Environmental risk limits for polycyclic aromatic hydrocarbons (PAHs)

For direct aquatic, benthic, and terrestrial toxicity

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E.M.J. Verbruggen
Colophon

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This investigation has been performed by order and for the account of Ministry of Infrastructure and Environment (I&M), within the framework of Soil Quality, Prevention and Risk Assessment
Abstract

Environmental risk limits for polycyclic aromatic hydrocarbons (PAHs)
For direct aquatic, benthic, and terrestrial toxicity

RIVM derived maximum permissible concentrations (MPCs) and serious risk concentrations (SRC) for ecosystems for the 16 well-known polycyclic aromatic hydrocarbons (PAHs). This is done for all individual PAHs for water, sediment and soil. Data on the toxic effects were collected for each PAH in water, soil and sediment organisms. For this study, the methodology of the framework ‘International and national environmental quality standards for substances in the Netherlands’ (INS) is used. This method is nationally recognized and where possible, based on European directives.

Alternative research method for environmental risk limits PAHs
In this study the environmental risk limits were also derived in an alternative way. For this goal, the knowledge was used from previous research on the environmental risk limits of mineral oil that was suitable for PAHs as well. The environmental risk limits are derived based on the calculated concentration of substances in the organisms after they have taken up the substances from the water (for sediment and soil: water in sediment or soil moisture). This method is based on the assumption that certain effects of all 16 PAHs occur at the same concentrations in organisms that live in water, soil and sediment. Because PAHs cause effects in the same way, the concentrations can be added together. This provides insight into the effect of all PAHs simultaneously, as they occur in the environment (toxic unit approach).

Difference in internal and external concentrations
The internal effect concentration of PAHs does not differ between organisms in soil, water and sediment. In contrast, large differences between the effect concentrations of the substances outside the organisms were observed. Especially the effect concentrations between soil or sediment on the one hand and water on the other hand were different, and also the effect concentrations of individual PAHs in water. The harmful effects of the substances are thus largely determined by the extent to which a substance is partitioned between water, soil and sediment, and is taken up from water (equilibrium partitioning). As an example, soil binds a substance strongly, so less will end up in soil moisture and eventually in soil organisms. Measurements of concentrations of substances in the environment would thus be better based on concentrations in water.

Keywords:
naphthalene, acenaphthene, acenaphthylene, fluorene, phenanthrene, anthracene, pyrene, fluoranthene, chrysene, benzo[a]anthracene, benzo[k]fluoranthene, benzo[b]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene, dibenz[a,h]anthracene, indeno[1,2,3-cd]pyrene
Rapport in het kort

Milieurisicogrenzen voor polycyclische aromatische koolwaterstoffen (PAK's)
Voor directe aquatische, benthische en terrestrische toxiciteit

Het RIVM heeft de maximaal toelaatbare risiconiveaus (MTR) en ernstige risiconiveaus (ER) voor ecosystemen afgeleid voor de 16 bekendste polycyclische aromatische koolwaterstoffen (PAK's). Dit is voor alle afzonderlijke PAK's gedaan voor water, sediment en bodem. Hiervoor zijn gegevens verzameld over de giftige effecten van elke PAK op water-, bodem- en sedimentorganismen. Voor het onderzoek is de methodologie van het kader ‘(Inter)nationale normen stoffen’ (INS) gebruikt. Deze methode is nationaal erkend en waar mogelijk gebaseerd op Europese richtlijnen.

Alternatieve onderzoekswijze voor milieurisicogrenzen PAK's
In dit onderzoek zijn de milieurisicogrenzen ook op een alternatieve manier afgeleid. Hiervoor is de kennis gebruikt van eerder uitgevoerd onderzoek naar de milieurisicogrenzen van minerale olie die ook geschikt bleek voor PAK's. De milieurisicogrenzen zijn afgeleid op basis van de berekende concentratie van stoffen in organismen nadat zij de stoffen via het water hebben opgenomen (voor sediment en bodem: water in sediment of bodemvocht). Deze methode is gebaseerd op de aannemer dat bepaalde effecten van alle 16 PAK's optreden bij dezelfde concentraties in organismen die leven in water, bodem en sediment. Omdat de PAK's op dezelfde manier effecten veroorzaken, mogen de concentraties bij elkaar opgeteld worden. Hierdoor wordt inzicht verkregen in het effect van alle PAK's tegelijkertijd, zoals ze ook in het milieu voorkomen (toxic unit approach).

Verschil inwendige en externe concentraties
De inwendige effectconcentratie van PAK's blijkt bij organismen in bodem, water en sediment niet te verschillen. Daarentegen zijn grote verschillen tussen de effectconcentraties van de stoffen aangetroffen als deze buiten de organismen werden waargenomen. Vooral de effectconcentraties tussen bodem of sediment enerzijds en water anderszijds verschilren, evenals de effectconcentraties van de individuele PAK's in water. De schadelijke effecten van de stoffen worden dus in grote mate bepaald door de mate waarin een stof zich verdeeld tussen water, bodem en sediment en wordt opgenomen vanuit water (evenwichts-partitie). Zo bindt de bodem een stof sterk aan zich waardoor er minder in bodemvocht en uiteindelijk in bodemorganismen terechtkomt. Metingen van concentraties van stoffen in het milieu zouden daardoor beter gebaseerd kunnen worden op concentraties in water.

Trefwoorden:
naftaleen, acenafteen, acenaftyleen, fluoreen, fenantreen, antraceen, pyreen, fluoranteen, chryseen, benz[a]antraceen, benzo[k]fluoranteen, benzo[b]fluoranteen, benzo[a]pyreen, benzo[ghi]peryleen, dibenzo[a,h]antraceen, indeno[1,2,3-cd]pyreen
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Summary

In this report, maximum permissible concentrations for ecosystems (MPC_{eco}), maximum acceptable concentrations for aquatic ecosystems (MAC_{eco,water}), and serious risk concentrations for ecosystems (SRC_{eco}) are derived for polycyclic aromatic hydrocarbons (PAHs). These environmental risk limits (ERLs) are derived using data on ecotoxicology and environmental chemistry, and represent the potential risk of substances to the ecosystem. They are the scientific basis for environmental quality standards (EQSs) set by the Ministry of Infrastructure and the Environment.

Polycyclic aromatic hydrocarbons are substances that have both natural and anthropogenic origins. They can be formed as a result of combustion, and are constituents of many petroleum products as well. PAHs have different physicochemical and environmental properties (e.g., log K_{ow}, log K_{oc}, solubility and BCF). The PAHs that have been considered in this report are the 16 PAHs that were selected by the US Environmental Protection Agency (EPA). These 16 PAHs are also considered in the European Risk Assessment Report (RAR) on coal tar pitch, high temperature (European Commission, 2008). This work forms the basis of the derivation of the environmental risk limits as presented in this report. Additional data that were retrieved after the completion of the RAR, were added to this data set.

For each of the individual PAHs, environmental risk limits for direct ecotoxicity were derived for water, soil, and sediment. The methodology used for this derivation was that of the project ‘International and national environmental quality standards for substances in the Netherlands’ (INS). Environmental quality standards should be protective for direct ecotoxicity, secondary poisoning of predators such as birds and mammals, and human toxicology through indirect exposure of humans. However, in this report only the route of direct ecotoxicity is addressed. Thus, the derived risk limits cannot be considered directly as proposals for environmental quality standards.

All cited ecotoxicity studies were collected and carefully evaluated for their usefulness and reliability. Because of the volatility of especially the lower PAHs and the adsorptive behaviour especially for the higher PAHs, only studies in which the exposure concentrations were verified were considered reliable. An overview of the derived risk limits for each individual PAH is given in Table 94. Contrary to earlier reports on derivation of risk limits for PAHs, a substantial amount of terrestrial and benthic ecotoxicity data was retrieved. Therefore, the number of risk limits for individual PAHs that is derived by equilibrium partitioning is substantially lower. Although many more data were retrieved in comparison with earlier risk limit derivations, and consequently lower assessment factors were applied, the values are in general not higher than, but comparable with the existing risk limits.

Apart from the derivation of risk limits for each PAH individually, an approach is presented in which the risk limits are derived based on internal residues. This method has been developed and applied for the derivation of risk limits for total petroleum hydrocarbons (TPH) before. It is assumed that toxicity of all PAHs is similar and possibly caused by narcosis, for which the total concentration of compounds in the cell membrane is the key parameter. This means that toxicity of different PAHs differs only as a consequence of different accumulation potential. However, effects are equal on molar basis expressed as residues in the cell membranes. Further, because of similar action, the sum of the internal
concentrations of different compounds gives rise to the same effect as that of a similar concentration of an individual compound, which is referred to as concentration additivity.

To calculate the total internal residues, pore water concentrations were calculated first for soil and sediment, by considering partitioning between organic carbon and water. From water concentrations, the internal residues were calculated using a partition coefficient between the membrane and water. From all chronic toxicity data for individual PAHs expressed as internal residues, a set of no observed effect residues (NOERs) for 54 species was obtained, partly geometric means of data for individual PAHs. On basis of these data, a species sensitivity distribution (SSD) was constructed, including aquatic, terrestrial and benthic species. On basis of internal residues there appeared to be no significant differences between the compartments and between the individual PAHs, which confirms the assumption that indeed accumulation from (pore) water is the determining factor for toxicity. This SSD appeared to be very similar to the SSD for TPH, suggesting a similar mode of toxic action.

From the SSD the HC5 and HC50 were derived. These values, based on internal residues, were transferred to the environmental risk limits for water, soil and sediment for each PAH by means of the equilibrium partition coefficients between membranes and water and between soil or sediment and water. For the MPC values a default assessment factor of 5 has been applied to the HC5, to account for uncertainties in the method and for the potential of certain PAHs to exert a high acute toxicity through phototoxicity, which is not well covered by the chronic data set. The obtained quality standards are generally higher (less conservative) than the quality standard for each PAH individually. An overview of the standards derived by this method is presented in Table 99.

If monitoring data are compared with the environmental risk limits it must be kept in mind that the toxic unit approach should be applied, because of the assumed concentration additivity for PAHs. Because toxicity can be explained by equilibrium partitioning, it could be considered to use techniques that are capable to measure freely dissolved concentrations in field samples (such as SPME). This would take account of the possibly strongly reduced bioavailability of PAHs in the field.
1 Introduction

1.1 Project framework

In this report, environmental risk limits (ERLs) for surface water (freshwater and marine), sediment, and soil are derived for 16 polycyclic aromatic hydrocarbons (PAHs). 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 $10^{-6}$ per year of death can be calculated (for carcinogenic substances).

