounds. In this way a picture is obtained of compounds that pose a *potential* threat to the preparation of

drinking water from surface water, when it would be purified by simple techniques only. For the priority compounds of the WFD, it appears that the concept 'guidance values' for water bodies with drinking water abstraction offer adequate protection to the drinking water function (including a simple purification procedure), except for dichloromethane and trichloromethane. Moreover, DWA standards for trichlorobenzene and hexachlorobutadiene have not been defined yet. The MTR provides insufficient protection for the drinking water function, taking a simple purification procedure into account, for about 60 compounds (out of the 67 tested).

Current problem compounds

By checking the current water quality for a number of intake points in the Rhine and Meuse rivers against the derived standards for protection of the drinking water function (after simple purification) a picture was obtained of compounds that form a current threat to the preparation of drinking water from surface water when this would be purified by simple techniques. It appears that in the river Meuse a number of pesticides, some poly-aromatic hydrocarbons (PAHs) and fluoride exceed the derived surface water standards. Diuron exceeds the standard by the greatest amount (up to five times the derived surface water standard). In the River Rhine, crossing of the derived surface water standards was occasionally observed for a few PAHs, pesticides and chloride. The largest excess was observed for isoproturon (five times the derived surface water standard in Nieuwegein, 2002).

Overall, the picture emerges that the number of *current* problem compounds (ca. 15) is far less than the number of *potential* problem compounds (ca. 65).

Recommendations

In order to ensure that the protection level desired by the drinking water sector is complied with it is recommended that the concept 'guidance values' under the WFD are made stricter for dichloromethane (from 20 to 2 µg/l) and trichloromethane (from 100 to 50 µg/l) for water bodies with a drinking water function. We also recommend the inclusion of the thus-far missing 'guidance values' for trichlorobenzene (1.5 µg/l) and hexachlorobutadiene (0.15 µg/l) for water bodies with a drinking water function. In addition it is important to notify the Ministry of Transport, Public Works and Water Management that realization of the MTR for non-priority compounds takes insufficient account of the drinking water function of the rivers Rhine and Meuse.

During our assessment of current surface water quality in The Netherlands it became apparent that the number of measurements in general is too limited to allow a definitive statement to be made regarding problem compounds. It is imperative that more frequent measurements are made at the existing measuring points in order to achieve an adequate analysis of the problem. This is especially important for compounds for which ecological standards offer too little protection for the interests of the drinking water sector.

Finally we recommend that the performance of other simple purification procedures, such as river bank infiltration, is examined.

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1 Introduction

1.1 Reason for this study

The general objective of the European Water Framework Directive (WFD) is to achieve a good ecological status (or good ecological potential) and a good chemical status of surface waters and ground water. Surface water destined for drinking water supply must be of such quality that safe drinking water can be provided via a simple purification procedure. The WFD requires that member states establish a register of protected areas (article 6). This register should contain details of all bodies of water that are used for extraction of water destined for human consumption that provide more than 10 m³ per day or that supply more than 50 persons, as well as those bodies of water intended to be used for this purpose in the future (article 7 of the WFD).

The current Dutch system of allocating a drinking water function to surface water with setting of appropriate standards will be replaced by the WFD requirements. Considering the obligatory character of the WFD objectives, the competent authorities are inclined to limit the size of the protected areas. The Netherlands Ministry of Transport, Public Works and Water Management is presently performing a study that should lead to advice on which bodies of surface water can be used for the supply of drinking water.

The protected areas should offer adequate guarantees to the water supply companies regarding their desired level of protection of surface water as a source of drinking water. It is VEWIN's opinion that the sector must develop its own vision on the protection of surface water used for drinking water supply. A discussion on this point took place between VEWIN, RIWA and Kiwa on 18 June 2004. Among other points, it was established that a good ecological status does not always ensure that 100% reliable drinking water can be supplied from surface water via a *simple purification procedure*. Different requirements are put on surface water that serves as a source for drinking water than on surface water that acts as a carrier for an ecosystem. These different requirements imply that quality standards protecting the drinking water function can either be stronger or weaker than the standards that are set for surface water quality from an ecological viewpoint.

During the discussion on 18 June, VEWIN/RIWA asked Kiwa to 'translate' the current drinking water standards (EU guideline 98/83, Water Supply Act) into standards for surface water, taking a simple purification procedure into account. This would result in surface water standards that would be needed from the viewpoint of drinking water production under the WFD. Moreover, these standards can be compared to existing ecological standards for priority and non-priority compounds. An examination of current water quality data was also requested, in order to provide insight into the nature and magnitude of the bottlenecks.

1.2 Objective of project

The general objective of the project is to establish water quality standards for surface water protection from the viewpoint of drinking water supply, taking a simple purification procedure into account. One of the objectives derived from this is to sketch a picture of which compounds form a potential and a current threat to the preparation of drinking water from surface water, when it would be purified using simple techniques (as envisaged by the WFD).

In order to realize this objective, the following steps were taken:

- Establishing an operational definition of the term 'simple purification of surface water';
- Composing a list of compounds that are relevant for drinking water production from surface water;
- Deriving purification performance values for a simple purification procedure for the compounds relevant to drinking water production;
- Deriving standards for surface water quality based on the EU standards for drinking water (98/83) and the performance of a simple purification procedure;
- Listing the *potential problem compounds*, i.e., compounds for which the WFD standards (priority compounds) or current Dutch water policy (other compounds) provide insufficient protection for the drinking water function;
- Listing the *current problem compounds* by comparison of the current water quality at a number of extraction points with the derived surface water standards (EU guideline 98/83 + simple purification).

1.3 How this report is set-up

A definition of the term 'simple purification' from the viewpoint of the Dutch water companies is given in chapter 2. At the same time a description is given of the current purification procedures of Dutch water companies which treat surface water. A selection is made of compounds that can form a risk for the drinking water sector based on current EU and national standards for surface and drinking water. Then the performance of a simple purification procedure is determined for the selected compounds, based on field data and theoretical considerations. The desired surface water standards protecting the drinking water function are derived by combining current drinking water standards and the performance of simple purification. The derived standards for surface water are compared with WFD standards (priority compounds) and current Dutch ecological standards (non-priority compounds) in chapter 3. This gives a picture of the compounds for which WFD standards and/or current Dutch water policy provide insufficient protection for the drinking water function. In chapter 4, a comparison is made between the current surface water quality in The Netherlands at a number of extraction points and the derived surface water standards, in order to gain a picture of compounds that already form a problem for drinking water supply from surface water in the Netherlands. Chapter 5 shows our conclusions and recommendations.

2 Simple purification of surface water

2.1 Definition of 'simple purification'

The WFD contains two articles that refer directly to the drinking water function of surface water (see Table 1). Article 7 of the WFD is meant to lower the level of purification required for the production of drinking water. In the long term a simple purification procedure should be sufficient to produce drinking water from surface water. This implies that surface water which is used for drinking water supply must eventually comply with the standards for drinking water quality (98/83/EG), taking into account the purification performance of the 'simple purification' procedure.

Table 1: Articles 6 and 7 WFD

Article 6 - Register of protected areas

1. Member States shall ensure the establishment of a register or registers of all areas lying within each river basin district which have been designated as requiring special protection under specific Community legislation for the protection of their surface water and groundwater or for the conservation of habitats and species directly depending on water. They shall ensure that the register is completed at the latest four years after the date of entry into force of this Directive.
2. The register or registers shall include all bodies of water identified under Article 7(1) and all protected areas covered by Annex IV.
3. For each river basin district, the register or registers of protected areas shall be kept under review and up to date.

Article 7 - Waters used for the abstraction of drinking water

1. Member States shall identify, within each river basin district:

- all bodies of water used for the abstraction of water intended for human consumption providing more than 10 m³ a day as an average or serving more than 50 persons, and
- those bodies of water intended for such future use.

Member States shall monitor, in accordance with Annex V, those bodies of water which according to Annex V, provide more than 100 m³ a day as an average.

2. For each body of water identified under paragraph 1, in addition to meeting the objectives of Article 4 in accordance with the requirements of this Directive, for surface water bodies including the quality standards established at Community level under Article 16, Member States shall ensure that under the water treatment regime applied, and in accordance with Community legislation, the resulting water will meet the requirements of Directive 80/778/EEC as amended by Directive 98/83/EC.
3. Member States shall ensure the necessary protection for the bodies of water identified with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water. Member States may establish safeguard zones for those bodies of water.

What exactly is understood by the term 'simple purification' is still under discussion. It is expected that the European Commission will propose one performance value for each compound that will apply to all member states. A study by EUREAU on purification performances of various member states indicated in general that the performance both nationally and internationally can differ considerably.

According to EUREAU, coagulation together with sand filtration is the only possible definition of 'simple purification' because it is the most commonly used treatment method that is also adequate for producing drinking water. The Dutch water companies define 'simple purification' as¹: simple physical treatment (coagulation, aeration, rapid filtration) and disinfection (using chlorine, ozone or UV). Application of active carbon, membrane filtration, etc., expressly fall outside simple purification and will therefore not be considered in this report in the determination of purification performance.

2.2 Purification of surface water in the Netherlands

Table 2 shows the purification techniques that are currently used by water companies in the Netherlands for surface water. These applied purification procedures for surface water are not exactly 'simple'. This is logical as, after all, the current quality of the surface water means that substantial purification is required. However, the *pre-purification* of surface water can in fact be seen as simple. Examples of pre-purification are the use of storage reservoirs in the Brabant Biesbosch (Evides) and Heel (WML), dosing of iron chloride in an enclosed side branch of the river Meuse (DZH) and the production of b-water (process water for industrial purposes) in Nieuwegein (WLBA), where Rhine water is treated using coagulation, precipitation and rapid filtration. These pre-treatments conform to the EUREAU definition of simple purification.

Groundwater is also usually purified using coagulation and rapid filtration, however this also requires a separate aeration step. Use will therefore also be made of data from groundwater purification for the analysis of purification performance in section 2.4.

¹ A comparable definition is also contained in Guideline 75/440/EEG.

Table 2: Purification techniques of Dutch water companies which treat surface water.

Water company	Location	Purification
Waterbedrijf Groningen	De Punt	Basins - flocculation - ACF - aeration - RF - SSF
Vitens	Elsbeekweg	Coagulation - flotation
	Weerseloseweg	ACF - SSF - UV + 2-times aeration - RF - ACF - SSF - UV
PWN	Andijk	Micro sieves - break point chlorination - coagulation - RF - ACF - ClO ₂
	Bergen	Infiltration - aeration - RF
	Mensink	Infiltration - cascade aeration - WS - RF - ClO ₂
	Heemskerk	Ultra filtration - RO
WLB Amsterdam	Leiduin	Flocculation - sedimentation - dune infiltration - ozone - WS - RF - ACF - SSF
	Weesperkarspel	Basins - flocculation - sedimentation - RF - ozone - WS - ACF - SSF
DZH	Katwijk	Flocculation - micro sieves - RF - infiltration - WS (pellets) - ACF - aeration - RF - SSF
	Scheveningen	Flocculation - micro sieves - RF - infiltration - ACF - WS (pellets) - aeration - RF - SSF
	Monster	Flocculation - micro sieves - RF - infiltration - aeration - RF - ACF - SSF
Evides	Kralingen	Basins - flocculation - sedimentation - RF - ozone - ACF - HOCl
	Berenplaat	Basins - flocculation - HOCl - sedimentation - ACF - HOCl
	Ouddorp	Infiltration - tower aeration - RF - ACF - ultra filtration
	Baanhoek	Tower aeration - RF - WS (pellets) + basins - flocculation - RF - RF - ozone - ACF - NaOCl
WML	Heel	Cascade aeration - RF - ACF - UV
	Roosteren	Aeration - RF (micro sieve) - UV + Aeration - RF - tower aeration + RF - UV

- ACF: active-carbon filtration
- ClO₂: chlorine dioxide
- HOCl: hypochlorite
- SSF: slow sand filtration
- WS: water softening
- RF: rapid filtration
- UV: ultraviolet
- RO: reversed osmosis

2.3 Compounds relevant for the drinking water sector

The compounds that can in principle pose a risk to the preparation of drinking water from surface water originated from two compound lists:

- The 'priority compounds' of the Water Framework Directive, comprising 33 compounds or groups of compounds. The priority compounds have been selected at the request of VEWIN because a discussion is on-going with regard to surface water standards for drinking water abstraction, depending on the performance of a simple purification procedure;
- A list compiled by VEWIN including compounds for which current drinking water standards (Water Supply Act) are stricter than current water quality goals in the Netherlands (MTR), as stated in the 4th National Policy Document on Water Management (1998).

The resulting list contains 100 compounds and is included in appendix I, in which the priority compounds from the WFD are shown in italics. The appropriate standards are also given for each compound, both for drinking water quality (Water Supply Act) and surface water quality. The standards for the priority compounds, still in concept form, have been taken from the so-called 'non-paper' from the European Commission of June 2004. The standards deviate from the values proposed before by the Fraunhofer Institute (Lepper, 2002). For inland waters, two types of standards are envisaged by the non-paper, i.e. one general standard and one standard to protect the drinking water abstraction function of specific water bodies.

The MTR (maximum allowable risk) was used as indicative standard for the water quality for the non-priority compounds because it reflects the level of ambition of Dutch water policy (see Ambition Memo, Ministry of Transport, Public Works and Water Management 2004). The non-priority compounds were selected if the drinking water requirements are stricter than the MTR.

2.4 Purification performance of risk compounds for the drinking water sector

2.4.1 *Practical purification performance for surface water*

According to the view of the Dutch water companies, simple purification of surface water is defined in this study as physical treatment (coagulation, aeration, rapid filtration) and disinfection. This pre-treatment results in physico-chemical reactions which partially remove micro-pollutants:

- Coagulation: removal of suspended matter, organic compounds and heavy metals;
- Aeration: removal of volatile organic compounds;
- Rapid filtration: removal of remaining suspended matter, heavy metals and organic compounds;
- Disinfection: breakdown of organic compounds under the influence of chlorine, ozone or UV.

The purification performance of these processes can be calculated by measuring the concentrations of compounds in the incoming and outgoing water. Unfortunately, such data are almost never available in the Netherlands because the surface water companies use advanced purification techniques when producing drinking water from surface water (see Table 2). The only extraction point for which data were available for calculating the performance of a simple purification procedure is station Cornelis Biemond, Nieuwegein. At this location, water from the Lek Canal (Rhine water) is partially purified by coagulation, precipitation and rapid filtration. The performance of the whole purification process at station Cornelis Biemond is shown in Table 3.

Table 3: Removal of heavy metals and organic compounds by simple purification of surface water at station Cornelis Biemond (Lek Canal, Nieuwegein).

Compound	% Removal
Cadmium	>95 (av.)
Lead	>86 (av.)
Mercury	>50 (av.)
Nickel	50 (av.)
Chromium	>33 (max)
Dieldrin	>80 (max)
Hexachlorobenzene	>80 (max)
α -Endosulfan	>80 (max)
α -HCH	>80 (max)
β -HCH	>80 (max)
Benzene	>67 (max)
2,4-D	60 (max)
Atrazin	0
Bentazon	0
Carbendazim	0
Diuron	0
Isoproturon	0

The results shown in Table 3 are based on a single location and must therefore be looked on with some discretion. This is especially valid for the organic compounds for which the removal is based on maximum measured concentrations. Removal percentages based on average concentrations are more representative for the performance of the purification procedure.

Heavy metals are partially (chromium, mercury, nickel) to mainly (lead, cadmium) removed by the purification procedure. This removal is caused by coagulation and sedimentation, as is the removal of dieldrin and hexachlorobenzene, which are strongly associated with the suspended matter in the water. Benzene does neither adsorb to suspended matter nor in the filter bed; the removal of this compound must be ascribed to volatilization. Apparently, the conditions during the production process (turbulence, time) are such that volatile compounds are removed in substantial amounts, despite the fact that there is no separate aeration of the water.

Very little or no removal of the very soluble pesticides is to be expected during water purification based on coagulation and rapid filtration. Indeed, that is the case for atrazin, bentazon, carbendazim, diuron and isoproturon. However, endosulfan, HCH and 2,4-D appear to be largely removed (>80% based on maximum concentration), although these compounds are poorly adsorbing and not volatile. For the time being the removal percentages for these compounds are not seen to be realistic.

2.4.2 Practical purification performance for groundwater

As mentioned earlier simple purification is generally applied by groundwater companies and in addition to coagulation and rapid filtration they always use aeration as well. The removal percentages for the groundwater companies which use a simple purification procedure are shown in Table 4.

Table 4: Removal of compounds by simple purification of groundwater (data from REWAB 2003).

Compound	Removal (%)	No. locations
Chloride	10 - 50	3
Fluoride	30 - <50	2
Arsenic	20 - 75	7
Cadmium	50 - 60	2
Chromium	15 - 50	3
Mercury	< 44	1
Lead	40 - 60	2
Nickel	40 - 50	3
Benzene	15 - >50	3
Toluene	25 - 98	6
m-Xylene	< 50	1
Dichloromethane	25 - 50	3
Trichloromethane	30 - 60	8
1,2-Dichloroethane	30	1
1,1,1-Trichloroethane	50 - 90	3
1,1,2-Trichloroethane	< 40	1
1,2-Dichloroethene	< 99	1
Trichloroethene	40 - 65	5
Tetrachloroethene	38 - 91	2
1,2-Dichloropropane	50 - >95	3
1,3-Dichloropropane	< 65	1
β-HCH	10 - 20	1
Bentazon	15	1

An unexpected result of this data analysis is the apparent removal of chloride and fluoride from raw groundwater, of about 30% on average. Chloride and fluoride are univalent ions that do not adsorb significantly to soil particles (in contrast to phosphate, for example). It is not clear whether this is a realistic result or an artifact.

Heavy metals are substantially removed by the coagulation step but not so strongly as in surface water (see Table 5). The reason for this is that surface water contains more suspended matter than groundwater which leads to a more effective coagulation/sedimentation process. There is sometimes a large

variation in the values for the purification performance, especially for arsenic (20-75%). This might be explained by a difference in the iron concentration in the raw water which would lead to differences in the amount of flocculation and (therefore) in the adsorptive conditions during the coagulation process.

Benzene and its derivatives (toluene, xylene) and all small chlorinated aliphatic hydrocarbons are also substantially removed, which must be due to volatilization. There is really a large variation in the purification performance (e.g., toluene: 25-98%). This will be related to the different aeration techniques employed, such as plate, tower and cascade aeration. Volatilization is greatly dependent on operational conditions; turbulence and residence time play an especially important role. In other words, if the process conditions would be optimized, volatile organic compounds would be largely removed by simple purification.

Data on the removal of pesticides from groundwater are only rarely available; they often show concentrations that are lower than the detection limit in both raw water and treated water, so that no purification performance can be calculated. The removal percentages could be calculated only once: around 15% for β -HCH and bentazon.

2.4.3 Purification performance for heavy metals, chloride and fluoride

Although it appears to be possible to remove chloride and fluoride from groundwater (see Table 4), the purification performance is considered to be zero. In fact, the Dutch quality objectives for chloride and fluoride in surface water with a drinking water function (using simple purification) are equal to the drinking water standards (150 mg/l for chloride and 1 mg/l for fluoride). This reflects the common view that chloride and fluoride are not removed by simple purification.

The purification performances for ground and surface water of various heavy metals are shown in Table 5 together with proposals for a generic purification performance for each metal. The proposed generic purification performances are mainly based on the empirically established performances for the surface water station Cornelis Biemond (Table 3), and to a lesser extent on the various groundwater stations (Table 4).

Table 5: Practical performances of simple purification of surface and ground water for removal of heavy metals and proposals for a generic performance for each metal.

	Performance for surface water (Table 3)	Performance for ground water (Table 4)	Generic performance
Cadmium	> 95%	50 - 60%	90%
Lead	> 86%	40 - 60%	90%
Mercury	> 50%	< 44%	50%
Nickel	50%	40 - 50%	50%
Arsenic		20 - 75 %	50%
Antimony			50%*
Chromium	> 33%	15 - 50%	35%

* the chemical behavior of antimony is very similar to that of arsenic

2.4.4 Purification performance for organic compounds

Organic compounds can be removed in two ways by simple purification, i.e. by coagulation/rapid filtration and volatilization. Additional removal may take place during the disinfection step, which is not considered in this report (due to lack of data). The degree of removal depends on the physico-chemical properties of the compounds. Compounds that bind tightly to suspended matter will be efficiently removed as will volatile compounds. The strength by which organic compounds bind to suspended matter is expressed as the so-called partition coefficient (Koc); the volatility of compounds is expressed in the Henry constant. An overview of the Koc and Henry constants of the studied compounds is given in appendix II.

Removal by coagulation and rapid filtration

Three types of binding (fractions) are distinguished for organic compounds in surface water:

1. truly dissolved,
2. bound to DOC (dissolved organic carbon), and
3. bound to POC (particulate organic carbon; in suspended matter).

This distinction into chemical fractions is relevant because each fraction will behave differently during purification. The starting point for this study is that the dissolved fraction is not retained by simple purification, 50% of the DOC-bound fraction is retained and 100% of the POC-bound fraction (suspended matter is completely retained). These percentages are compatible with the removal performance of DOC and POC, respectively, in simple purification.

The three different fractions can be calculated using the following equations (Gschwend & Wu, 1985):

$$\text{Dissolved fraction} = 1 / (1 + X_{\text{DOC}} * \text{DOC} * K_{\text{oc}} + \text{POC} * K_{\text{oc}})$$

$$\text{DOC fraction} = X_{\text{DOC}} * \text{DOC} * K_{\text{oc}} / (1 + X_{\text{DOC}} * \text{DOC} * K_{\text{oc}} + \text{POC} * K_{\text{oc}})$$

$$\text{POC fraction} = \text{POC} * K_{\text{oc}} / (1 + X_{\text{DOC}} * \text{DOC} * K_{\text{oc}} + \text{POC} * K_{\text{oc}})$$

The term X_{DOC} describes the relative affinity of DOC compared to POC for adsorption of organic compounds. In practice this factor is often chosen between 0.1 and 0.5; in this study we used the value 0.2 (expert judgment).

From these formulas it appears that the distribution of a compound over the three fractions depends not only on the K_{oc} value but also on the DOC and POC concentrations in the surface water under study. The current DOC and POC concentrations in the rivers Meuse and Rhine, Lake IJsselmeer, and the Lek and Twente canals are shown in Table 6.

Table 6: Average DOC and POC concentrations in Dutch surface waters in the period 2001-2003 (www.waterbase.nl).

Water system	Location	n	DOC (mg/l)	POC (mg/l)
Meuse	Eijsden	152	3.9	1.28
Meuse	Belfeld	45	4.2	0.73
Meuse	Nederweert	38	4.2	0.76
Meuse	Stevensweert	37	4.0	0.89
Meuse	Keizersveer	25	4.4	0.60
Meuse	(av.)		4.1	0.85
Rhine	Lobith	76	3.5	1.24
Lek canal	Nieuwegein	25	3.6	1.40
Rhine and Lek	(av.)		3.5	1.32
IJsselmeer	Vrouweinzand	47	6.4	2.85
Twente canal	Wiene	42	14.8	1.83

The distribution of organic micro-pollutants over the three fractions can be determined for each system based on the DOC and POC concentrations in Table 6, the K_{oc} values in appendix II and an expert judgment of X_{DOC} (0.2). The results are shown in Table 7, which shows only compounds of which at least 5% of the total concentration is bound to POC and DOC. The other studied compounds are essentially (> 95%) present in dissolved form in the surface water and will therefore not be noticeably removed by coagulation and rapid filtration.