The MPCs for water and soil should not result in risks due to secondary poisoning (considered as part of the ecosystem in the definition above) and/or risks for human health aspects. These aspects are therefore also addressed in the MPC derivation. Within the context of the Water Framework Directive a risk of $10^{-6}$ on a life-time basis is used. Therefore, this value has been adapted within the framework of the project ‘International and national environmental quality standards for substances in the Netherlands’ (INS) (Van Vlaardingen and Verbruggen, 2007). However, in this report only the direct ecotoxic effects are considered.

- **Maximum acceptable concentration (MACeco)** – concentration protecting aquatic ecosystems for effects due to short-term exposure or concentration peaks.

- **Serious risk concentration (SRCeco)** – concentration at which possibly serious ecotoxicological effects are to be expected. The derivation of SRC values based on human-toxicological endpoints (SRChuman) is not part of this report.

These ERLs serve as advisory values that are used by the Steering Committee for Substances to set environmental quality standards (EQS) for various policy purposes. EQSs are all legally and non legally binding standards used in Dutch environmental policy.

The NC can be used to set the target value (TV). The MPC and the MACeco can be used as generic environmental quality standards. The SRCeco can be used to derive intervention values (IV), after comparison with the human toxicological SRC value, and for groundwater also with the maximum concentration in drinking water. Above IV soil and groundwater is considered to be seriously contaminated.

1.2 Selection of substances

ERLs are derived for naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, pyrene, fluoranthene, chrysene, benzo[a]anthracene, benzo[k]fluoranthene, benzo[b]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene, dibenz[a,h]anthracene, and indeno[1,2,3-
cd]pyrene (Table 1), which are selected because of their importance for soil, sediment, and groundwater in the scope of the project ‘Risk Assessment of contaminated Soil and Ground Water’.

<table>
<thead>
<tr>
<th>Compound</th>
<th>CAS number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>91-20-3</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>208-96-8</td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>83-32-9</td>
</tr>
<tr>
<td>Fluorene</td>
<td>86-73-7</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>85-01-8</td>
</tr>
<tr>
<td>Anthracene</td>
<td>120-12-7</td>
</tr>
<tr>
<td>Pyrene</td>
<td>129-00-0</td>
</tr>
<tr>
<td>Fluoranthen</td>
<td>206-44-0</td>
</tr>
<tr>
<td>Chrysene</td>
<td>218-01-9</td>
</tr>
<tr>
<td>Benz[a]anthracene</td>
<td>56-55-3</td>
</tr>
<tr>
<td>Benzo[k]fluoranthen</td>
<td>207-08-9</td>
</tr>
<tr>
<td>Benzo[b]fluoranthen</td>
<td>205-99-2</td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>50-32-8</td>
</tr>
<tr>
<td>Benzo[ghi]perylene</td>
<td>191-24-2</td>
</tr>
<tr>
<td>Dibenzo[a,h]anthracene</td>
<td>53-70-3</td>
</tr>
<tr>
<td>Indeno[1,2,3-cd]pyrene</td>
<td>193-39-5</td>
</tr>
</tbody>
</table>

These substances have been chosen, because they represent the 16 PAHs selected by the US Environmental Protection Agency (US EPA). These 16 PAHs were considered in the EU RAR on coal tar pitch high-temperature (European Commission, 2008). The same 16 PAHs were considered for the human toxicological part of the serious risk concentration (SRChuman), with one additional compound, which was benzo[j]fluoranthen (Lijzen et al., 2001; Baars et al., 2001). This was done for the revision of the first tranche of intervention values in 2001. At that time the ecotoxicological data underlying risk limits for PAHs were not updated and the SRCeco values were derived based on the old data for 10 PAHs (Verbruggen et al., 2001). These PAHs were selected by the Dutch Ministry for Housing, Spatial Planning and the Environment (VROM) and contained the above mentioned PAHs, except acenaphthylene, acenaphthene, fluorene, pyrene, benzo[b]fluoranthen, and dibenz[a,h]anthracene. The data for these 10 PAHs were collected prior to 1995, when the MPCs and NCs for these substances were derived (Kalf et al., 1995).

1.3 Reading guide to the report

In chapter 2, the methodology followed in the derivation of the environmental risk limits will be shortly derived. In chapter 3, the derivation of the ERLs in water (freshwater and marine water), sediment, and soil will be presented for each of the PAHs individually. In chapter 4, a summary of the derived ERLs will be given and a comparison is presented with existing risk limits and quality standards, including the human toxicological part of the SRCs. Further, an alternative method to the ERLs derived in chapter 3 is proposed. With this approach, ERLs are derived as one value for all PAHs, based on internal concentrations in the lipids (membranes) of organisms.
2 Methods

2.1 Guidance followed for this project

In this report ERLs are derived following the methodology of the project 'International and national environmental quality standards for substances in the Netherlands' (INS) (Van Vlaardingen and Verbruggen, 2007). The updated INS guidance is in accordance with the guidance by Lepper (2005) which forms part of the Priority Substances Daughter Directive (2006/0129 (COD)) amending the Water Framework Directive (2000/60/EC) (WFD guidance) and the Technical Guidance Document (TGD) for the risk assessment of new and existing substances and biocides (European Commission, 2003). The WFD guidance, which is based on the Technical Guidance Document, only applies to the derivation of MPC and MACeco for water and the MPC for sediment. ERL derivations for water and sediment are performed for both the freshwater and marine compartment. For the MPC for soil, the updated INS guidance follows the Technical Guidance Document.

Because of the extent of this work, this report takes only direct aquatic, benthic and terrestrial ecotoxicological effects of PAHs into account. The risk limits derived are the serious risk concentration for ecosystems (SRCeco), which serves as basis for the intervention value, the maximum permissible concentration for ecosystems (MPCeco) and the maximum acceptable concentration for ecosystems (MACeco, water), a concentration that protects aquatic ecosystems from adverse effects caused by short-term exposure or concentration peaks. The compartments considered in the derivation of the SRCeco and MPCeco are fresh and marine water, fresh and marine sediment, and soil. The MACeco, water is only derived for the water compartment, because this is the most dynamic compartment and quickly fluctuating concentrations are not deemed relevant for soil and sediment. An overview of which ERLs are derived in this report is given in Table 2.

It is important to note that a complete SRC, MPC and NC derivation integrates both ecotoxicological data, consisting of both direct toxicity as well as secondary poisoning of predators, and a human toxicological threshold value. The height of the final environmental risk limit can be determined by either one of these protection objectives. Because the indirect routes were not taken into account, no further evaluation of bioconcentration and biomagnification data is made in this report. However, it can be stated that BCF values for these substances are generally higher than 100 (see section 2.2.2). On basis of these BCF values, PAHs trigger the route for the derivation of secondary poisoning and human toxicological based MPC values (see section 2.2.2). The human toxicological values for the SRC for soil and groundwater are derived by the exposure model CSOIL and for the SRC for aquatic sediment by the model SEDISOIL (Lijzen et al., 2001). In section 4.1, these values are compared with the ecotoxicological values derived in this report.
Table 2: Overview of which ERLs are derived in this report

<table>
<thead>
<tr>
<th>Protection level</th>
<th>Protection goal</th>
<th>Water</th>
<th>Sediment</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>MPC</td>
<td>Ecotoxicity</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Secondary</td>
<td>X</td>
<td>I</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>poisoning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Human</td>
<td>X</td>
<td>I</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>toxicological</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAC&lt;sub&gt;eco&lt;/sub&gt;</td>
<td>Ecotoxicity</td>
<td>Y</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>SRC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compound</th>
<th>BCF fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>462, 515, 66, 76, 310, 320</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>510, 507, 678, 698</td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>973, 988</td>
</tr>
<tr>
<td>Fluorene</td>
<td>1158, 1658, 818, 755</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>1805, 4751, 2544, 2423, 2546, 1149</td>
</tr>
<tr>
<td>Anthracene</td>
<td>2545, 1960, 1126, 3581, 2476, 4973</td>
</tr>
<tr>
<td>Pyrene</td>
<td>1474, 75, 50</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>2771</td>
</tr>
<tr>
<td>Chrysene</td>
<td></td>
</tr>
<tr>
<td>Benz[a]anthracene</td>
<td>260</td>
</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
<td></td>
</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td></td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>~30</td>
</tr>
<tr>
<td>Benzo[ghi]perylene</td>
<td></td>
</tr>
<tr>
<td>Dibenz[a,h]anthracene</td>
<td></td>
</tr>
<tr>
<td>Indeno[1,2,3-cd]pyrene</td>
<td></td>
</tr>
</tbody>
</table>

X: Not derived in this report.
Y: Derived in this report.
N: Not relevant for the specific compartment.

2.2 Trigger values

2.2.1 Sediment and suspended matter

This section reports on the trigger values for ERL water derivation (as demanded in the context of the WFD). In line with the upcoming new technical guidance document for deriving environmental quality standards, a sediment quality standard should be derived if the organic carbon-water partition coefficient ($K_{oc}$) is larger than 1000. With the equation as given by Karickhoff et al. (1979) for log $K_{oc}$ this is true for all 16 PAHs (see section 2.3.2).

2.2.2 Secondary poisoning

Under the Water Framework Directive (WFD) the route of secondary poisoning is triggered if the bioconcentration factor (BCF) is larger than 100 (Lepper, 2005; Van Vlaardingen and Verbruggen, 2007). Recently, an overview of the bioaccumulation of PAHs was made (Bleeker and Verbruggen, 2009). Apparently for the PAHs high BCF values are observed in fish (Table 3).

Table 3: Overview of BCF values for fish. If possible, data were normalized to 5% lipid content

<table>
<thead>
<tr>
<th>Compound</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>462, 515, 66, 76, 310, 320</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>510, 507, 678, 698</td>
</tr>
<tr>
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<tr>
<td>Fluorene</td>
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<tr>
<td>Phenanthrene</td>
<td>1805, 4751, 2544, 2423, 2546, 1149</td>
</tr>
<tr>
<td>Anthracene</td>
<td>2545, 1960, 1126, 3581, 2476, 4973</td>
</tr>
<tr>
<td>Pyrene</td>
<td>1474, 75, 50</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>2771</td>
</tr>
<tr>
<td>Chrysene</td>
<td></td>
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<tr>
<td>Benz[a]anthracene</td>
<td>260</td>
</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
<td></td>
</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td></td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>~30</td>
</tr>
<tr>
<td>Benzo[ghi]perylene</td>
<td></td>
</tr>
<tr>
<td>Dibenz[a,h]anthracene</td>
<td></td>
</tr>
<tr>
<td>Indeno[1,2,3-cd]pyrene</td>
<td></td>
</tr>
</tbody>
</table>
For invertebrates, higher and even more variable BCF values were observed, mainly due to the absence of metabolism in these species. For all PAHs for which reliable BCF data (all except benzo[b]fluoranthene and indeno[1,2,3-cd]pyrene) are available, BCF values tend to be much higher than 100 (Bleeker and Verbruggen, 2009). Therefore, the route of secondary poisoning is triggered for PAHs. This report focuses on direct ecotoxicity only and therefore, this route is not further considered here.