Table 7 shows that compounds with a $\log K_{\text{oc}} < 4$ are almost entirely in the dissolved form. A $\log K_{\text{oc}} > 6$ indicates a predominantly bound form for which the distribution between DOC and POC depends on the DOC and POC concentration in the water system. Thus in the Rhine and Lake IJsselmeer the fraction bound to POC for a randomly selected compound is always greater than the DOC fraction, whereas this is exactly the opposite in the Twente canal (in which DOC is very high).

Table 7: Calculated distribution (%) of organic micro-pollutants in Lake IJsselmeer (IJSL), the rivers Rhine and Meuse, and the Twente canal (TwC).

Compound	Log Koc	poc				doc				dis.			
		IJSL	Rhine	Meuse	TwC	IJSL	Rhine	Meuse	TwC	IJSL	Rhine	Meuse	TwC
Indeno(123-cd)pyrene	7.2	68	63	49	37	31	34	47	62	2	3	4	1
Benzo(ghi)perylene	7.0	67	62	48	37	31	33	46	61	2	5	6	2
Benzo(b)fluoranthene	6.6	65	58	44	36	30	31	43	59	6	11	13	5
Benzo(k)fluoranthene	6.6	65	58	44	36	30	31	43	59	6	11	13	5
Benzo(a)pyrene	6.6	65	58	44	36	30	31	43	59	6	11	13	5
Chrysene	6.4	63	54	41	35	29	29	40	58	9	17	19	8
Diethylhexylphthalate	6.2	59	49	37	33	27	27	36	55	13	24	27	12
Dieldrin	5.8	49	36	26	28	23	20	25	47	28	44	49	25
Fluoranthene	5.6	42	29	20	25	19	16	20	41	38	56	60	34
Hexachlorobenzene	5.6	42	29	20	25	19	16	20	41	38	56	60	34
Pentabromodiphenylether	5.6	42	29	20	25	19	16	20	41	38	56	60	34
Anthracene	5.3	31	19	13	18	14	10	12	31	55	71	75	51
Pentachlorobenzene	4.9	17	9	6	10	8	5	6	17	76	86	88	72
Tributyltin (cation)	4.6	10	5	3	6	4	3	3	10	86	93	94	84
Quintozene	4.3	5	2	2	3	2	1	2	5	93	96	97	91
Hexachlorobutadiene	4.1	3	2	1	2	2	1	1	4	95	98	98	94

The performance of simple purification can now be determined for each water system, under the assumption that the POC-bound fraction is completely removed together with half of the DOC-bound fraction. Finally we determined for each compound an average purification performance for 'surface water', by averaging the results for each water system (see Table 8).

Table 8: Removal (%) of hydrophobic organic compounds ($\log K_{oc} > 4$) by coagulation and rapid filtration for various water systems (based on Table 7).

	IJSL	Rhine	Meuse	TwC	Mean
Indeno(123-cd)pyrene	83	80	73	68	76
Benzo(ghi)perylene	82	79	71	67	75
Benzo(b)fluoranthene	79	73	66	65	71
Benzo(k)fluoranthene	79	73	66	65	71
Benzo(a)pyrene	79	73	66	65	71
Chrysene	77	69	61	63	68
Diethylhexylphthalate	73	63	55	61	63
Dieldrin	61	46	39	52	49
Fluoranthene	52	37	30	45	41
Hexachlorobenzene	52	37	30	45	41
Pentabromodiphenylether	52	37	30	45	41
Anthracene	38	24	19	34	28
Pentachlorobenzene	21	11	9	19	15
Tributyltin (cation)	12	6	5	11	8
Quintozene	6	3	2	6	4
Hexachlorobutadiene	4	2	2	4	3

Removal by volatilization

The degree of volatilization of a volatile compound depends on the Henry constant and the operational conditions during the purification process such as turbulence, flow speed and the type of aeration applied. The results of the studied groundwater purification procedures (Table 4) suggest that volatile compounds are removed very substantially but that the performance is very variable. There is certainly a relationship between the degree of removal and the Henry constant but this relationship cannot be quantified on the basis of the available data. In order to be able to estimate the purification performance for individual compounds the purification process is (conceptually) proposed as a slow stream of water for which existing equations for volatilization are applicable (Southworth, 1979).

Volatilization of compounds can be described as a first-order process:

$$C_t = C_0 \exp(-kt)$$

For the rate constant k:

$$k = k_g k_l He / (k_g He + RT k_l) / Z$$

where:

- k_g and k_l are the exchange coefficients for the gas and water phases, respectively (m/d);
- H_e is the Henry constant (Pa m³/mol);
- R is the gas constant (8.314 J/mol/K);
- T is the temperature (K);
- Z is the depth of the water column (m).

The resulting dimension of the rate constant k is 1/day.

The exchange coefficients k_g and k_l can be calculated from the wind and flow speed (V_w and V_c , respectively; m/s), the depth of the water column (Z , m) and the molecular mass of the compound (M , g/mol). The equations are as follows:

$$k_l \text{ (m/d)} = 5.64 V_c^{0.969} / Z^{0.673} \text{ SQRT}(32/M) \exp(0.526 (V_w - 1.9))$$

$$k_g \text{ (m/d)} = 273 (V_c + V_w) \text{ SQRT}(18/M)$$

The variables in the equations were chosen such that the apparent removal of trichloromethane (30-60%, $n=8$) and trichloroethene (40-65%, $n=5$) in existing groundwater purification (Table 4) are reproduced as well as possible. These compounds were chosen as a reference (validation) because they provide the greatest number of measurements and their purification ranges are relatively limited. The conditions in the hypothetical purification process were chosen as follows:

- $V_c = 0.5$ m/s
- $V_w = 1.5$ m/s
- $T = 293$ K
- $Z = 0.2$ m
- time = 1 hour.

Under these conditions, 48% trichloromethane and 49% trichloroethene are removed from raw water, which is fairly in between the practical purification performance of the groundwater stations for these compounds (see Table 4).

The removal of organic compounds by volatilization can now be calculated (under the above conditions) for all compounds from appendix II. The results are shown in Table 9, which is limited to compounds which are removed by at least 3% ($H_e > 3$ Pa m³/mol).

Otherwise volatilization is only applicable to the dissolved fraction; it is assumed that the DOC and POC-bound fractions exchange too slowly with the dissolved fraction to contribute to the volatilization. This means that the total performance of volatilization must be multiplied by the dissolved fraction in order to obtain the net result. This correction is only relevant for a few compounds (hexachlorobenzene, pentachlorobenzene, anthracene).

Table 9: Removal of organic micro-pollutants during simple purification by volatilization. Compounds are listed in order of decreasing volatility.

Compound	M (g/mol)	He (Pa m ³ /mol)	Removal (total) (%)	Removal (net) (%)
Vinyl chloride	62.5	2350	64	64
Tetrachloroethene	165.83	2300	46	46
1,1-Dichloroethene	96.94	2290	56	56
Tetrachloromethane	153.8	2040	47	47
1,1,1-Trichloroethane	133.4	1260	49	49
Hexachlorobutadiene	260.8	1030	38	37
Ethylbenzene	106.2	800	53	53
Trichloroethene	131.4	700	49	49
Toluene	92.13	670	55	55
Xylene	106.2	640	52	52
1,2-Dichloroethene	96.94	560	54	54
Benzene	78.11	550	58	58
Monochlorotoluene	126.6	407	48	48
Monochlorobenzene	112.6	350	50	50
Nonylphenol	220	315	38	38
Trichloromethane	119.4	280	48	48
Dichlorobenzene	147	240	44	44
Styrene	104.2	232	49	49
Pentachloroethane	202.3	220	38	38
Dichloromethane	84.9	210	52	52
1,2-Dichloropropane	112.99	210	47	47
1,3-Dichloropropane	112.99	210	47	47
3-Chloropropene	76.52	200	54	54
1,3-Dichloropropene	110.97	200	47	47
2,3-Dichloropropene	110.97	200	47	47
1,2,4-Trichlorobenzene	181.5	101	35	35
1,2-Dichloroethane	98.97	100	44	44
Tetrachlorobenzene	215.9	80	31	31
1,1,2-Trichloroethane	133.4	70	36	36
Pentachlorobenzene	250.3	59	26	21
Tolclofos-methyl	301.1	49	23	23
Naphthalene	128.2	43	31	31
Hexachlorobenzene	284.8	41	21	10
1,1,2,2-Tetrachloroethane	167.85	30	23	23
Octylphenol	206.3	16	15	15
Tetrabutyltin	347.2	9.5	7.9	7.9
Anthracene	178.2	6	7.5	4.7
Trifluralin	335.3	5.4	5.0	5.0
Pentabromodiphenylether	565	4.9	3.6	1.7
Chloridazon	221.6	3.7	4.4	4.4
Endosulfan	407	3	2.7	2.7

The overall effect of simple purification, i.e. the sum of coagulation, rapid filtration and volatilization, for organic compounds is given in Table 10. This table is limited to compounds that are actually influenced by the purification process (removal > 10%). It should be noted here that modern pesticides are not significantly removed by simple purification, except for tolclofos-methyl. Compounds which are removed significantly include PAHs, benzene and its derivatives, chlorinated aliphatics, chlorobenzenes, endocrine disrupters, and a few other compounds.

Table 10: Overall removal of organic micro-pollutants by simple purification of surface water. Combination of data in Table 8 and Table 9.

Compound	Coagulation + rapid filtration (%)	Volatilization (%)	Total (%)	Rounded (%)
Indeno(123-cd)pyrene	76	0	76	75
Benzo(ghi)perylene	75	0	75	75
Benzo(b)fluoranthene	71	0	71	70
Benzo(k)fluoranthene	71	0	71	70
Benzo(a)pyrene	71	0	71	70
Chrysene	68	0	68	70
Fluoranthene	41	0	41	40
Anthracene	28	5	33	35
Naphthalene	0	31	31	30
Benzene	0	58	58	60
Toluene	0	55	55	55
Ethylbenzene	0	53	53	55
Xylene	0	52	52	50
Styrene	0	49	49	50
Dichloromethane	0	52	52	50
Trichloroethane	0	48	48	50
Tetrachloromethane	0	47	47	45
1,2-Dichloroethane	0	44	44	45
1,1,1-Trichloroethane	0	49	49	50
1,1,2-Trichloroethane	0	36	36	35
1,1,2,2-Tetrachloroethane	0	23	23	25
Pentachloroethane	0	38	38	40
Vinyl chloride	0	64	64	65
1,1-Dichloroethene	0	56	56	55
1,2-Dichloroethene	0	54	54	55
Trichloroethene	0	49	49	50
Tetrachloroethene	0	46	46	45
3-Chloropropene	0	54	54	55
1,3-Dichloropropene	0	47	47	45
2,3-Dichloropropene	0	47	47	45
1,2-Dichloropropane	0	47	47	45
1,3-Dichloropropane	0	47	47	45

Compound	Coagulation + rapid filtration (%)	Volatilization (%)	Total (%)	Rounded (%)
Monochlorobenzene	0	50	50	50
Monochlorotoluene	0	48	48	50
Dichlorobenzene	0	44	44	45
1,2,4-Trichlorobenzene	0	35	35	35
Tetrachlorobenzene	0	31	31	30
Pentachlorobenzene	15	21	36	35
Hexachlorobenzene	41	10	51	50
Diethylhexylphthalate	63	0	63	65
Pentabromodiphenylether	41	2	43	45
Nonylphenol	0	38	38	40
Octylphenol	0	15	15	15
Dieldrin	49	0	49	50
Hexachlorobutadiene	3	37	40	40
Tolclofos-methyl	0	23	23	25

3 Standards for surface water

3.1 Comparison of desired surface water standards and concept standards for priority compounds

The desired surface water standards for adequate protection of the drinking water function can be derived from the drinking water standards in the Water Supply Act and the performance of simple purification (Tables 5 and 10). The results are shown in Table 11 for the WFD priority compounds. A comparison is also made with the standards proposed in the 'non-paper' of the European Commission (June 2004). (both inland water and drinking water abstraction)

Table 11: Standards of priority compounds (in µg/l): a) drinking water (WSA-DWS), b) desired surface water standard (DSWS), c) WFD (inland water), d) WFD (DWA).

Compounds	WSA DWS	Performance (%) of simple purification	DSWS	WFD (inland water)	WFD (DWA)
Cadmium	5	90	50	(0.45-1.5) + BC	
Mercury	1	50	2	0.07 + BC	
Lead	10	90	100	2 + BC	
Nickel	20	50	40	1.7 + BC	
Benzene	1	60	2.5	49	1.7
Anthracene	0.1	35	0.15	0.4	< 0.2
Fluoranthene	0.1	40	0.17	0.9	< 0.2
Benzo(b)fluoranthene	0.1	70	0.33		0.1
Benzo(k)fluoranthene	0.1	70	0.33		0.1
Benzo(a)pyrene	0.01	70	0.03	0.05	0.01
Benzo(ghi)perylene	0.1	75	0.40		0.1
Indeno(123-cd)pyrene	0.1	75	0.40		0.1
Dichloromethane	1	50	2.00	1900	20
Trichloromethane	25	50	50.00	270	100
1,2-Dichloroethane	3	45	5.45	1180	3
Trichlorobenzene	1	35	1.54	50	
Pentachlorobenzene	1	35	1.54	1	
Hexachlorobenzene	1	50	2.00	0.05	
Pentachlorophenol	1	0	1.00	1	0.1
γ-HCH (lindane)	0.1	0	0.10	0.04	
Diuron	0.1	0	0.10	1.8	0.1
Isoproturon	0.1	0	0.10	1.3	0.1
Alachlor	0.1	0	0.10	0.7	0.1
Atrazin	0.1	0	0.10	2.9	0.1
Simazin	0.1	0	0.10	3.4	0.1
Chlorofenvinfos	0.1	0	0.10	0.3	0.1
Chloropyrifos	0.1	0	0.10	0.1	
Tributyltin (cation)	0.1	0	0.10	0.002	
Endosulfan	0.1	0	0.10	0.01	
Hexachlorobutadiene	0.1	40	0.17	0.6	
Trifluralin	0.1	0	0.10	1	0.1

- WSA-DWS: Water Supply Act, drinking water standard (set down in law).
- DSWS: Desired surface water standard, derived from the drinking water standard and the performance of simple purification (no official status).
- WFD (inland water), WFD (DWA): the concept priority compounds guideline distinguishes between fresh waters with and without drinking water function. The accompanying standards are mentioned in Table 11 under 'DWA' (drinking water abstraction) and 'inland water', respectively. The listed standards refer to maximum concentrations (MAC); for inland water a set with mean annual values is also available. The DWA standards are not yet known for all compounds.
- BC: background concentration (heavy metals)

Table 11 shows that the standards set by the WFD offer adequate protection to the drinking water function for heavy metals (according to the standards for inland waters; the DWA standards may be stricter). The DWA standards for PAHs seem to offer adequate protection as well, as they are comparable to or lower than the desired surface water standards. However, this comparison is not completely fair because the PAH drinking water standard and hence the surface water standard derived from it is based on the sum of ten PAHs. For the other organic micro-contaminants, the DWA standards are lower than or equal to the desired surface water standards (i.e. offer sufficient protection for the drinking water function), except for dichloromethane and trichloromethane. Adjusting the DWA values for dichloromethane (from 20 to 2 µg/l) and trichloromethane (from 100 to 50 µg/l) is necessary to meet the desired quality of surface water as a source of drinking water. In the absence of DWA values, the inland water standards offer sufficient protection for the drinking water function except for trichlorobenzene and hexachlorobutadiene. In order to meet the desired surface water standards, it is recommended to set DWA values for trichlorobenzene (1.5 µg/l) and hexachlorobutadiene (0.15 µg/l).

The Water Supply Act does not mention drinking water standards for the following priority compounds: naphthalene, diethylhexylphthalate, octylphenol, nonylphenol and bromodiphenylether, so that no comparison with the proposed and desired surface water standards can be made.

3.2 Comparison of desired surface water standards with the MTR for non-priority compounds

Table 12 shows a comparison between the MTR (the ecological objective of Dutch water policy) and desired surface water standards (based on simple purification) for non-priority compounds. The table is ranked on the quotient MTR/desired surface water standard. In other words, compounds causing the largest (potential) problem are at the top. Table 12 shows that in fact it does not matter whether the MTR is compared with the drinking water standard or with the desired surface water standard. In the first case 64 potential problem compounds are distinguished; in the second case 62. This is so because the MTR for most compounds is one to three orders of magnitude greater than the drinking water standard. For example, for vinyl chloride the drinking water standard is 0.5 µg/l, the desired surface water standard is 1.4 µg/l, but the MTR is 820 µg/l. The performance of simple purification is high (65%), but because of the large difference between drinking water standard

and MTR, vinyl chloride still remains a potential problem compound. This situation applies to many other organic compounds as well (see Table 12).

Table 12: Standards of non-priority compounds (in µg/l): a) drinking water (WSA-DWS), b) desired surface water standard (DSWS), c) ecological objective (MTR).

Compounds	WSA DWS	Performance (%) of simple purification	DSWS	MTR	MTR/DSWS
1,1,2-Trichloroethane	1	35	1.54	7900	5135
1,2-Dichloroethene	1	55	2.22	6100	2745
1,1,2,2-Tetrachloroethane	1	25	1.33	3300	2475
1,1-Dichloroethene	1	55	2.22	3400	1530
1,1,1-Trichloroethane	1	50	2.00	2100	1050
Chloridazon	0.1	0	0.10	73	730
Bentazon	0.1	0	0.10	64	640
Tetrachloromethane	1	45	1.82	1100	605
Vinyl chloride	0.5	65	1.43	820	574
Dichlorprop	0.1	0	0.10	40	400
Monochlorobenzene	1	50	2.00	690	345
Metazachlor	0.1	0	0.10	34	340
Desmetryn	0.1	0	0.10	34	340
Toluene	1	55	2.22	730	329
Styrene	1	50	2.00	570	285
Dimethoate	0.1	0	0.10	23	230
DNOC	0.1	0	0.10	21	210
Xylenes	1	50	2.00	380	190
Ethylbenzene	1	55	2.22	370	167
Monochlorotoluenes	1	50	2.00	310	155
Pentachloroethane	1	40	1.67	230	138
Dichlorobenzenes	1	45	1.82	250	138
Trichloroethene	10	50	20.00	2400	120
Metobromuron	0.1	0	0.10	10	100
Metamitron	0.1	0	0.10	10	100
2,4-D	0.1	0	0.10	10	100
2,4,5-T	0.1	0	0.10	9	90
1,2-Dichloropropane	1	45	1.82	76	42
1,3-Dichloropropane	1	45	1.82	76	42
Mecoprop	0.1	0	0.10	4	40
α-HCH	0.1	0	0.10	3.3	33
Quintozene	0.1	0	0.10	3.1	31
Monochlorophenols	1	0	1.00	25	25
MCPA	0.1	0	0.10	2	20
Triallate	0.1	0	0.10	1.9	19
Tetrachloroethene	10	45	18.18	330	18
Metabenzthiazuron	0.1	0	0.10	1.8	18
Oxamyl	0.1	0	0.10	1.8	18
Tetrachlorobenzenes	1	30	1.43	24	17
Tetrabutyltin	0.1	0	0.10	1.6	16
Dichlorophenols	1	0	1.00	15	15
Propachlor	0.1	0	0.10	1.3	13
Carbofuran	0.1	0	0.10	0.91	9.1

Compound	WSA DWS	Performance of simple purification (%)	DSWS	MTR	MTR/ DSWS
β-HCH	0.1	0	0.10	0.86	8.6
Tolclofos-methyl	0.1	25	0.13	0.80	6.0
1,3-Dichloropropene	1	45	1.82	8	4.4
2,3-Dichloropropene	1	45	1.82	8	4.4
Trichlorophenols	1	0	1.00	3	3.0
Chrysene	0.1	70	0.33	0.9	2.7
Linuron	0.1	0	0.10	0.25	2.5
Carbaryl	0.1	0	0.10	0.23	2.3
Metolachlor	0.1	0	0.10	0.2	2.0
Cyanazin	0.1	0	0.10	0.19	1.9
Arsenic	10	50	20	32	1.6
Benomyl	0.1	0	0.10	0.15	1.5
Demeton	0.1	0	0.10	0.14	1.4
Fluoride (mg/l)	1.1	0	1.1	1.5	1.4
3-Chloropropene	1	55	2.22	3	1.4
Chloride (mg/l)	150	0	150	200	1.3
Carbendazim	0.1	0	0.10	0.11	1.1
Captan	0.1	0	0.10	0.11	1.1
Chromium	50	35	77	84	1.1
Antimony	5	50	10	7.2	0.7
Dieldrin	0.03	50	0.06	0.039	0.7

Our conclusion is that the ecological objective (MTR) for the non-priority compounds examined here offers insufficient protection for the drinking water function of surface water if simple purification is to be applied. This holds even more if we note that it is not the maximum concentration but the 90-percentile that in practice is tested against the MTR. Indeed, MAC values will be considerably higher than the 90-percentile.

It can be concluded overall that the proposed guidance values in the 'non-paper' from the European Commission (June 2004) offer sufficient protection for the drinking water function of surface water (except for two compounds). For about 60 compounds the MTR is really much too high to offer adequate protection for the drinking water function when simple purification is to be applied.

4 Water quality of the Rhine and Meuse

4.1 Comparison of current water quality and desired surface water standards

In order to get an idea of the current problem compounds for the preparation of drinking water and problem areas in the Netherlands related to drinking water supply a comparison has been made between the current water quality in the Rivers Rhine and Meuse and the desired surface water standards for protection of the drinking water function (based on simple purification).

4.1.1 *Selecting measuring locations*

The current water quality has been examined for the following locations situated in the catchment areas of the Rivers Meuse and Rhine (names of water companies are given in brackets):

- Meuse: Eijsden (WML), Heel (WML) and Keizersveer (Evides);
- Rhine: Lobith, Lek canal (Nieuwegein, WLBA), Amsterdam-Rhine canal (Nieuwersluis, WLBA), Twente canal (Vitens), IJsselmeer (Andijk, PWN).

Water quality data from the years 2002 and 2003 were considered so as to get the best possible picture of the current situation. The data were obtained from the Directorate-General for Public Works and Water Management and RIWA, representing the above-mentioned river water companies.

4.1.2 *Current water quality in the Rhine and Meuse Rivers*

The water quality (maximum concentrations; 100-percentile) for the above-mentioned locations is shown in appendix III, in which for each catchment area a distinction is made between priority and non-priority compounds. It can be seen in appendix III that both the Rivers Meuse and Rhine contain a number of compounds for which the maximum concentration levels exceed the desired surface water standards. Account must be taken of the fact that for a large number of compounds the number of annual measurements is very limited, often not more than four per year. Therefore the observations and conclusions presented here should be considered as preliminary.