2.2.3 Human toxicological threshold limits and carcinogenicity

The classification in EU framework is shown in Table 4. Those substances, for which no Risk Phrases (R-phrases) are listed, have not been classified in EU framework (EC Regulation No. 1272/2008). In this table, the values presented by the US Environmental Protection Agency, the Integrated Risk Information System (US EPA IRIS) (http://www.epa.gov/ncea/iris/index.html) and the Agency for Toxic Substances and Disease Registry (ATSDR) (http://www.atsdr.cdc.gov/mrls/index.asp) are included as well. Further, the human toxicological MPR values that were derived in the framework of intervention values and served as basis for the $\text{SRC}_{\text{human}}$ are presented in Table 4 (Baars et al., 2001). It should be noted that the values for carcinogenicity are based on a cancer risk of $10^{-4}$ per lifetime. The limit value for generic quality standards under the WFD an within the framework of INS is a probability of $10^{-6}$ per lifetime (Lepper, 2005). Therefore, these MPR values (Van Vlaardingen and Verbruggen, 2007) should be divided by a factor of 100 for the derivation of the human toxicological MPC values within the context of the WFD and INS.

RIVM (Baars et al., 2001) concluded that naphthalene, fluorene, anthracene, and benzo[ghi]perylene are not carcinogenic. It was concluded that acenaphthene, acenaphthylene, phenanthrene and pyrene should be considered as suspected carcinogens. However, for phenanthrene an MPR value was derived based on a threshold approach (TDI), because the relative carcinogenic potential is extremely low. For the other substances (fluoranthene, chrysene, benzo[a]anthracene, benzo[k]fluoranthene, benzo[b]fluoranthene, benzo[a]pyrene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene), it was concluded that these substances were probably carcinogenic.

US EPA (IRIS) concluded that acenaphthylene, phenanthrene, anthracene, pyrene, fluoranthene, and benzo[ghi]perylene are not classifiable for human carcinogenicity. For fluoranthene and pyrene this is in contrast with the conclusion by RIVM that pyrene was possibly and fluoranthene probably carcinogenic to humans. US EPA (IRIS) concluded that chrysene, benzo[a]anthracene, benzo[k]fluoranthene, benzo[b]fluoranthene, benzo[a]pyrene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene are probably human carcinogens.

For all substances with a classification R40 (limited evidence of a carcinogenic effect), R45 (may cause cancer), R46 (may cause heritable genetic damage), R60 (may impair fertility), R61 (may cause harm to the unborn child), or R68 (possible risk of irreversible effects) the derivation of a human toxicological quality standard under the Water Framework Directive is triggered (Lepper, 2005). For the other substances that were not classified in EU framework, but are suspected or probable carcinogens, this holds true as well. Still for the other substances fluorene, phenanthrene and anthracene the TDI values are low, while the BCF values are rather high, which makes them eligible for the derivation of a human toxicological MPC (e.g. one of the R-phrases R22, R25,
R28 (harmful, toxic, or very toxic if swallowed), or R48 (danger of serious
damage to health by prolonged exposure) in combination with a BCF > 100
would trigger the human route as well).

However, this report is restricted to the derivation of the environmental risk
limits for direct ecotoxicity. As such, the derivation of human toxicological
maximum permissible concentration or serious risk concentrations is outside the
scope of this report. The derivation of SRC\textsubscript{human} for the 16 PAHs can be found in
another report (Lijzen et al., 2001). In section 4.1, they are compared to the
SRC\textsubscript{eco} values derived in this report.

Table 4: Overview of human toxicological data: Classification in EU framework,
Reference dose (RfD) from US EPA (IRIS), minimal risk level (MRL) from ATSDR,
and maximum permissible risk (MPR) from RIVM

<table>
<thead>
<tr>
<th>Compound</th>
<th>Classification</th>
<th>US EPA (IRIS) RfD mg/kg\textsubscript{bw}/d</th>
<th>ATSDR MRL (oral intermediate exposure mg/kg\textsubscript{bw}/d)</th>
<th>RIVM MPR (TDI or 10^{-4} lifetime cancer risk) mg/kg\textsubscript{bw}/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>R40, R22, R50/53</td>
<td>0.02</td>
<td>0.6</td>
<td>0.04</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acenaphthene</td>
<td></td>
<td>0.06</td>
<td>0.6</td>
<td>0.50 *</td>
</tr>
<tr>
<td>Fluorene</td>
<td></td>
<td>0.04</td>
<td>0.4</td>
<td>0.040</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthracene</td>
<td></td>
<td>0.30</td>
<td>10</td>
<td>0.040</td>
</tr>
<tr>
<td>Pyrene</td>
<td></td>
<td>0.030</td>
<td></td>
<td>0.50 *</td>
</tr>
<tr>
<td>Fluorantheine</td>
<td></td>
<td>0.040</td>
<td>0.4</td>
<td>0.050 *</td>
</tr>
<tr>
<td>Chrysene</td>
<td>R45, R68, R50/53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benz[a]anthracene</td>
<td>R45, R50/53</td>
<td></td>
<td></td>
<td>0.0050 *</td>
</tr>
<tr>
<td>Benz[k]fluoranthe</td>
<td>R45, R50/53</td>
<td></td>
<td></td>
<td>0.0050 *</td>
</tr>
<tr>
<td>Benz[b]fluoranthe</td>
<td>R45, R50/53</td>
<td></td>
<td></td>
<td>0.0050 *</td>
</tr>
<tr>
<td>Benz[a]pyrene</td>
<td>R45, R46, R60, R61, R43, R50/53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzo[ghi]perylene</td>
<td></td>
<td></td>
<td></td>
<td>0.030</td>
</tr>
<tr>
<td>Dibenz[a,h]anthracene</td>
<td>R45, R50/53</td>
<td></td>
<td></td>
<td>0.00050 *</td>
</tr>
<tr>
<td>Indeno[1,2,3-cd]pyrene</td>
<td></td>
<td></td>
<td></td>
<td>0.0050 *</td>
</tr>
</tbody>
</table>

* These values are based on a cancer risk of 10^{-4} per lifetime (Baars et al., 2001).

2.3 Data collection and evaluation

2.3.1 Ecotoxicity data

Initially, data were collected for the European Risk Assessment Report on coal
tar pitch, high-temperature. An on-line literature search was performed on
TOXLINE (literature from 1985 to 2001) and Current Contents (literature from
1997 to 2002) and was updated at regular time intervals up to 2008 by Current
Contents or Scopus. In addition to this, all references in the RIVM e-tox base
and EPA’s ECOTOX database were evaluated, if available. Next to that, many
references were retrieved by retrospective searching of cited references.
Evaluated toxicity data are reported in a separate appendix to this report.
Ecotoxicity studies were screened for relevant endpoints (i.e. those endpoints
that have consequences at the population level of the test species). All
Ecotoxicity tests were then thoroughly evaluated with respect to the validity (scientific reliability) of the study. A detailed description of the evaluation procedure is given in the INS-Guidance (Van Vlaardingen and Verbruggen, 2007), sections 2.2.2 and 2.3.2. In short, the following reliability indices were assigned:

- **Ri 1: Reliable without restriction**
  ‘Studies or data ... generated according to generally valid and/or internationally accepted testing guidelines (preferably performed according to GLP) or in which the test parameters documented are based on a specific (national) testing guideline ... or in which all parameters described are closely related/comparable to a guideline method.’

- **Ri 2: Reliable with restrictions**
  ‘Studies or data ... (mostly not performed according to GLP), in which the test parameters documented do not totally comply with the specific testing guideline, but are sufficient to accept the data or in which investigations are described which cannot be subsumed under a testing guideline, but which are nevertheless well documented and scientifically acceptable.’

- **Ri 3: Not reliable**
  ‘Studies or data ... in which there are interferences between the measuring system and the test substance or in which organisms/test systems were used which are not relevant in relation to the exposure (e.g., unphysiologic pathways of application) or which were carried out or generated according to a method which is not acceptable, the documentation of which is not sufficient for an assessment and which is not convincing for an expert judgment.’ Since most PAHs, especially the lower ones, are volatile substances, studies using an open system in which actual concentrations are not monitored are rewarded Ri 3.

- **Ri 4: Not assignable**
  ‘Studies or data ... which do not give sufficient experimental details and which are only listed in short abstracts or secondary literature (books, reviews, etc.).’

- **Ri 4*: Data from other sources**
  ‘Studies or data ... which are most likely copied from other sources’

All available studies were summarized in data tables, which are included as a database to this report. These tables contain information on species characteristics, test conditions and endpoints. Explanatory notes are included with respect to the assignment of the reliability indices. Endpoints with Ri 1 or 2 are accepted as valid, but this does not automatically mean that the endpoint is selected for the derivation of ERLs. The validity scores are assigned on the basis of scientific reliability, but valid endpoints may not be relevant for the purpose of ERL-derivation (e.g. due to inappropriate exposure times).

After data collection and validation, toxicity data were combined into an aggregated data table with one effect value per species according to section 2.2.6 of the INS-Guidance. When for a species several effect data were available, the geometric mean of multiple values for the same endpoint was calculated where possible. Subsequently, when several endpoints were available for one species, the lowest of these endpoints (per species) is reported in the aggregated data table.
2.3.2 Physicochemical data

The collected physicochemical properties were collected for the European Risk Assessment Report on coal tar pitch, high-temperature as well. Most data were retrieved from the Handbook of physical-chemical properties and environmental fate for organic chemicals (Mackay et al., 2006) and the references cited therein. The selection criteria were based on the INS-Guidance (Van Vlaardingen and Verbruggen, 2007) and preference was given to slow-stirring and generator-column methods for both solubility and the n-octanol-water partition coefficient ($K_{ow}$), and the gas saturation and effusion methods for the vapour pressure, and wetted-wall, gas-stripping, or headspace methods for Henry’s law constant. The organic carbon-water partition coefficient ($K_{oc}$) was calculated from $\log K_{ow}$ by means of the QSAR equation from Karickhoff et al. (1979). This equation proved to be most suitable for describing sorption of PAHs to organic carbon (Verbruggen et al., 2008):

$$\log K_{oc} = \log K_{ow} - 0.21$$

2.4 Additional methodology and deviations from the guidance

2.4.1 MACeco, marine

The assessment factor for the MACeco, marine value is based on:
- the assessment factor for the MACeco, water value when acute toxicity data for at least two specific marine taxa are available, or
- the assessment factor for the MACeco, water value with an additional assessment factor of 5 when acute toxicity data for only one specific marine taxon are available (analogous to the derivation of the MPC according to Van Vlaardingen and Verbruggen, (2007)), or
- the assessment factor for the MACeco, water value with an additional assessment factor of 10 when no acute toxicity data are available for specific marine taxa.

If freshwater and marine data sets are not combined, the MACeco, marine is derived on the marine toxicity data using the same additional assessment factors as mentioned above. It has to be noted that this procedure is currently not agreed upon. Therefore, the MACeco, marine value needs to be re-evaluated once an agreed procedure is available.

2.4.2 Equilibrium partitioning for soil and sediment

Equilibrium partitioning (EqP) can be used to derive ERLs for soil and sediment from ERLs for water. If equilibrium partitioning is applied, an additional factor of 10 should be used for the derivation of the MPC of substances with a $\log K_{ow}$ higher than 5 (Van Vlaardingen and Verbruggen, 2007). This factor was introduced to take account of the possible role of food ingestion, both in sediment and soil. However, the increase in total uptake due to food ingestion in earthworms was non-existing for 1,2,3,4-tetrachlorobenzene, and pentachlorobenzene and only a factor 2 to 3 for hexachlorobenzene (Belfroid et al., 1994). This set of three compounds is actually too small to base a conclusion upon and in general, it has been shown that this additional uptake is actually very limited (Jager, 1998). Based on experimental data, this was confirmed for the PAHs in this report. Applying an additional factor of 10 would be an overestimation of the environmental risk limits, while without this factor environmental risk limits derived by equilibrium partitioning and from direct terrestrial and benthic toxicity data are in good accordance with each other.
Therefore, the additional factor of 10 for equilibrium partitioning is not applied in this report.
3 Derivation of environmental risk limits

3.1 Naphthalene

3.1.1 Substance identification and physicochemical properties

3.1.1.1 Identity

Figure 1: Structural formula of naphthalene.

Table 5: Identification of naphthalene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Naphthalene, naphthene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>Naphthalene</td>
</tr>
<tr>
<td>CAS number</td>
<td>91-20-3</td>
</tr>
<tr>
<td>EC number</td>
<td>202-049-5</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c12ccccc1ccccc2</td>
</tr>
</tbody>
</table>

3.1.1.2 Physicochemical properties

Table 6: Physicochemical properties of naphthalene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>128.2</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>31900</td>
<td>Geometric mean of 7 values by generator-column method</td>
</tr>
<tr>
<td>log (K_{OW})</td>
<td>[-]</td>
<td>3.34</td>
<td>Average of 1 value by generator-column and 1 by slow-stirring method</td>
</tr>
<tr>
<td>log (K_{OC})</td>
<td>[-]</td>
<td>3.13</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>10.8</td>
<td>Geometric mean of 8 values by gas saturation method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>217.9</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa.m³/mol]</td>
<td>50.4</td>
<td>Geometric mean of 7 values by gas stripping method, 1 value by wetted-wall method and 1 value by headspace method</td>
</tr>
</tbody>
</table>

3.1.2 Water

Naphthalene is highly volatile. Many toxicity studies for naphthalene were rejected due to high uncertainty in exposure concentrations, either because analysis showed that the concentrations in static systems dropped very quick or because exposure concentrations were not analytically verified. Still, many valid toxicity data are available for naphthalene. The selected acute toxicity data for freshwater species include algae, an amphibian, crustaceans, a cyanophyte, insects, a mollusk and fish (Table 7). The selected acute toxicity data for marine species include seaweed, an annelid, a bacterium, crustaceans, mollusks and fish (Table 8). No higher plant was selected but a study with duckweed showed that naphthalene only causes about 10% effect up to the solubility of 32,000 µg/L (Ren et al., 1994). It can thus be concluded that duckweed is not a very sensitive species for naphthalene.
Table 7: Selected acute toxicity data of naphthalene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Nitzschia palea</td>
<td>2820</td>
</tr>
<tr>
<td>Algae</td>
<td>Pseudokirchneriella subcapitata</td>
<td>2960</td>
</tr>
<tr>
<td>Algae</td>
<td>Scenedesmus vacuolatus</td>
<td>3800</td>
</tr>
<tr>
<td>Amphibia</td>
<td>Xenopus laevis</td>
<td>2100</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia magna</td>
<td>1896 a</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Diporeia spp.</td>
<td>1587</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Gammarus minus</td>
<td>3930</td>
</tr>
<tr>
<td>Algae</td>
<td>Arthrospira spp.</td>
<td>4677</td>
</tr>
<tr>
<td>Cyanophyta</td>
<td>Anabaena flos-aqua</td>
<td>24,000</td>
</tr>
<tr>
<td>Insecta</td>
<td>Chironomus riparius</td>
<td>600 b</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Physa gyrina</td>
<td>5020</td>
</tr>
<tr>
<td>Pisces</td>
<td>Oncorhynchus mykiss</td>
<td>2212 c</td>
</tr>
<tr>
<td>Pisces</td>
<td>Pimephales promelas</td>
<td>4572 d</td>
</tr>
</tbody>
</table>

Notes to Table 7

a Geometric mean of 2160 and 1664 µg/L for the most sensitive parameter (immobility) at a standard exposure time of 48 hours.

b Most sensitive lifestage exposed under light conditions including some UV-A.

c Geometric mean of 2100, 3220, and 1600 µg/L.

d Geometric mean of 1680, 1990, and 7900 µg/L.

Table 8: Selected acute toxicity data of naphthalene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Champia parvula</td>
<td>1378 a</td>
</tr>
<tr>
<td>Annelida</td>
<td>Neanthes arenaceodentata</td>
<td>1069</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Vibrio fischeri</td>
<td>710 b</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Artemia salina</td>
<td>3190</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Calanus finmarchicus</td>
<td>2400</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Callinectes sapidus</td>
<td>2301 c</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Elasmopus pectenricus</td>
<td>2680</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Eualis suckleyi</td>
<td>1390</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Eurytemora affinis</td>
<td>3000</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Hemigrapsus nudus</td>
<td>1100 d</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Neomysis Americana</td>
<td>825 e</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Oithona davisae</td>
<td>4480 f</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Palaemonetes pugio</td>
<td>2111</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Paracartia grani</td>
<td>2467 f</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Parhyale hawaiensis</td>
<td>6000</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Mytilus edulis</td>
<td>922</td>
</tr>
<tr>
<td>Pisces</td>
<td>Fundulus heteroclitus</td>
<td>5300</td>
</tr>
<tr>
<td>Pisces</td>
<td>Oncorhynchus gorbuscha</td>
<td>1200 g</td>
</tr>
</tbody>
</table>

Notes to Table 8

a Geometric mean of 1000 and 1900 µg/L for the most sensitive lifestage (tetrasporophyte).

b Geometric mean of 700 and 720 µg/L at standard exposure time (15 min).

c Lowest value at highest salinity of 30‰.

d Lowest value obtained with continuous exposure instead of intermittent exposure.

e Geometric mean of 800 and 850 µg/L at highest test temperature of 25 ºC.

f Most sensitive parameter (immobility).

g Most relevant exposure time (96 h) and probably also most relevant life-stage for acute toxicity testing.
To test for differences in sensitivity between freshwater and marine species, data were log-transformed first. Thereafter, a t-test with two-tailed distribution and equal variance was performed after running an F-test to test for equal variances. No significant differences were observed in the sensitivity of freshwater and marine species in acute toxicity tests (F-test 0.29; t-test 0.13). It is therefore considered justified to calculate a species sensitivity distribution with the acute toxicity data on basis of the combined dataset for 30 species. This SSD is shown in Figure 2. The HC5 of this SSD is 650 µg/L, the HC50 is 2324 µg/L. The MACeco, water is derived from the HC5(acute), default by applying an assessment factor of 10. However, the number of toxicity data and the taxonomic diversity is high and the differences in species sensitivity are low, which is characteristic of narcotic effects. The MACeco, water should be protective of any acute toxicity effects. However, the values used in the SSD are 50% effective concentration. Therefore, an assessment is made between the 50% and 10% effective concentrations (EC50 and EC10). A direct comparison can be made for 9 species from 5 taxonomic groups (Table 9). The no-effect level is at most a factor of 5 lower than the 50% effect level. Therefore, an assessment factor of 5 is applied to the HC(acute) to derive the MACeco, water. The MACeco, water is thus 130 µg/L. Because of the large number of marine data, including non standard species such as seaweed, annelids, or molluscs, an extra assessment factor for the MACeco, marine is not necessary. The MACeco, marine is 130 µg/L too.

Figure 2: Species sensitivity distribution for the acute toxicity of naphthalene to freshwater and marine species

Chronic toxicity studies for naphthalene have often been performed in flow-through systems, with regular renewal of the aqueous phase or with tightly closed vials. This renders a relatively high number of valid toxicity data. The selected chronic data for naphthalene to freshwater species include algae, crustaceans, a higher plant and fish (Table 10). For marine species data are available for seaweed, a sea squirt species, crustaceans, including a crab species, echinoderms, a mollusc and fish (Table 11).
Table 9: Acute no effect levels (10% cut-off by means of EC10) versus 50% effect levels (EC50) for naphthalene

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>EC50/EC10 or LC50/LC10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphibia</td>
<td><em>Xenopus laevis</em></td>
<td>1.6</td>
</tr>
<tr>
<td>Algae</td>
<td><em>Scenedesmus vacuolatus</em></td>
<td>2.2</td>
</tr>
<tr>
<td>Algae</td>
<td><em>Champia parvula</em></td>
<td>1.4 – 2.1</td>
</tr>
<tr>
<td>Bacteria</td>
<td><em>Vibrio fischeri</em></td>
<td>4.8</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Calanus finmarchicus</em></td>
<td>1.1</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Oithona davisae</em></td>
<td>1.8</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Paracartia grani</em></td>
<td>1.6</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Parhyale hawaiensis</em></td>
<td>1.6</td>
</tr>
<tr>
<td>Cyanophyta</td>
<td><em>Anabaena flos-aqua</em></td>
<td>2.5</td>
</tr>
</tbody>
</table>

Table 10: Selected chronic toxicity data of naphthalene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td><em>Scenedesmus vacuolatus</em></td>
<td>1700</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Ceriodaphnia dubia</em></td>
<td>514</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Hyalella azteca</em></td>
<td>1161</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Lemma gibba</em></td>
<td>32,000</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Micropterus salmoides</em></td>
<td>37</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Oncorhynchus kisutch</em></td>
<td>460 a</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Oncorhynchus mykiss</em></td>
<td>20</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Pimephales promelas</em></td>
<td>450 b</td>
</tr>
</tbody>
</table>

Notes to Table 10

- a Most sensitive parameter (length).
- b Most sensitive parameter (length and weight).