Considering the River Meuse, pesticides, PAHs and fluoride regularly exceed the desired surface water standards, especially at the border station Eijsden. Table 13 shows an overview of the water quality for these compounds at the three measuring locations in the River Meuse. The maximum concentration is presented and, if this exceeds the desired surface water standard, also the 90-percentile. Pesticides (notably diuron, isoproturon, and atrazin) exceeding the standards were found at all measuring locations along the Meuse. Diuron showed the biggest excess (up to five times the standard). At station Eijsden (border), the water quality is obviously more critical than further downstream (cf. Eijsden, Heel and Keizersveer). A number of PAHs exceeded the desired standards at Eijsden in 2002 (but not in 2003). Fluoride exceeded the standard only in Eijsden, both in 2002 and 2003 (a well-known problem in the Meuse indeed). More downstream, fluoride levels decreased gradually as shown by the levels observed at Heel and Keizersveer (see Table 13).

Considering the Rhine River, an occasional excess over the derived surface water standards was found for PAHs, pesticides and chloride. Table 14 shows an overview of the concentrations of these compounds in the Rhine River at the border (Lobith), canals fed by Rhine water, and Lake IJsselmeer. Again, the maximum concentration is shown, and if this exceeds the standard also the 90-percentile. The largest excess was observed for isoproturon (five times the surface water standard in Nieuwegein, 2002).

Overall, the picture emerges that the number of *current* problem compounds (Tables 13 and 14) is far less than the number of *potential* problem compounds (Table 12 and a few priority compounds mentioned in section 3.1), although it should be stressed once again that the number of measurements is too low to allow definitive conclusions.

Table 13: Examination of water quality of the Meuse River against the desired surface water standards (DSWS). When a maximum concentration exceeds the standard the 90-percentile is also shown and checked. (n.a. = compound was not measured). Values exceeding the standard are shown in red.

MEUSE	DSWS	Unit	Eijsden				Heel				Keizersveer			
			2002	2002	2003	2003	2002	2002	2003	2003	2002	2002	2003	2003
			90pcl	max	90pcl	max	90pcl	max	90pcl	max	90pcl	max	90pcl	max
Priority compounds														
Anthracene	0.15	µg/l	0.03	0.24		< 0.02		< 0.005		< 0.005		0.015		< 0.01
Fluoranthene	0.17	µg/l	< 0.02	0.21		0.06		0.009		0.02		0.132		0.01
Benzo(a)pyrene	0.03	µg/l	< 0.05	0.08		< 0.03		< 0.005		0.013	< 0.01	0.083		< 0.01
Diuron	0.10	µg/l	0.35	0.45	0.36	0.52	0.44	0.51	0.29	0.38	0.3	0.37	0.21	0.21
Isoproturon	0.10	µg/l	0.09	0.15	0.04	0.15	0.13	0.6	0.08	0.15	0.12	0.15		0.07
Atrazin	0.10	µg/l	0.09	0.19	0.09	0.22	0.16	0.18	0.09	0.15	0.15	0.18	0.1	0.12
Simazin	0.10	µg/l	0.05	0.12		0.04		0.04		0.06		0.07		0.07
Non-priority compounds														
Fluoride	1.1	mg/l	0.99	1.4	1.3	1.8		0.76		0.95		0.52		0.5
2,4-D	0.10	µg/l		0.06	< 0.05	0.13		< 0.05		< 0.05		0.03		0.05
Dichlorophenols	1.0	µg/l		< 0.06	< 0.11	2.2		< 0.6		< 0.6	n.a.	n.a.	n.a.	n.a.
Dichlorprop	0.10	µg/l		0.08	< 0.05	0.11		< 0.05		< 0.05		< 0.03		< 0.03
Dimethoate	0.10	µg/l	0.02	0.12		0.05	n.a.	n.a.	n.a.	n.a.		< 0.1		< 0.1
Mecoprop	0.10	µg/l		0.09	< 0.05	0.16		0.05		0.06		0.08	0.1	0.12
Metolachlor	0.10	µg/l		0.06		0.1		< 0.01		0.01	0.08	0.2	0.06	0.19

Table 14: Examination of water quality against the desired surface water standards in the River Rhine (Lobith), canals fed by the Rhine (Nieuwegein, Nieuwersluis, Twentekanaal) and Lake IJsselmeer (Andijk). When a maximum concentration exceeds the standard the 90-percentile is also shown and checked. (n.a.= compound was not measured; - too few measurements for deriving the 90-percentile). Values exceeding the standard are shown in red.

	DSWS		Lobith		Nieuwegein		Nieuwersluis		Andijk		Twentekanaal	
			2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Priority compounds												
Fluoranthene	0.17	90pcl			-							
	µg/l	Max	n.a.	n.a.	0.23	0.03	0.12	< 0.04	< 0.01	< 0.01	0.03	0.05
Benzo(a)pyrene	0.03	90pcl			-							
	µg/l	Max	n.a.	n.a.	0.05	< 0.01	0.03	0.02	< 0.01	< 0.01	0.02	0.03
Diuron	0.1	90pcl				0.07						
	µg/l	Max	0.05	0.08	0.1	0.13	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1
Isoproturon	0.1	90pcl			0.15		0.14					
	µg/l	Max	0.08	0.07	0.51	0.09	0.2	< 0.3	0.07	< 0.03	< 0.1	< 0.1
Atrazin	0.1	90pcl			< 0.1							
	µg/l	Max	0.07	0.07	0.17	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.02	< 0.02
Simazin	0.1	90pcl									0.17	
	µg/l	Max	< 0.02	< 0.03	0.03	< 0.03	< 0.05	< 0.05	< 0.05	< 0.05	0.17	0.09
Non-priority compounds												
Chloride	150	90pcl		142						163		200
	Mg/l	Max	140	184	114	150	97	136	101	180	92	250
Mecoprop	0.1	90pcl									-	0.11
	µg/l	Max	n.a.	n.a.	< 0.02	0.03	0.1	0.06	0.02	< 0.02	0.15	0.12
β-HCH	0.1	90pcl			-							
	µg/l	Max	< 0.06	< 0.001	0.12	< 0.01	< 0.01	< 0.01	< 0.01	n.a.	< 0.05	< 0.05

5 Conclusions and recommendations

This study has demonstrated that a good ecological status of surface water does not ensure that 100% reliable drinking water will be produced from it using simple purification techniques. The requirements set on surface water as a source for drinking water production are different than those intended to protect the aquatic ecosystem. Although this may sound like an open door, it is important to realize the difference.

5.1 Conclusions

Potential problem compounds

Standards for surface water as a source for drinking water were derived by combining the performance of simple purification with the current drinking water standards (EU guidelines 98/83, Water Supply Act), for all of the 100 compounds studied. These desired surface water standards were compared with current standards for water quality, i.e., the concept guidance values for the priority compounds (WFD) and the MTR for the remaining compounds. It was concluded that the concept guidance values for priority compounds offer adequate protection for the drinking water function of surface water, except for dichloromethane and trichloromethane. Moreover, appropriate standards should be set for trichlorobenzene and hexachlorobutadiene. For most of the non-priority compounds studied here, the ecological objective (MTR) does not offer sufficient protection for the drinking water function of surface water (see Table 12).

Current problem compounds

The current water quality data at a number of extraction points in the Rhine and Meuse Rivers has been checked against the derived surface water standards, in order to identify compounds that form a current threat to the preparation of drinking water from surface water when purified by simple techniques. It appears that in the River Meuse a number of compounds (pesticides, various PAHs and fluoride) regularly exceeded the derived surface water standards, with diuron showing the greatest problem. In the River Rhine PAHs, pesticides and chloride occasionally exceeded the derived surface water standards, with the biggest problem being isoproturon.

Overall, the picture emerges that the number of *current* problem compounds (ca. 15) is far less than the number of *potential* problem compounds (ca. 65), although it should be realized that the number of measurements is too low to allow definitive conclusions.

5.2 Recommendations

Our recommendations for setting standards in the WFD are:

- Decreasing the DWA values for dichloromethane (from 20 to 2 µg/l) and trichloromethane (from 100 to 50 µg/l).
- Including DWA values for trichlorobenzene (1.5 µg/l) and hexachlorobutadiene (0.15 µg/l).

In addition it is important that the Ministry of Transport, Public Works and Water Management should be aware that realization of the MTR for non-priority compounds takes insufficient account of the drinking water function of the Rivers Rhine and Meuse (see Table 12).

No drinking water standards are known for naphthalene and the endocrine disrupters from the WFD (diethylhexylphthalate, octylphenol, nonylphenol and bromodiphenylether). It is recommended that drinking water standards be derived for these compounds to enable evaluation whether the WFD offers adequate protection for the drinking water function.

Expansion of the measuring network for surface water (meaning expansion of the number of compounds measured and the frequency of measurements) is essential for a well-founded evaluation of the current quality of surface water. This is especially appropriate for compounds for which we have concluded that the current ecological standards offer too little protection for drinking water production.

One recommendation for further study is to examine the performance of other forms of simple purification, such as storage basins and bank filtration.

6 References

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- Carbamates (RIZA, 1993)
- Carboximides (RIZA, 1995)
- Chlorophenoxy-carbonic acids (RIZA, 1994)
- Dithiocarbamates (RIZA, 1993)
- Phenol herbicides (RIZA, 1994)
- Phenylurea herbicides (RIZA, 1997)
- Nitroanilines (RIZA, 1996)
- Organochloro pesticides (RIZA, 1995)
- Organophosphor pesticides (RIZA, 1994)
- Triazines (RIZA, 1993)

I Compound list

	Compound (priority compounds in italics)	WSA (drinking water)	NW4 MTR	WFD MAC, inland	WFD MAC, DWA	Unit
Anions						
1	Chloride	150	200			mg/l
2	Fluoride	1.1	1.5			mg/l
Metals and metalloids						
3	Antimony	5	7.2			µg/l
4	Arsenic	10	32			µg/l
5	<i>Cadmium</i>	5	2	(0.45-1.5) + AC		µg/l
6	Chromium	50	84			µg/l
7	<i>Mercury</i>	1	1.2	0.07 + AC		µg/l
8	<i>Lead</i>	10	220	2 + AC		µg/l
9	<i>Nickel</i>	20	6.3	1.7 + AC		µg/l
Benzene and derivatives						
10	<i>Benzene</i>	1	240	49	1.7	µg/l
11	Toluene	1	730			µg/l
12	Xylenes	1	380			µg/l
13	Ethylbenzene	1	370			µg/l
14	Styrene	1	570			µg/l
PAHs						
15	<i>Naphthalene</i>		1.2	80	< 0.2	µg/l
16	<i>Anthracene</i>	0.1 (sum)	0.08	0.4	< 0.2	µg/l
17	<i>Fluoranthene</i>	0.1 (sum)	0.5	0.9	< 0.2	µg/l
18	Chrysene	0.1 (sum)	0.9			µg/l
19	<i>Benzo(b)fluoranthene</i>	0.1 (sum)			0.1	µg/l
20	<i>Benzo(k)fluoranthene</i>	0.1 (sum)	0.2		0.1	µg/l
21	<i>Benzo(a)pyrene</i>	0.01	0.2	0.05	0.01	µg/l
22	<i>Benzo(ghi)perylene</i>	0.1 (sum)	0.5		0.1	µg/l
23	<i>Indeno(123-cd)pyrene</i>	0.1 (sum)	0.4		0.1	µg/l
Chlorinated aliphatics						
24	<i>Dichloromethane</i>	1	20000	1900	20	µg/l
25	<i>Trichloromethane</i>	25	590	270	100	µg/l
26	Tetrachloromethane	1	1100			µg/l
27	<i>1,2-Dichloroethane</i>	3	700	1180	3	µg/l
28	1,1,1-Trichloroethane	1	2100			µg/l
29	1,1,2-Trichloroethane	1	7900			µg/l
30	1,1,2,2-Tetrachloroethane	1	3300			µg/l
31	Pentachloroethane	1	230			µg/l
32	Vinyl chloride	0.5	820			µg/l
33	1,1-Dichloroethene	1	3400			µg/l
34	1,2-Dichloroethene	1	6100			µg/l
35	Trichloroethene	10 (sum)	2400			µg/l
36	Tetrachloroethene	10 (sum)	330			µg/l