Table 11: Selected chronic toxicity data of naphthalene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td><em>Champia parvula</em></td>
<td>811 a</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Cancer magister</em></td>
<td>21 b</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Paracartia grani</em></td>
<td>530 c</td>
</tr>
<tr>
<td>Echinodermata</td>
<td><em>Paracentrotus lividus</em></td>
<td>649 d</td>
</tr>
<tr>
<td>Echinodermata</td>
<td><em>Strongylocentrotus droebachiensis</em></td>
<td>738 e</td>
</tr>
<tr>
<td>Mollusca</td>
<td><em>Mytilus galloprovincialis</em></td>
<td>4037 d</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Gadus morhua</em></td>
<td>1000</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Oncorhynchus gorbuscha</em></td>
<td>260 f</td>
</tr>
<tr>
<td>Tunicata</td>
<td><em>Ciona intestinalis</em></td>
<td>610 d</td>
</tr>
</tbody>
</table>

Notes to Table 11

- a Geometric mean of 1400 and 470 µg/L for the most sensitive lifestage (tetrasporophyte).
- b Most sensitive strain (from Alaska).
- c Most sensitive parameter (egg production).
- d Lowest value with tests performed in the dark.
- e Geometric mean of 940 and 580 µg/L.
- f Most sensitive parameter (weight).

An LC50 of 110 (Black et al., 1983) or 120 µg/L (Milleman et al., 1984) is reported for an early life stage study (ELS) with rainbow trout exposed from 20 minutes after fertilization of the eggs until 4 days after hatching of the fry (after 23 d, total exposure 27 d). The presented data (Black et al., 1983) show a
clear dose-response relationship. The LC50 value of 117 μg/L derived from a
dose-response relationship with a log-logistic equation (r^2=0.96) is similar to the
values mentioned above. The EC10 for survival after 4 days post-hatching is
20 μg/L. Clearly, this is the lowest usable effect concentration for naphthalene in
freshwater species. In the RAR of naphthalene the study of Black et al. (1983),
was disregarded because the method could not be repeated with toluene and it
generally gives much lower results than standard studies. After reconsideration,
it was concluded in the RAR of coal tar pitch that the value could be used.
There are some differences between the studies with toluene and naphthalene.
First, for toluene the difference with the other toxicity data is several orders of
magnitude, while for naphthalene, there are several studies which show the
onset of chronic effects or effects on sensitive life stages around the value of
20 μg/L. For the most sensitive strain of Dungeness crabs a NOEC of 21 μg/L
was found in a 40-d study (Caldwell et al., 1977). In this study only two
exposure concentrations are used. Although well-performed, the statistical
power of this test is limited. For the marine herbivororous copepod
Eurytemora affinis 1 concentration of 14 μg/L tested in a 15-d study resulted in significant
effects (Ott et al., 1978). However, a 10-d study with the same species resulted
in no significant effects up to 50 μg/L (Berdugo et al., 1977).
Second, the EC10 for toluene is also an order of magnitude lower than that for
naphthalene, while naphthalene is a compound with a log Kow that is 0.6 unit
higher than that of toluene. For this reason, the EC10 for naphthalene would be
expected to be lower than the EC10 for toluene, which is apparently not the
case.
Further, both EC10s do not originate from the same publication, or at least
toluene has been omitted from the publication. If a read-across is performed
with the data for phenanthrene instead of toluene with data from the same
study (Black et al., 1983), the data are very well in line with another study with
the same species and with data for other species tested with phenanthrene.
Therefore, the EC10 is considered to be useful in this case.
Chronic NOEC or EC10 values are very similar for freshwater and marine species
and no significant differences are observed (F-test 0.19; t-test 0.99). Both
datasets can therefore be combined. Valid chronic toxicity data are available for
17 species originating from 7 taxonomic groups. No selected value for an insect
is available. However, in a full life-cycle study with the midge Tanytarsus
dissimilis, it was concluded that concentrations below 500 μg/L resulted in
minimal effects (Darville and Wilhm, 1984). However, details on the dose-
response relationship for this species are missing. With this value missing, a
species sensitivity distribution can in principle not be applied. For comparative
purposes the figure is shown below (Figure 3). The HC5 is 25 μg/L and the HC50
is 520 μg/L. The data do not fit well to a log-normal distribution. Next to that,
effects for 1 species are observed in 1 study and not in the other or differences
exist even between different strains for the same species and there are some
effects observed even below the lowest EC10. The wide range of NOEC or EC10
values for different species, also raise some question whether there are more
specific modes of toxic action involved besides the baseline toxicity caused by
narcosis. Part of the differences might also be explained from the difficulties in
maintaining constant exposure concentration in toxicity experiments.
Because the uncertainties, the MPCeco_water is derived by applying an assessment
factor of 10 to the lowest EC10, instead of using the outcome of the species
sensitivity distribution. In the EU-RAR no chronic toxicity data for algae were
available. Hence, an assessment factor of 50 was applied. Useful data for algae
are now available (e.g.Walter et al., 2002). Therefore, the use of an assessment
factor of 10 instead of 50 seems to be justified, certainly because of the
extensive dataset with chronic data. The lowest usable effect concentration for
freshwater species is the EC10 from the ELS study with *Oncorhynchus mykiss* of 20 µg/L. The MPC\textsubscript{eco, water} is thus 2.0 µg/L. This value is almost identical to the PNEC value derived in the EU-RAR for naphthalene. However, an assessment factor of 10 has been used here instead of 50.

With 6 taxonomic groups for marine species, an assessment factor of 10 can be applied to the lowest NOEC as well. The MPC\textsubscript{eco, marine} is thus equal to the MPC\textsubscript{eco, water} of 2.0 µg/L. The SRC\textsubscript{eco} is both for freshwater and marine water equal to the HC50 of 520 µg/L.

![Figure 3: Species sensitivity distribution for the chronic toxicity of naphthalene to freshwater and marine species](image)

3.1.3 Sediment

All available effect concentrations for benthic organisms relate to 50% effect. The EC\textsubscript{50} for reburial of *Rhepoxynius abronius* after 10 days of exposure (Boese et al., 1998) is 1700 mg/kg\textsubscript{dw}, recalculated to Dutch standard sediment with an organic carbon matter of 10%. Irradiation of the crustaceans with UV light had no effect on this parameter. It should be noted that although this value is an EC\textsubscript{50}, the exposure time (10-d) as well as the endpoint (reburial) are rather chronic than acute. Nevertheless, the difference with the LC\textsubscript{50} is negligible.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC\textsubscript{50}/EC\textsubscript{50} [mg/kg\textsubscript{standard sediment}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td><em>Rhepoxynius abronius</em></td>
<td>1712</td>
</tr>
</tbody>
</table>

With an assessment factor of 1000, an MPC\textsubscript{eco, sediment} of 1.7 mg/kg\textsubscript{dw}, standard sed would be derived. Because the MPC is based on 1 acute effect concentration, this MPC has to be compared with one derived by equilibrium partitioning, which is 0.16 mg/kg\textsubscript{dw}. This value of 0.16 mg/kg\textsubscript{dw} is therefore the final MPC\textsubscript{eco, sediment}. Because the MPC\textsubscript{eco, marine} is equal to the MPC\textsubscript{eco, water} the MPC\textsubscript{eco, marine sediment} is equal to the MPC\textsubscript{eco, sediment} as well.
The SRC_{eco, sediment} is derived by comparing the direct acute EC50 divided by a factor of 10 with the value derived by equilibrium partitioning. The value derived by equilibrium partitioning is the lowest. This value of 42 mg/kg_{dw, standard sed} is the SRC_{eco, sediment}.

3.1.4 Soil

Concentrations of naphthalene in soil rapidly diminish. The concentrations at the end of a 28-d experiment with the pot worm *Enchytraeus crypticus* and the springtail *Folsomia candida* were only 1 to 10% of the actual initial concentrations (Bleeker et al., 2003; Droge et al., 2006). In a similar test with the springtail *Folsomia fimetaria* the concentrations at the end of the 21-d experiment were 4 to 10% of the actual initial concentrations (Sverdrup et al., 2001). In a test on microbial processes (Kirchmann et al., 1991) the concentrations dropped to 9 and 2% of the actual initial concentration after 5 and 10 days in the highest concentration (21 mg/kg_{dw}) and to 13 and 8% in the lowest concentration (0.1 mg/kg_{dw}).

Time-weighted average concentrations for these studies were estimated to be 24% over 28 days (Bleeker et al., 2003; Droge et al., 2006), 33% over 21 days (Sverdrup et al., 2001), and 34-38% over 7 days (Kirchmann et al., 1991). It appears that the rate of disappearance varies considerably between the studies. Because of the rapid disappearance of naphthalene in all studies, time-weighted average concentrations are preferred to base the effect concentration upon. Studies that have only measured initial concentrations are prone to errors and especially studies, in which concentrations have not been verified, should be considered as invalid.