	Compound	WSA	NW4	WFD	WFD	Unit
	(priority compounds in italics)	(drinking water)	MTR	MAC, inland	MAC, DWA	
37	1,2-Dichloropropane	1	76			µg/l
38	1,3-Dichloropropane	1	76			µg/l
39	3-Chloropropene	1	3			µg/l
40	1,3-Dichloropropene	1	8			µg/l
41	2,3-Dichloropropene	1	8			µg/l
Chlorobenzenes						
42	Monochlorobenzene	1	690			µg/l
43	Dichlorobenzenes	1	250			µg/l
44	<i>Trichlorobenzenes (1,2,4-TCB)</i>	1	67	50		µg/l
45	Tetrachlorobenzenes	1	24			µg/l
46	<i>Pentachlorobenzene</i>	1	0.3	1		µg/l
47	<i>Hexachlorobenzene</i>	1	0.009	0.05		µg/l
48	Monochlorotoluenes	1	310			µg/l
Chlorophenols						
49	Monochlorophenols	1	25			µg/l
50	Dichlorophenols	1	15			µg/l
51	Trichlorophenols	1	3			µg/l
52	<i>Pentachlorophenol</i>	1	4	1	0.1	µg/l
HCH isomers						
53	α -HCH	0.1	3.3			µg/l
54	β -HCH	0.1	0.86			µg/l
55	γ -HCH (<i>lindane</i>)	0.1	0.92	0.04		µg/l
Phenyl-urea herbicides						
56	<i>Diuron</i>	0.1	0.43	1.8	0.1	µg/l
57	<i>Isoproturon</i>	0.1	0.32	1.3	0.1	µg/l
58	Linuron	0.1	0.25			µg/l
59	Metabenzthiazuron	0.1	1.8			µg/l
60	Metobromuron	0.1	10			µg/l
Anilides						
61	<i>Alachlor</i>	0.1		0.7	0.1	
62	Metazachlor	0.1	34			µg/l
63	Metolachlor	0.1	0.2			µg/l
64	Propachlor	0.1	1.3			µg/l
Triazines						
65	<i>Atrazin</i>	0.1	2.9	2.9	0.1	µg/l
66	Cyanazin	0.1	0.19			µg/l
67	Desmetryn	0.1	34			µg/l
68	Metamitron	0.1	10			µg/l
69	<i>Simazin</i>	0.1	0.14	3.4	0.1	µg/l

	Compound	WSA	NW4	WFD	WFD	Unit
	(priority compounds in italics)	(drinking water)	MTR	MAC, inland	MAC, DWA	
Carbamates						
70	Benomyl	0.1	0.15			µg/l
71	Carbaryl	0.1	0.23			µg/l
72	Carbendazim	0.1	0.11			µg/l
73	Carbofuran	0.1	0.91			µg/l
74	Oxamyl	0.1	1.8			µg/l
75	Triallate	0.1	1.9			µg/l
Chlorophenoxyacetic acids						
76	2,4-D	0.1	10			µg/l
77	2,4,5-T	0.1	9			µg/l
78	Dichlorprop	0.1	40			µg/l
79	MCPA	0.1	2			µg/l
80	Mecoprop	0.1	4			µg/l
Organophosphate esters						
81	<i>Chlorfenvinfos</i>	0.1	0.002	0.3	0.1	µg/l
82	<i>Chlorpyrifos</i>	0.1	0.003	0.1		µg/l
83	Demeton	0.1	0.14			µg/l
84	Dimethoate	0.1	23			µg/l
85	Tolclofos-methyl	0.1	0.80			µg/l
Organotin compounds						
86	<i>Tributyltin (cation)</i>	0.1	0.014	0.002		µg/l
87	Tetrabutyltin	0.1	1.6			µg/l
Other pesticides						
88	Bentazon	0.1	64			µg/l
89	Chloridazon	0.1	73			µg/l
90	Captan	0.1	0.11			µg/l
91	Dieldrin	0.03	0.039			µg/l
92	DNOC	0.1	21			µg/l
93	<i>Endosulfan</i>	0.1	0.02	0.01		µg/l
94	<i>Hexachlorobutadiene</i>	0.1		0.6		µg/l
95	Quintozene	0.1	3.1			µg/l
96	<i>Trifluralin</i>	0.1	0.038	1	0.1	µg/l
Endocrine disrupters						
97	<i>DEHP</i>					µg/l
98	<i>Octylphenol</i>			0.13		µg/l
99	<i>Nonylphenol</i>			2.1		µg/l
100	<i>Penta-bromodiphenylether</i>			1.4		µg/l

WSA = Water Supply Act

NW4 = 4th National Policy Document on Water Management (1998)

MTR = maximum allowable risk

MAC = maximum allowable concentration

DWA = drinking water abstraction

II Overview of Koc and Henry constant of the studied compounds

Compound	MW	log Koc	ref	He (Pa m ³ /mol)	ref
Benzene and derivatives					
Benzene	78.11	1.90	CIW	550	Mackay
Toluene	92.13	2.08	CIW	670	Mackay
Xylenes	106.2	2.80	CIW	640	Mackay
Ethylbenzene	106.2	2.23	CIW	800	Mackay
Styrene	104.2	2.95	CIW	232	ECB
PAHs					
Naphthalene	128.2	3.3	CIW	43	Mackay
Anthracene	178.2	5.3	RIZA	6	Mackay
Fluoranthene	202.3	5.6	RIZA	0.65	Hulscher
Chrysene	228.3	6.4	RIZA	0.45	Mackay
Benzo(b)fluoranthene	252.3	6.6	RIZA	0.051	Hulscher
Benzo(k)fluoranthene	252.3	6.6	RIZA	0.044	Hulscher
Benzo(a)pyrene	252.0	6.6	RIZA	0.034	Hulscher
Benzo(ghi)perylene	276.3	7.0	RIZA	0.027	Hulscher
Indeno(123-cd)pyrene	276.3	7.2	RIZA	0.029	Hulscher
Chlorinated aliphatics					
Dichloromethane	84.9	1.56	CIW	210	Tse
Trichloromethane	119.4	1.81	CIW	280	Tse
Tetrachloromethane	153.8	2.83	CIW	2040	Tse
1,2-Dichloroethane	98.97	1.26	CIW	100	Tse
1,1,1-Trichloroethane	133.4	1.82	CIW	1260	Tse
1,1,2-Trichloroethane	133.4	1.99	CIW	70	Tse
1,1,2,2-Tetrachloroethane	167.85	1.92	CIW	30	Tse
Pentachloroethane	202.3	3.63	CIW	220	Mackay
Vinyl chloride	62.5	1.52	CIW	2350	Mackay
1,1-Dichloroethene	96.94	1.86	CIW	2290	Tse
1,2-Dichloroethene	96.94	1.86	CIW	560	Tse
Trichloroethene	131.4	2.04	CIW	700	Tse
Tetrachloroethene	165.83	2.38	CIW	2300	Mackay
1,2-Dichloropropane	112.99	1.61	CIW	210	Tse
1,3-Dichloropropane	112.99	1.61	CIW	210	Mackay
3-Chloropropene	76.52	1.45	CIW	200	exp jud
1,3-Dichloropropene	110.97	1.69	CIW	200	exp jud
2,3-Dichloropropene	110.97	1.97	CIW	200	exp jud
Chlorobenzenes					
Monochlorobenzene	112.6	2.34	CIW	350	Mackay
Monochlorotoluenes	126.6	3.26	CIW	407	Howard IV
Dichlorobenzenes	147.0	2.64	CIW	240	Mackay
1,2,4-Trichlorobenzene	181.5	3.31	CIW	101	Hulscher

Compound	MW	log Koc	ref	He (Pa m ³ /mol)	ref
Tetrachlorobenzenes	215.9	3.78	CIW	80	Hulscher
Pentachlorobenzene	250.3	4.9	RIZA	59	Hulscher
Hexachlorobenzene	284.8	5.6	RIZA	41	Hulscher
Chlorophenols					
Monochlorophenols	128.6	2.13	CIW	0.056	Howard I
Dichlorophenols	163.0	2.53	CIW	0	exp jud
Trichlorophenols	197.5	2.83	CIW	0.006	Howard I
Pentachlorophenol	266.3	3.16	CIW	0.275	Howard III
α -HCH	290.8	3.25	RIVM	0.2	exp jud
β -HCH	290.8	3.36	RIVM	0.2	exp jud
γ -HCH (lindane)	290.8	2.98	RIVM	0.2	WSV
Phenyl-urea herbicides					
Diuron	233.1	2.55	CIW	5.60E-05	WSV
Isoproturon	206.3	2.45	CIW	1.10E-05	WSV
Linuron	249.1	2.78	CIW	6.30E-03	WSV
Metabenzthiazuron	221.3	2.80	CIW	4.90E-04	WSV
Metobromuron	259.1	2.27	CIW	3.10E-04	WSV
Anilides					
Alachlor		2.27	RIVM	0	exp jud
Metazachlor	277.8	2.11	CIW	0.00056	WSV
Metolachlor	283.8	2.33	CIW	0.0013	WSV
Propachlor	211.7	1.91	CIW	0.010	WSV
Triazines					
Atrazin	215.7	2.20	CIW	2.90E-04	WSV
Cyanazin	240.7	2.26	CIW	3.00E-07	WSV
Desmetryn	213.3	2.27	CIW	4.90E-05	WSV
Metamitron		2.20	CIW	0	exp jud
Simazin	201.7	2.04	CIW	3.40E-04	WSV
Carbamates					
Benomyl	290.3	1.84	CIW	0	exp jud
Carbaryl	201.2	2.26	CIW	1.30E-03	Howard III
Carbendazim	191.2	2.61	CIW	2.50E-06	WSV
Carbofuran	221.3	1.53	CIW	5.10E-04	WSV
Oxamyl	219.3	1.05	CIW	2.60E-05	WSV
Triallate	304.7	3.12	CIW	6.20E-04	WSV
Chlorophenoxy carb. acids					
2,4-D	221.0	1.66	CIW	0	WSV
2,4,5-T	255.5	1.99	CIW	6.70E-04	Howard III
Dichlorprop	235.1	3.13	CIW	0	WSV
MCPA	200.6	1.73	CIW	0	WSV
Mecoprop	214.6	0.92	CIW	0	WSV

Compound	MW	log Koc	ref	He (Pa m ³ /mol)	ref
Organophosphate esters					
Chlorfenvinfos	359.6	3.12	CIW	2.80E-04	WSV
Chlorpyrifos	350.6	3.81	CIW	1.75	WSV
Demeton					
Dimethoate	229.2	1.76	CIW	1.10E-04	WSV
Tolclofos-methyl	301.1	3.45	CIW	49	WSV
Organotin compounds					
Tributyltin (cation)	290.0	4.6	WSV	0.02	WSV
Tetrabutyltin	347.2	3.1	WSV	9.47	WSV
Other pesticides					
Bentazon	240.3	1.52	CIW	0	WSV
Chloridazon	221.6	1.91	CIW	3.68	WSV
Captan	300.6	2.30	CIW	0.6	WSV
Dieldrin	373.9	5.80	CIW	1.1	Mackay
DNOC	198.1	2.34	CIW	1.10E-02	WSV
Endosulfan	407.0	3.04	CIW	3.0	WSV
Hexachlorobutadiene	260.8	4.07	Howard I	1030	Howard I
Quintozene		4.29	CIW	0	exp jud
Trifluralin	335.3	3.93	CIW	5.42	WSV
Endocrine disrupters					
DEHP	391.0	6.2	RIZA/RIKZ	1.7	RIZA/RIKZ
Octylphenol	206.3	3.4	RIKZ	16	RIKZ
Nonylphenol	220.0	3.7	RIKZ	315	RIKZ
Penta-bromodiphenylether	565.0	5.6	RIZA/RIKZ	4.9	RIZA/RIKZ

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III Current water quality in the Rivers Rhine and Meuse

These tables show the current water quality (maximum concentration) of the Rivers Rhine and Meuse. Compounds have been divided into priority and non-priority. Excess values above the desired surface water standards (DSWS) are shown in red; orange indicates that the detection limit is above the desired surface water standard (i.e. no assessment with regard to standard compliance can be made).