Selected terrestrial toxicity data are available for 1 annelid species, 2 springtail species, and microbial processes (Table 13). Effect concentrations from terrestrial studies are first transferred to values for standard soil containing 10% organic matter by correcting for the organic carbon content. The lowest usable effect concentration is the NOEC of 6.9 mg/kg_{dw, standard soil} for reproduction of the springtail *Folsomia candida* from a 28-d study (Bleeker et al., 2003). No value was selected for terrestrial plants. For lettuce (*Lactuca sativa*) a NOEC of 230 and an EC10 of 340 mg/kg_{dw, standard soil} are available based on nominal concentrations. However, at 100 mg/kg_{dw} (714 mg/kg_{dw, standard soil}) the initial concentration appeared to be only 46%, while at 10 mg/kg_{dw} this measured initial concentration was only 10%. After the test period of 14 days, the concentration at both levels had dropped below the detection limit of 0.2 mg/kg_{dw}. This means that the time weighted average concentrations over this period can be at most 5 to 8% of the nominal concentration. Nevertheless, this is still amply higher than the value for *Folsomia candida*. It is therefore concluded that terrestrial plants are not the most sensitive species for naphthalene.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg_{standard soil}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td><em>Enchytraeus crypticus</em></td>
<td>17</td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Folsomia candida</em></td>
<td>6.9</td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Folsomia fimetaria</em></td>
<td>24</td>
</tr>
<tr>
<td>Process/activity</td>
<td>respiration, nitrogen</td>
<td>≥24</td>
</tr>
<tr>
<td></td>
<td>mineralization, nitrification</td>
<td></td>
</tr>
</tbody>
</table>

With terrestrial plants included the toxicity data cover primary producers, consumers, and decomposers. Therefore, an assessment factor of 10 can be
applied to the lowest EC10. This results in an MPCeco, soil of 0.69 mg/kg dw, standard soil. The SRCeco, soil based on the chronic data for three species is 14 mg/kg dw, standard soil.

3.2 Acenaphthylene

3.2.1 Substance identification and physicochemical properties

3.2.1.1 Identity

![Figure 4: Structural formula of acenaphthylene](image)

Table 14: Identification of acenaphthylene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Acenaphthylene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>Acenaphthylene</td>
</tr>
<tr>
<td>CAS number</td>
<td>208-96-8</td>
</tr>
<tr>
<td>EC number</td>
<td>205-917-1</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c1ccc2cccc3c2c1C=C3</td>
</tr>
</tbody>
</table>

3.2.1.2 Physicochemical properties

Table 15: Physicochemical properties of acenaphthylene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>152.2</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>16,100</td>
<td>Generator-column method</td>
</tr>
<tr>
<td>log $K_{OW}$</td>
<td>[-]</td>
<td>3.55</td>
<td>HPLC-RT</td>
</tr>
<tr>
<td>log $K_{OC}$</td>
<td>[-]</td>
<td>3.34</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>0.89</td>
<td>Gas saturation method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>91.8</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa.m³/mol]</td>
<td>11.9</td>
<td>Geometric mean of two values by the gas stripping method and one by the wetted-wall method</td>
</tr>
</tbody>
</table>

3.2.2 Water

Very few data are available for acenaphthylene. The selected acute toxicity data for freshwater species are presented in Table 16. For all studies the stability of the aqueous concentration is not reported. In the acute toxicity study 48-h with Daphnia magna, concentrations were measured (Bisson et al., 2000). In a 96-h acute toxicity study with the Japanese Medaka, test solutions were renewed but it is unclear whether or not concentrations were measured (Yoshioka and Ose, 1993).

Table 16: Selected acute toxicity data of acenaphthylene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td>Daphnia magna</td>
<td>1800</td>
</tr>
<tr>
<td>Pisces</td>
<td>Oryzias latipes</td>
<td>6400</td>
</tr>
</tbody>
</table>
The only selected value for marine species is shown in Table 17. In a short-term bioluminescence test with *Vibrio fischeri*, illumination with simulated solar radiation had no effect on the EC50 (340 µg/L versus 330 µg/L in the dark) (El-Alawi et al., 2001). Concentrations in these tests were not verified, but considering the exposure time (15 minutes) this is not considered invalidating the test.

**Table 17: Selected acute toxicity data of acenaphthylene to marine species**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td><em>Vibrio fischeri</em></td>
<td>330 a</td>
</tr>
</tbody>
</table>

Notes to Table 17

a Geometric mean of 330 and 340 µg/L at standard exposure time (15 min).

Strictly, the base set, which consists of acute data for algae, *Daphnia*, and fish, is not complete, because an acute toxicity study with algae is missing. However, a 72-h static study with *Pseudokirchneriella subcapitata* was performed but only the EC10 value is reported (Bisson et al., 2000). For algae, the EC50 is derived from the same study as the NOEC or EC10. The EC50 must therefore be higher than this EC10 value. Therefore, the base set is considered to be complete. If there is no significant difference between freshwater and marine species, the data are combined. In this case there are insufficient data for a meaningful statistical test. Therefore, the data are assumed to be similar as for the other PAHs. The most sensitive species in acute tests is the bacterium species *Vibrio fischeri*. The MACeco, water is based on this value. Normally an assessment factor of 100 is applied to this value. However, the presumed mode of toxic action of acenaphthylene in ecotoxicity studies is narcosis, at least in acute tests. Further, the EC50 for *Vibrio fischeri* is considerably lower than the other EC50s and only a factor of 4 to 6 higher than the chronic values (Table 18). Therefore, an assessment factor of 10 seems justified. The MACeco, water thus is 33 µg/L.

Because the data set does not contain a marine species, other than *Vibrio fischeri*, an extra assessment factor of 10 is applied for the marine environment. The MACeco, marine is thus 3.3 µg/L.

Two long term toxicity studies with acenaphthylene are available (Table 18), a 72-h static study with *Pseudokirchneriella subcapitata* and a 7-d renewal reproduction study with *Ceriodaphnia dubia*. In both studies, concentrations were experimentally determined (Bisson et al., 2000).

**Table 18: Selected chronic toxicity data of acenaphthylene to freshwater species**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td><em>Pseudokirchneriella subcapitata</em></td>
<td>82</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Ceriodaphnia dubia</em></td>
<td>64</td>
</tr>
</tbody>
</table>

Two chronic NOECs for 2 trophic levels are available. These are the EC10 for growth of the algae *Pseudokirchneriella subcapitata* and for reproduction of the crustacean *Ceriodaphnia dubia*. To apply an assessment factor of 50 to these data, the group showing the lowest L(E)50 should be included in the data. It can be questioned if algae would be the trophic level showing the lowest L(E)50, because the bacterium species *Vibrio fischeri*, which appeared to be the most sensitive species in acute studies, has an EC50 of 330 to 340 µg/L, which is only a factor of 4 higher than the EC10 for *Pseudokirchneriella subcapitata*. However, chronic data for any species of bacteria are not considered in the derivation of the MPC for water in the case that assessment factors are used.

The 30-min EC50 and EC10 values for *Vibrio fischeri* were reported based on measured concentrations (Loibner et al., 2004). The EC10 was 180 µg/L. If the
short term EC10 for bioluminescence is considered as a representative measure of growth, growth of *Vibrio* is not inhibited at concentrations below the lowest EC10 value for *Ceriodaphnia dubia*. Also the EC10 for *Pseudokirchneriella subcapitata* is lower than the EC10 for *Vibrio fischeri*. Some long-term experiments were performed with *Vibrio fischeri* as well (El-Alawi et al., 2001). Growth and bioluminescence were examined after 18 hours of exposure. The tests were performed in a complex medium, and therefore, they are not considered to be representative of the aqueous environment. However, from the test it appeared that bioluminescence is almost 1:1 correlated with growth of the bacteria. Therefore, an assessment factor of 50 seems to be justified and can be applied to the lowest EC10 of 64 µg/L for *Ceriodaphnia dubia*. The MPCeco, water then becomes 1.3 µg/L. With no additional NOECs or EC10s for marine species, an assessment factor of 500 is applied for the marine environment. The MPCeco, marine thus becomes 0.13 µg/L. The SRCeco, water is derived by comparing the geometric mean of the acute toxicity data, divided by a factor of 10, and the geometric mean of the chronic toxicity data. The geometric mean of the chronic toxicity data is the lowest value. The SRCeco, water is 72 µg/L.

### 3.2.3 Sediment

No data for benthic organisms are available. Therefore, the ERLs are derived by means of equilibrium partitioning. The MPCeco, sediment is 0.17 mg/kg dw, standard sed. For the marine environment, this number is a factor of 10 lower. The MPCeco, marine sediment is 0.017 mg/kg dw, standard sed. The SRCeco, sediment is 9.5 mg/kg dw, standard sed.

### 3.2.4 Soil

Only 1 toxicity test with terrestrial species is available for acenaphthylene (Table 19). On the basis of this test an MPCeco, soil of 0.51 mg/kg dw, standard soil is derived. Because there is only 1 value, the MPC has to be derived by equilibrium partitioning as well. A value of 0.17 mg/kg dw, standard soil is derived, which is lower than the value derived from the study with springtails. The MPCeco, soil is thus equal to 0.17 mg/kg dw, standard soil.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard soil]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insecta</td>
<td><em>Folsomia fimetaria</em></td>
<td>51</td>
</tr>
</tbody>
</table>

Table 19: Selected chronic toxicity data of acenaphthylene to terrestrial species and processes

Also the SRCeco, soil is derived by comparing the terrestrial value with a value derived by equilibrium partitioning: 51 versus 9.4 mg/kg dw, standard soil. The SRCeco, soil is thus 9.4 mg/kg dw, standard soil.

### 3.3 Acenaphthene

#### 3.3.1 Substance identification and physicochemical properties

#### 3.3.1.1 Identity

![Figure 5: Structural formula of acenaphthene](image-url)
### Table 20: Identification of acenaphthene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Acenaphthene, ethylenenaphthalene, periethylenenaphthalene,</td>
</tr>
<tr>
<td></td>
<td>1,2-dihydro-acenaphthalene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>1,8-hydroacenaphthyene</td>
</tr>
<tr>
<td>CAS number</td>
<td>83-32-9</td>
</tr>
<tr>
<td>EC number</td>
<td>201-469-6</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c1ccc2cccc3c2c1CC3</td>
</tr>
</tbody>
</table>

#### 3.3.1.2 Physicochemical properties

### Table 21: Physicochemical properties of acenaphthene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>154.2</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>4160</td>
<td>Geometric mean of 7 values by generator-column method</td>
</tr>
<tr>
<td>log $K_{OW}$</td>
<td>[-]</td>
<td>3.92</td>
<td>Shake-flask method</td>
</tr>
<tr>
<td>log $K_{OC}$</td>
<td>[-]</td>
<td>3.71</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>0.35</td>
<td>Geometric mean of 2 values by gas saturation method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>93.4</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>279</td>
<td></td>
</tr>
<tr>
<td>Henry's law constant</td>
<td>[Pa.m³/mol]</td>
<td>13.9</td>
<td>Geometric mean of 5 values by gas stripping method, 1 value by wetted-wall method and 1 value by headspace method</td>
</tr>
</tbody>
</table>

#### 3.3.2 Water

Acute toxicity tests with freshwater species and acenaphthene have been performed with crustaceans (*Daphnia*) and fish (Table 22). The lowest EC50s are for the fish species *Salmo trutta* and *Oncorhynchus mykiss* from studies with continuous flow-system and measured concentrations (Holcombe et al., 1983).

### Table 22: Selected acute toxicity data of acenaphthene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td><em>Daphnia magna</em></td>
<td>958</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Ictalurus punctatus</em></td>
<td>1720</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Oncorhynchus mykiss</em></td>
<td>670</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Pimephales promelas</em></td>
<td>986 a</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Salmo trutta</em></td>
<td>580</td>
</tr>
</tbody>
</table>

Notes to Table 22

* Geometric mean of 608 and 1600 µg/L.

Acute toxicity data for marine species are available for bacteria, molluscs and fish (Table 23). Illumination with simulated solar radiation had no effect on the EC50 for the bacterium species *Vibrio fischeri* (830 µg/L versus 810 µg/L in the dark) (El-Alawi et al., 2001).

There is no significant difference between the freshwater and marine acute toxicity data (F-test 0.12, t-test 0.88). Therefore, data can be combined. The lowest value is for the marine species *Mytilus edulis*. The EC50 for this species is 382 µg/L. However, no EC50 for algae is reported. A valid toxicity study with *Pseudokirchneriella subcapitata* is available (Bisson et al., 2000) for which only the EC10 of 38 µg/L is reported (Table 24). The EC50 must therefore be higher than this value. However, it is not likely that the EC50 will be higher than the...
value for the mollusc species, which is a factor of 10 higher than the EC10 for algae. This has to be taken into account in deriving the MAC\textsubscript{eco, water}. Therefore, the default assessment factor of 100 is not lowered to 10 in this case. The MAC\textsubscript{eco, water} is then 3.8 µg/L. One EC50 is available for a typical marine species (mollusc). The extra assessment factor for the MAC\textsubscript{eco, marine} is therefore 5 instead of 10. Then, the MAC\textsubscript{eco, marine} is 0.76 µg/L.

Table 23: Selected acute toxicity data of acenaphthene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>Vibrio fischeri</td>
<td>820 (^a)</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Mytilus edulis</td>
<td>382</td>
</tr>
<tr>
<td>Piscines</td>
<td>Cyprinodon variegates</td>
<td>3100</td>
</tr>
</tbody>
</table>

Notes to Table 23

\(^a\) Geometric mean of 810 and 830 µg/L at standard exposure time (15 min).

With the toxicity study with algae in the chronic data, the base set can be considered complete. Besides algae, chronic toxicity data are available for a crustacean, an insect and fish (Table 24). The crustacean (Bisson et al., 2000) and the insect species (Meier et al., 2000) both have EC10 values that are almost identical to the value for algae. Two independent ELS tests with \textit{Pimephales promelas} were carried out, one with dimethylformamide as solvent and one without carrier (Cairns and Nebeker, 1982). The fish were exposed by a flow-through system and concentrations were measured.

Table 24: Selected chronic toxicity data of acenaphthene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>\textit{Pseudokirchneriella subcapitata}</td>
<td>38</td>
</tr>
<tr>
<td>Crustacea</td>
<td>\textit{Ceriodaphnia dubia}</td>
<td>42</td>
</tr>
<tr>
<td>Insecta</td>
<td>\textit{Paratanytarsus parthenogeneticus}</td>
<td>39</td>
</tr>
<tr>
<td>Piscines</td>
<td>\textit{Pimephales promelas}</td>
<td>289 (^a)</td>
</tr>
</tbody>
</table>

Notes to Table 24

\(^a\) Geometric mean of 190 and 440 µg/L for the most sensitive endpoint (wet weight).

The only available valid chronic study with marine species is a flow-through ELS study with the marine fish \textit{Cyprinidon variegatus} (Ward et al., 1981) (Table 25).

Table 25: Selected chronic toxicity data of acenaphthene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piscines</td>
<td>\textit{Cyprinodon variegatus}</td>
<td>610</td>
</tr>
</tbody>
</table>

The algae species \textit{Pseudokirchneriella subcapitata} is the most sensitive species tested, and although the EC50 for this species is missing, it will most likely also be the species with the lowest EC50 (see discussion above). Hence, an assessment factor of 10 can be applied to the lowest NOEC or EC10. The MPC\textsubscript{eco, water} then becomes 3.8 µg/L. No additional chronic toxicity data for typically marine species are available. Therefore, an assessment factor of 100 will be applied to the lowest NOEC or EC10 to derive the MPC\textsubscript{eco, marine}. This MPC\textsubscript{eco, marine} thus is 0.38 µg/L. The SRC\textsubscript{eco, water} is derived from the geometric mean of the chronic toxicity data, which is 100 µg/L.
3.3.3 Sediment

The marine crustacean *Rhepoxynius abronius* is the only benthic species tested with acenaphthene (Swartz et al., 1997; Boese et al., 1998). In this case reburial was not strongly influenced by irradiation with UV. This is similar to the results obtained for naphthalene and phenanthrene but different from the results for fluoranthene and pyrene, for which a significant photoactivation by UV radiation was found (Boese et al., 1997). The lowest endpoint, is therefore the EC10 for mortality, derived from the data presented by Swartz et al. (1997).

Table 26: Selected chronic toxicity data of acenaphthene to benthic species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard sediment]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td><em>Rhepoxynius abronius</em></td>
<td>97 a</td>
</tr>
</tbody>
</table>

Notes to Table 26

a Geometric mean of 95 and 99 mg/kg_{dw, standard sed}, recalculated to standard sediment with 10% organic matter.

One chronic toxicity study is available for benthic species. In this case, the MPC for freshwater sediment will be derived with an assessment factor of 100. After application of this factor, the MPC_{eco, sediment} becomes 0.97 mg/kg_{dw}.

For marine sediment an assessment factor of 1000 should be applied. The MPC_{eco, marine sediment} therefore is 0.097 mg/kg_{dw}.

The SRC_{eco, sediment} is derived by comparing the value of the NOEC for the benthic species with a value derived by equilibrium partitioning. The value derived by equilibrium partitioning is 31 mg/kg_{dw} and consequently, the SRC_{eco, sediment} is 31 mg/kg_{dw}.

3.3.4 Soil

Two studies with terrestrial species are available for acenaphthene. The first study is a 14-d study for germination and shoot growth of *Lactuca sativa* (Hulzebos et al., 1993) The EC50 for acenaphthene is 139 mg/kg_{dw, rec}, recalculated to a soil with 10% organic matter. No dose-response data or NOEC or EC10 are given in the publication. However, in an unpublished underlying report the NOEC is stated to be 5.6 mg/kg_{dw, rec} recalculated to a soil with 10% organic matter. However, the concentrations of acenaphthene were not experimentally determined. Given the highly volatile character of the substance in combination with the analytical results for naphthalene showing less than 50% recovery at the start of the test under the same conditions (Adema and Henzen, 1990), this study should be considered as invalid.

The EC10 from a 21-d reproduction study with *Folsomia fimetaria* (Sverdrup et al., 2002) was 68 mg/kg_{dw, rec} recalculated to a soil with 10% organic matter. The concentrations in the original study are expressed as initial measured concentrations, but the concentrations were recalculated to time weighted average concentrations to take the loss of the substance during the 28-d exposure period into account.

Valid chronic toxicity data (Table 27) are available for springtails only. Therefore, an assessment factor of 100 can be applied to the lowest NOEC or EC10. This value has to be compared with a value derived by equilibrium partitioning. The value derived by equilibrium partitioning is 1.15 mg/kg_{dw}. Therefore, the MPC_{eco, soil} is 0.68 mg/kg_{dw}.
Table 27: Selected chronic toxicity data of acenaphtene to terrestrial species and processes

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard soil]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insecta</td>
<td>Folsomia fimetaria</td>
<td>68</td>
</tr>
</tbody>
</table>

Similar to the SRC\textsubscript{eco,sediment}, SRC\textsubscript{eco,soil} is derived by comparing the value of the NOEC for the terrestrial species with a value derived by equilibrium partitioning. The value derived by equilibrium partitioning is 31 mg/kg\textsubscript{dw} and consequently, the SRC\textsubscript{eco, soil} is 31 mg/kg\textsubscript{dw}.

3.4 Fluorene

3.4.1 Substance identification and physicochemical properties

3.4.1.1 Identity

![Figure 6: Structural formula of fluorene]

Table 28: Identification of fluorene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Fluorene, 2,3-benzindene, diphenylenemethane, 9H-fluorene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>diphenylenemethane</td>
</tr>
<tr>
<td>CAS number</td>
<td>86-73-7</td>
</tr>
<tr>
<td>EC number</td>
<td>201-695-5</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c12cccccc1c3cccccc3C1</td>
</tr>
</tbody>
</table>

3.4.1.2 Physicochemical properties

Table 29: Physicochemical properties of fluorene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>166.2</td>
<td>Geometric mean of five values by the generator-column method</td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>1880</td>
<td>Two values by the shake-flask method</td>
</tr>
<tr>
<td>log $K_{OW}$</td>
<td>[-]</td>
<td>4.18</td>
<td>QSAR</td>
</tr>
<tr>
<td>log $K_{OC}$</td>
<td>[-]</td>
<td>3.97</td>
<td></td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>0.084</td>
<td>Geometric mean of two values by the gas saturation method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>114.8</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>295</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa.m$^3$/mol]</td>
<td>8.7</td>
<td>Geometric mean of six values by the gas/batch stripping method and one by the wetted-wall method</td>
</tr>
</tbody>
</table>

3.4.2 Water

Reliable acute toxicity data for fluorene to freshwater species are available for crustaceans, an insect species and fish (Table 30). No EC50 for algae is available. However, an EC10 for algae is reported from which it appears that algae are not very sensitive in this case (Bisson et al., 2000). For the marine environment selected data are available for an annelid and a bacterium species and two crustaceans (Table 31). There are no significant differences between the freshwater and marine species ($F$-test 0.58, $t$-test 0.17). Therefore, data can be combined.
Table 30: Selected acute toxicity data of fluorene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td>Daphnia magna</td>
<td>339 (^a)</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Gammarus pseudolimnaeus</td>
<td>346</td>
</tr>
<tr>
<td>Insecta</td>
<td>Chironomus riparius</td>
<td>1539</td>
</tr>
<tr>
<td>Pisces</td>
<td>Lepomis macrochirus</td>
<td>525</td>
</tr>
<tr>
<td>Pisces</td>
<td>Oncorhynchus mykiss</td>
<td>473</td>
</tr>
</tbody>
</table>

Notes to Table 30

\(^a\) Geometric mean of 408 and 282 µg/L.