Table 15: Priority compounds in the River Rhine (Lobith), Lake IJsselmeer (Andijk) and canals mainly fed by Rhine water (other), compared with the desired surface water standards (DSWS). All data in $\mu\text{g/l}$.

RHINE Compound	DSWS	Lobith		Nieuwegein		Nieuwersluis		Andijk		Twente canal	
		2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
		max	max	max	max	max	max	max	max	max	max
Cadmium	50	0.1	0.4	0.15	0.4	0.11	0.13	< 0.1	< 0.1	0.22	0.16
Mercury	2	0.054	0.22	0.07	0.08	0.02	0.05	0.07	< 0.05	0.24	0.19
Lead	100	8.3	33	4.3	17.7	3.7	3.3	3.4	3	7.5	5.5
Nickel	40	9.5	19	3	3	4	2	3	2.3	8	9.5
Benzene	2.50	0.33	0.1	< 0.1	0.15	< 0.1	0.06	< 0.1	< 0.1	< 0.01	0.01
Anthracene	0.15	n.a.	n.a.	0.04	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Fluoranthene	0.17	n.a.	n.a.	0.23	0.03	0.12	< 0.04	< 0.01	< 0.01	0.03	0.05
Benzo(b)fluoranthene	0.33	n.a.	n.a.	0.05	0.01	0.04	0.02	< 0.01	< 0.01	0.02	0.03
Benzo(k)fluoranthene	0.33	n.a.	n.a.	0.03	< 0.01	0.02	< 0.01	< 0.01	< 0.01	0.01	0.01
Benzo(a)pyrene	0.03	n.a.	n.a.	0.05	< 0.01	0.03	0.02	< 0.01	< 0.01	0.02	0.03
Benzo(ghi)perylene	0.40	n.a.	n.a.	0.01	< 0.01	0.03	0.01	< 0.01	< 0.01	0.02	0.02
Indeno(123-cd)pyrene	0.40	n.a.	n.a.	< 0.01	< 0.01	0.03	0.01	< 0.01	0.01	0.01	0.02
Dichloromethane	2.00	n.a.	n.a.	n.a.	n.a.	n.a.	0.1	n.a.	n.a.	n.a.	n.a.

RHINE	DSWS	Lobith		Nieuwegein		Nieuwersluis		Andijk		Twente canal	
Compound		2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
		max	max	max	max	max	max	max	max	max	max
Trichloromethane	50	0.07	0.07	< 0.1	< 0.1	< 0.1	0.05	< 0.1	0.2	5.5	6.6
1,2-Dichloroethane	5.45	0.14	0.05	n.a.	n.a.	n.a.	0.08	n.a.	< 1	< 0.1	< 0.1
Trichlorobenzenes (1,2,4-TCB)	1.54	n.a.	n.a.	n.a.	n.a.	< 0.1	< 0.05	n.a.	< 0.02	n.a.	n.a.
Pentachlorobenzene	1.54	n.a.	n.a.	n.a.	n.a.	< 0.05	< 0.05	n.a.	n.a.	< 0.05	< 0.05
Hexachlorobenzene	2.00	0.002	< 0.002	< 0.01	< 0.01	< 0.05	< 0.05	< 0.02	< 0.02	< 0.05	< 0.05
Pentachlorophenol	1.0	n.a.	n.a.	n.a.	n.a.	< 0.02	< 0.02	< 0.02	< 0.02	< 0.1	< 0.1
γ-HCH (lindane)	0.10	0.002	0.001	< 0.01	< 0.01	< 0.01	< 0.01	< 0.1	< 0.1	< 0.05	< 0.05
Diuron	0.10	0.05	0.08	0.1	0.13	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1
Isoproturon	0.10	0.08	0.07	0.51	0.09	0.2	< 0.3	0.07	< 0.03	< 0.1	< 0.1
Alachlor	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.1	< 0.1
Atrazin	0.10	0.07	0.07	0.17	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.02	< 0.02
Simazin	0.10	< 0.02	< 0.03	0.03	< 0.03	< 0.05	< 0.05	< 0.05	< 0.05	0.17	0.09
Chlorfenvinfos	0.10	0.01	< 0.01	< 0.05	< 0.06	< 0.05	< 0.06	n.a.	n.a.	< 0.05	< 0.05
Chlorpyrifos	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tributyltin (cation)	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Endosulfan	0.10	< 0.001	< 0.001	< 0.01	< 0.01	< 0.01	< 0.01	< 0.3	< 0.3	< 0.1	< 0.1
Hexachlorobutadiene	0.17	n.a.	n.a.	n.a.	n.a.	< 0.01	< 0.01	n.a.	n.a.	n.a.	n.a.
Trifluralin	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table 16: Priority compounds in the River Meuse ($\mu\text{g/l}$), at the border station Eijsden and two locations further downstream, compared with the desired surface water standards (DSWS).

MEUSE	DSWS	Eijsden		Heel		Keizersveer	
Compound		2002	2003	2002	2003	2002	2003
		max	max	max	max	max	max
Cadmium	50	1.8	1.6	< 0.2	< 0.5	0.4	0.24
Mercury	2	0.15	0.04	< 0.1	< 0.1	0.04	0.02
Lead	100	47	9.4	3.5	4	12	5
Nickel	40	33	12	4	5	7	5
Benzene	2.50	0.02	0.1	< 0.05	< 0.05	< 0.03	< 0.03
Anthracene	0.15	0.24	< 0.02	< 0.005	< 0.005	0.015	< 0.01
Fluoranthene	0.17	0.21	0.06	0.009	0.02	0.132	0.01
Benzo(b)fluoranthene	0.33	0.09	< 0.05	< 0.005	0.016	0.127	0.016
Benzo(k)fluoranthene	0.33	0.04	0.02	< 0.005	0.007	0.042	0.012
Benzo(a)pyrene	0.03	0.08	< 0.03	< 0.005	0.013	0.083	< 0.01
Benzo(ghi)perylene	0.40	0.06	< 0.04	< 0.005	0.011	0.065	0.024
Indeno(123-cd)pyrene	0.40	0.05	< 0.03	< 0.005	0.01	0.075	0.022
Dichloromethane	2.00	n.a.	n.a.	< 1	< 0.05	n.a.	n.a.
Trichloromethane	50	0.3	0.2	< 0.1	< 0.05	0.1	0.06
1,2-Dichloroethane	5.45	1.1	0.46	0.15	0.13	0.34	0.12
Trichlorobenzenes (1,2,4-TCB)	1.54	< 0.01	< 0.01	n.a.	< 0.05	n.a.	n.a.
Pentachlorobenzene	1.54	< 0.001	< 0.001	n.a.	n.a.	n.a.	n.a.
Hexachlorobenzene	2.00	< 0.001	< 0.001	< 0.02	< 0.02	< 0.02	< 0.02
Pentachlorophenol	1.0	< 0.02	0.02	< 0.1	< 0.1	n.a.	< 0.02
γ -HCH (lindane)	0.10	0.006	0.005	< 0.02	< 0.02	< 0.1	< 0.1
Diuron	0.10	0.45	0.52	0.51	0.38	0.37	0.21

MEUSE	DSWS	Eijsden		Heel		Keizersveer	
Compound		2002	2003	2002	2003	2002	2003
		max	max	max	max	max	max
Isoproturon	0.10	0.15	0.15	0.6	0.15	0.15	0.07
Alachlor	0.10	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.05
Atrazin	0.10	0.19	0.22	0.18	0.15	0.18	0.12
Simazin	0.10	0.12	0.04	0.04	0.06	0.07	0.07
Chlorfenvinfos	0.10	< 0.01	< 0.01	n.a.	n.a.	< 0.06	< 0.06
Chlorpyrifos	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tributyltin (cation)	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Endosulfan	0.10	0.003	0.005	< 0.1	< 0.1	n.a.	< 0.3
Hexachlorobutadiene	0.17	0.002	0.001	< 0.02	< 0.05	< 0.1	< 0.1
Trifluralin	0.10	< 0.01	< 0.01	n.a.	n.a.	n.a.	n.a.

Table 17: Non-priority compounds in the River Rhine (Lobith), Lake IJsselmeer (Andijk) and canals mainly fed by Rhine water (other), compared with the desired surface water standards (DSWS). All data in µg/l.

RHINE	DSWS	Lobith		Nieuwegein		Nieuwersluis		Andijk		Twente canal	
Compound		2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
		max	max	max	max	max	max	max	max	max	max
1,1,1-Trichloroethane	2.00	0.01	< 0.01	< 0.1	< 0.1	< 0.1	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05
1,1,2,2-Tetrachloroethane	1.33	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.2	n.a.	n.a.
1,1,2-Trichloroethane	1.54	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.1	< 0.05	< 0.05
1,1-Dichloroethene	2.22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 1	< 1
1,2-Dichloroethene	2.22	0.01	< 0.01	< 0.1	< 0.05	0.17	< 0.05	< 0.01	< 0.02	< 0.12	< 0.28
1,2-Dichloropropane	1.82	0.01	0.02	< 0.1	< 0.02	< 0.1	< 0.05	< 0.1	< 0.02	< 0.05	< 0.05
1,3-Dichloropropane	1.82	0.01	< 0.01	n.a.	n.a.	n.a.	< 0.05	n.a.	n.a.	< 0.05	< 0.05
1,3-Dichloropropene	1.82	0.01	< 0.01	< 0.1	< 0.02	< 0.1	< 0.05	< 0.1	n.a.	< 0.05	< 0.05
2,3-Dichloropropene	1.82	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2,4,5-T	0.10	n.a.	n.a.	< 0.02	< 0.02	< 0.02	0.05	< 0.02	< 0.02	< 0.05	< 0.05
2,4-D	0.10	n.a.	n.a.	0.1	0.05	0.02	0.05	< 0.02	< 0.02	< 0.1	< 0.1
3-Chloropropene	2.22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Antimony	10	0.5	0.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 3	< 3
Arsenic	20	2.3	3	2	1	2	2	1	2	< 2	< 2
Benomyl	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bentazon	0.10	n.a.	n.a.	0.03	0.03	0.06	0.04	0.03	0.02	< 0.05	< 0.05
Captan	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Carbaryl	0.10	n.a.	n.a.	n.a.	n.a.	< 0.01	< 0.05	< 0.01	n.a.	n.a.	n.a.
Carbendazim	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.03	n.a.	n.a.

RHINE	DSWS	Lobith		Nieuwegein		Nieuwersluis		Andijk		Twente canal	
Compound		2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
		max	max	max	max	max	max	max	max	max	max
Carbofuran	0.10	n.a.	n.a.	n.a.	n.a.	< 0.01	< 0.05	< 0.01	n.a.	n.a.	n.a.
Chloridazon	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.05	n.a.	n.a.	n.a.	n.a.
Chloride (mg/l)	150	140	184	114	150	97	136	101	180	92	250
Chromium	77	9.8	27	2	3	3	< 2	< 2	< 2	< 2	< 2
Chrysene	0.33	n.a.	n.a.	0.07	< 0.01	0.04	0.01	< 0.01	< 0.01	0.01	0.02
Cyanazin	0.10	n.a.	n.a.	< 0.05	< 0.05	< 0.05	0.05	< 0.05	< 0.05	< 0.05	< 0.05
Demeton	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Desmetryn	0.10	n.a.	n.a.	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.02	< 0.02
Dichlorobenzenes	1.82	n.a.	n.a.	< 0.3	< 0.15	< 0.15	< 0.15	< 0.3	< 0.02	< 0.03	< 0.03
Dichlorophenols	1.0	n.a.	n.a.	n.a.	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.3	< 0.3
Dichlorprop	0.10	n.a.	n.a.	< 0.02	< 0.02	0.02	< 0.02	< 0.02	< 0.02	< 0.05	< 0.05
Dieldrin	0.06	n.a.	n.a.	< 0.01	< 0.01	n.a.	< 0.01	< 0.01	n.a.	< 0.1	< 0.1
Dimethoate	0.10	0.01	0.01	< 0.05	< 0.1	< 0.05	< 0.1	< 0.05	< 0.1	n.a.	n.a.
DNOC	0.10	n.a.	n.a.	n.a.	< 0.03	n.a.	< 0.03	< 0.03	n.a.	< 0.1	< 0.1
Ethylbenzene	2.22	n.a.	0.01	< 0.1	< 0.1	< 0.1	< 0.05	< 0.1	< 0.02	< 0.01	< 0.01
Fluoride (mg/l)	1.1	0.19	0.23	0.18	0.22	0.17	0.19	0.16	0.19	0.12	0.13
Linuron	0.10	0.05	< 0.03	< 0.1	< 0.03	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1
MCPA	0.10	n.a.	n.a.	< 0.02	0.02	0.05	0.04	< 0.02	< 0.02	< 0.05	< 0.05
Mecoprop	0.10	n.a.	n.a.	< 0.02	0.03	0.1	0.06	0.02	< 0.02	0.15	0.12
Metabenzthiazuron	0.10	0.01	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Metamitron	0.10	n.a.	< 0.03	< 0.03	< 0.03	< 0.1	< 0.05	< 0.1	< 0.05	n.a.	n.a.
Metazachlor	0.10	n.a.	n.a.	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.2	< 0.2
Metobromuron	0.10	0.05	< 0.01	n.a.	n.a.	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1
Metolachlor	0.10	n.a.	n.a.	< 0.02	< 0.02	< 0.02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Monochlorobenzene	2.00	n.a.	n.a.	< 0.1	< 0.1	< 0.1	< 0.05	< 0.1	< 0.02	< 0.01	< 0.02

RHINE	DSWS	Lobith		Nieuwegein		Nieuwersluis		Andijk		Twente canal	
Compound		2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
		max	max	max	max	max	max	max	max	max	max
Monochlorophenols	1.0	n.a.	n.a.	n.a.	< 0.04	< 0.06	< 0.06	< 0.06	< 0.06	< 0.3	< 0.3
Monochlorotoluenes	2.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Oxamyl	0.10	n.a.	n.a.	n.a.	n.a.	< 0.01	< 0.05	< 0.01	n.a.	n.a.	n.a.
Pentachloroethane	1.67	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Propachlor	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Quintozene	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.1	< 0.1
Styrene	2.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tetrabutyltin	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tetrachlorobenzenes	1.43	n.a.	n.a.	n.a.	n.a.	< 0.15	< 0.15	n.a.	n.a.	n.a.	n.a.
Tetrachloroethene	18.18	0.09	0.05	< 0.1	0.1	0.17	< 0.05	< 0.1	< 0.1	< 0.05	< 0.05
Tetrachloromethane	1.82	0.01	< 0.01	< 0.1	< 0.1	< 0.1	0.05	< 0.1	< 0.1	< 0.05	< 0.05
Tolclofos-methyl	0.13	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.05	n.a.	n.a.	n.a.	n.a.
Toluene	2.22	0.03	0.03	0.1	< 0.05	< 0.1	0.06	0.1	< 0.02	0.08	0.07
Triallate	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Trichloroethene	20	0.02	0.01	< 0.1	< 0.1	< 0.1	< 0.05	< 0.1	< 0.1	0.08	0.28
Trichlorophenols	1.0	n.a.	n.a.	n.a.	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.6	< 0.6
Vinyl chloride	1.43	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Xylenes	2.00	0.06	0.02	< 0.1	< 0.1	< 0.1	< 0.05	< 0.05	< 0.02	0.01	0.05
α -HCH	0.10	< 0.001	< 0.001	< 0.01	< 0.01	< 0.01	< 0.01	< 0.1	< 0.1	< 0.05	< 0.05
β -HCH	0.10	< 0.06	< 0.001	0.12	< 0.01	< 0.01	< 0.01	< 0.01	n.a.	< 0.05	< 0.05

Table 18: Non-priority compounds in the River Meuse ($\mu\text{g/l}$), at the border station Eijsden and two locations further downstream, compared with the desired surface water standards (DSWS).

MEUSE	DSWS	Eijsden		Heel		Keizersveer	
Compound		2002	2003	2002	2003	2002	2003
		max	max	max	max	max	max
1,1,1-Trichloroethane	2.00	0.07	0.03	< 0.1	< 0.05	< 0.03	< 0.03
1,1,2,2-Tetrachloroethane	1.33	n.a.	n.a.	n.a.	< 0.05	n.a.	n.a.
1,1,2-Trichloroethane	1.54	0.04	0.02	n.a.	< 0.05	n.a.	n.a.
1,1-Dichloroethene	2.22	0.02	0.01	n.a.	< 0.05	n.a.	n.a.
1,2-Dichloroethene	2.22	0.22	0.22	n.a.	< 0.05	n.a.	n.a.
1,2-Dichloropropane	1.82	0.05	0.02	< 0.05	< 0.05	< 0.03	< 0.03
1,3-Dichloropropane	1.82	< 0.01	< 0.01	< 0.05	< 0.05	< 0.03	< 0.03
1,3-Dichloropropene	1.82	< 0.01	< 0.01	< 0.05	< 0.05	< 0.03	< 0.03
2,3-Dichloropropene	1.82	n.a.	n.a.	< 0.05	n.a.	n.a.	n.a.
2,4,5-T	0.10	< 0.05	< 0.05	< 0.05	< 0.05	n.a.	n.a.
2,4-D	0.10	0.06	0.13	< 0.05	< 0.05	0.03	0.05
3-Chloropropene	2.22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Antimony	10	n.a.	n.a.	n.a.	n.a.	2	< 1
Arsenic	20	2.5	1.8	5.5	3	3	2
Benomyl	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bentazon	0.10	0.02	0.04	< 0.05	< 0.05	0.05	0.1
Captan	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Carbaryl	0.10	n.a.	n.a.	n.a.	n.a.	< 0.05	< 0.05
Carbendazim	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Carbofuran	0.10	n.a.	n.a.	n.a.	n.a.	< 0.05	< 0.05

MEUSE	DSWS	Eijsden		Heel		Keizersveer	
Compound		2002	2003	2002	2003	2002	2003
		max	max	max	max	max	max
Chloridazon	0.10	< 0.01	0.04	n.a.	n.a.	< 0.05	n.a.
Chloride (mg/l)	150	104	88	66	72	61	67
Chromium	77	43	6.1	1	1	5	2
Chrysene	0.33	0.09	0.02	< 0.005	0.01	0.086	< 0.01
Cyanazin	0.10	n.a.	n.a.	0.02	< 0.02	n.a.	n.a.
Demeton	0.10	< 0.05	< 0.05	n.a.	n.a.	n.a.	n.a.
Desmetryn	0.10	n.a.	n.a.	< 0.02	< 0.02	< 0.03	< 0.03
Dichlorobenzenes	1.82	< 0.08	0.07	< 0.15	< 0.15	n.a.	n.a.
Dichlorophenols	1.0	< 0.06	2.2	< 0.6	< 0.6	n.a.	n.a.
Dichlorprop	0.10	0.08	0.11	< 0.05	< 0.05	< 0.03	< 0.03
Dieldrin	0.06	< 0.003	< 0.001	< 0.05	< 0.05	< 0.15	< 0.15
Dimethoate	0.10	0.12	0.05	n.a.	n.a.	< 0.1	< 0.1
DNOC	0.10	0.08	0.03	< 0.03	< 0.03	< 0.03	0.04
Ethylbenzene	2.22	< 0.01	0.04	< 0.05	< 0.05	< 0.03	< 0.03
Fluoride (mg/l)	1.1	1.4	1.8	0.76	0.95	0.52	0.5
Linuron	0.10	< 0.05	0.01	< 0.05	< 0.05	< 0.008	0.09
MCPA	0.10	0.07	0.09	< 0.05	< 0.05	0.08	0.09
Mecoprop	0.10	0.09	0.16	0.05	0.06	0.08	0.12
Metabenzthiazuron	0.10	< 0.01	< 0.01	< 0.05	< 0.1	< 0.02	< 0.02
Metamitron	0.10	< 0.05	< 0.05	n.a.	n.a.	n.a.	n.a.
Metazachlor	0.10	< 0.05	< 0.05	0.02	< 0.02	< 0.1	< 0.1
Metobromuron	0.10	< 0.05	< 0.01	< 0.05	< 0.05	< 0.02	< 0.02
Metolachlor	0.10	0.06	0.1	< 0.01	0.01	0.2	0.19
Monochlorobenzene	2.00	< 0.01	0.02	< 0.05	< 0.05	< 0.03	< 0.03
Monochlorophenols	1.0	< 1.5	< 0.15	< 0.3	< 0.22	n.a.	n.a.

MEUSE	DSWS	Eijsden		Heel		Keizersveer	
Compound		2002	2003	2002	2003	2002	2003
		max	max	max	max	max	max
Monochlorotoluenes	2.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Oxamyl	0.10	n.a.	n.a.	n.a.	n.a.	< 0.05	< 0.05
Pentachloroethane	1.67	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Propachlor	0.10	n.a.	n.a.	< 0.01	< 0.01	< 0.03	< 0.03
Quintozene	0.10	n.a.	n.a.	n.a.	n.a.	< 0.1	< 0.1
Styrene	2.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tetrabutyltin	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tetrachlorobenzenes	1.43	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tetrachloroethene	18.18	1.3	0.44	< 0.1	0.09	0.14	0.14
Tetrachloromethane	1.82	0.03	0.01	< 0.1	< 0.05	< 0.03	< 0.03
Tolclofos-methyl	0.13	< 0.05	< 0.01	n.a.	n.a.	n.a.	n.a.
Toluene	2.22	0.1	0.08	< 0.05	< 0.05	< 0.03	< 0.03
Triallate	0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Trichloroethene	20	0.31	0.31	< 0.1	0.06	0.09	0.13
Trichlorophenols	1.0	< 0.12	< 0.54	< 0.6	< 0.6	n.a.	n.a.
Vinyl chloride	1.43	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Xylenes	2.00	< 0.01	0.07	< 0.05	< 0.05	< 0.03	< 0.03
α -HCH	0.10	< 0.001	< 0.001	< 0.02	< 0.02	< 0.1	< 0.1
β -HCH	0.10	< 0.004	< 0.001	< 0.02	< 0.02	< 0.1	< 0.1