Table 31: Selected acute toxicity data of fluorene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td>Neanthes arenaceodentata</td>
<td>1000</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Vibrio fischeri</td>
<td>756 (^a)</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Oithona davisae</td>
<td>1660 (^b)</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Palaemonetes pugio</td>
<td>616</td>
</tr>
</tbody>
</table>

Notes to Table 31

\(^a\) Standard exposure time (15 min).
\(^b\) Most sensitive endpoint (immobility).

The most sensitive species is *Daphnia magna*. The MAC\(_{ec0, water}\) is based on this value. Normally an assessment factor of 100 is applied to this value. However, the presumed mode of toxic action of fluorene in ecotoxicity studies is narcosis, at least in acute test. Further, there are valid acute toxicity data for 9 species and the interspecies variation is low, i.e. all values are within a factor of 5.

Therefore, an assessment factor of 10 seems to be justified. The MAC\(_{ec0, water}\) is 34 µg/L. Because the data set does contain an additional marine species, which is the annelid *Neanthes arenaceodentata*, an extra assessment factor of 5 is sufficient for the marine environment. The MAC\(_{ec0, marine}\) is thus 6.8 µg/L.

Selected chronic toxicity data are available for an algal, three crustaceans, an insect and a fish species (Table 32). Additional data for marine species are available for the echinoderm *Paracentrotus lividus* (Table 33).

Table 32: Selected chronic toxicity data of fluorene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Pseudokirchneriella subcapitata</td>
<td>820</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Ceriodaphnia dubia</td>
<td>25</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia magna</td>
<td>15</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Hyalella azteca</td>
<td>327</td>
</tr>
<tr>
<td>Insecta</td>
<td>Chironomus riparius</td>
<td>142</td>
</tr>
<tr>
<td>Pisces</td>
<td>Lepomis macrochirus</td>
<td>42 (^a)</td>
</tr>
</tbody>
</table>

Notes to Table 32

\(^a\) Most sensitive endpoint (growth).

Table 33: Selected chronic toxicity data of fluorene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echinodermata</td>
<td>Paracentrotus lividus</td>
<td>492 (^a)</td>
</tr>
</tbody>
</table>

Notes to Table 33

\(^a\) Under both dark and light conditions.

The lowest value is for *Daphnia magna*, which is the same species that had the lowest acute value. The MPC\(_{ec0, water}\) is derived by applying an assessment factor
of 10 to the lowest chronic value. The resulting MPC_{eco, water} is 1.5 \mu g/L. Because there is one chronic value for an additional marine species, the assessment factor for the MPC_{eco, marine} is 50. This results in an MPC_{eco, marine} of 0.30 \mu g/L. The SRC_{eco, water} is calculated as the geometric mean of the chronic data and is 117 \mu g/L.

### 3.4.3 Sediment

No data for benthic organisms are available. Therefore, the ERLs are derived by means of equilibrium partitioning. The MPC_{eco, sediment} is 0.83 mg/kg_{dw, standard sed}. For the marine environment, this number is a factor of 5 lower. The MPC_{eco, marine sediment} is 0.17 mg/kg_{dw, standard sed}. The SRC_{eco, sediment} is 64 mg/kg_{dw, standard sed}.

### 3.4.4 Soil

Apart from acute toxicity to four species of earthworms (Neuhauser et al., 1986a), selected chronic toxicity data are available for seven terrestrial species and for nitrification (Table 34). The species include two annelids, an isopod, a springtail and four plant species.

**Table 34: Selected chronic toxicity data of fluorene to terrestrial species and processes**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg_{standard soil}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td><em>Eisenia veneta</em></td>
<td>114</td>
</tr>
<tr>
<td>Annelida</td>
<td><em>Enchytraeus crypticus</em></td>
<td>92</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Oniscus asellus</em></td>
<td>23 a</td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Folsomia fimetaria</em></td>
<td>16 b</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Lolium perenne</em></td>
<td>817 c</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Sinapis alba</em></td>
<td>115 c</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Trifolium pratense</em></td>
<td>67 c</td>
</tr>
<tr>
<td>Microbial process</td>
<td>nitrification</td>
<td>121</td>
</tr>
</tbody>
</table>

Notes to Table 34

- a Most sensitive endpoint (growth of females) corrected for time weighted average concentrations; NOECs much lower, EC10 is preferred.
- b Most sensitive endpoint (reproduction) corrected for time weighted average concentrations.
- c Most sensitive endpoint (fresh weight).

Fluorene is a substance that disappears rather quickly from the test system. In a test with the isopods *Oniscus asellus* and *Porcellia scaber*, only 20% of the initial concentration was left in food substrate consisting of poplar leaves enriched with dog food after 6 days of exposure (Van Brummelen et al., 1996). In a test with the springtail *Folsomia fimetaria* the concentrations at the end of the 21-d experiment were 31 to 35% of the actual initial concentrations (Sverdrup et al., 2001). In a test with the snail *Helix aspersa* the concentrations at the end of the 28-d experiment were only 16% of the actual initial concentrations (Sverdrup et al., 2006).

Time-weighted average concentrations for these studies were 46% over 28 days (Sverdrup et al., 2006), 58% over 21 days (Sverdrup et al., 2001) and 57% over 1 week (Van Brummelen et al., 1996). Because of the rapid disappearance of fluorene in some studies, time-weighted average concentrations are preferred to base the effect concentration upon. Studies that have only measured initial concentrations and especially studies, in which concentrations have not been verified should be used with caution.
The lowest value for fluorene is the EC10 for reproduction of *Folsomia fimetaria*. An assessment factor of 10 is applied to this value to derive the MPCeco, soil of 1.6 mg/kgdw. The SRCeco, soil is calculated as the geometric mean of the chronic terrestrial toxicity data for the 7 species and is 82 mg/kgdw.

3.5 Phenanthrene

3.5.1 Substance identification and physicochemical properties

3.5.1.1 Identity

![Figure 7: Structural formula of phenanthrene](image)

*Table 35: Identification of phenanthrene*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Phenanthrene, o-diphenyleneethene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>Phenanthrene</td>
</tr>
<tr>
<td>CAS number</td>
<td>85-01-8</td>
</tr>
<tr>
<td>EC number</td>
<td>201-581-5</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c12cccc1c3cccc3cc2</td>
</tr>
</tbody>
</table>

3.5.1.2 Physicochemical properties

*Table 36: Physicochemical properties of phenanthrene*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>178.23</td>
<td>Geometric mean of seven values by the generator-column method</td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>1034</td>
<td>Geometric mean of seven values by the generator-column method</td>
</tr>
<tr>
<td>log $K_{OW}$</td>
<td>[-]</td>
<td>4.502</td>
<td>Geometric mean of three values by the slow-stirring method</td>
</tr>
<tr>
<td>log $K_{OC}$</td>
<td>[-]</td>
<td>4.292</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>0.018</td>
<td>Geometric mean of five values by the gas saturation method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>99.2</td>
<td>Geometric mean of seven values by the gas stripping method, one by the headspace method and one by the wetted-wall method</td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>340</td>
<td></td>
</tr>
<tr>
<td>Henry's law constant</td>
<td>[Pa.m³/mol]</td>
<td>3.8</td>
<td></td>
</tr>
</tbody>
</table>

3.5.2 Water

Many acute toxicity data for phenanthrene are available. A strict selection has been performed on the available data, because phenanthrene concentrations are not stable in aquatic test systems. The selected acute toxicity data for freshwater species are listed in Table 37.

Selected toxicity data for marine species are shown in Table 38. In a toxicity experiment with three marine European crustaceans low LC50s were observed. The LC50 for *Corophium multisetosum*, *Gammarus aequicauda*, and *Gammarus locusta* were 215, 174, and 148 µg/L, respectively (Sanz-Lazaro et al., 2008). It is noteworthy that although these values are based on nominal concentrations,
the values are lower than for the selected values in Table 38 for other marine crustaceans.

Table 37: Selected acute toxicity data of phenanthrene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Nitzschia palea</td>
<td>870</td>
</tr>
<tr>
<td>Algae</td>
<td>Pseudokirchneriella subcapitata</td>
<td>233</td>
</tr>
<tr>
<td>Algae</td>
<td>Scenedesmus vacuolatus</td>
<td>590</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia magna</td>
<td>700</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia pulex</td>
<td>100</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Diporeia spp.</td>
<td>74 b</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Gammarus minus</td>
<td>460</td>
</tr>
<tr>
<td>Cyanophyta</td>
<td>Anabaena flos-aqua</td>
<td>1300</td>
</tr>
<tr>
<td>Insecta</td>
<td>Chironomus riparius</td>
<td>41 c</td>
</tr>
</tbody>
</table>

Notes to Table 37

- Geometric mean of 180 and 302 µg/L for the growth rate (most relevant parameter) under optimal growth conditions (2 d, pH restricted to 7.0-7.3).
- Longest exposure time of 5 d.
- Most sensitive life-stage (1st instar) illuminated with a mercury light source 330-800 nm, including some UV-A.

Table 38: Selected acute toxicity data of phenanthrene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td>Neanthes arenaceous dentata</td>
<td>187</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Vibrio Fischer</td>
<td>310 a</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Acartia tonsa</td>
<td>422</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Artemia salina</td>
<td>520</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Oithona davisae</td>
<td>522 b</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Palaemonetes pugio</td>
<td>360</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Mytilus edulis</td>
<td>148</td>
</tr>
</tbody>
</table>

Notes to Table 38

- Geometric mean of 530, 530, 510, 520, 144, 142, and 182 µg/L for standard exposure time (15 min).
- Most sensitive endpoint (mortality).

There are no reliable acute toxicity studies with fish. There is one 96-h toxicity test with fry of rainbow trout (Oncorhynchus mykiss) tested in freshwater under static conditions (Edsall, 1991), and one 96-h toxicity test with the marine fish sheepshead minnow (Cyprinodon variegatus) with renewal of the solution every 24 hours (Moreau et al., 1999). Concentrations were not verified in these studies. The LC50s based on nominal concentrations were 3200 µg/L for rainbow trout and 478 µg/L for sheepshead minnow.

There are no reliable toxicity data for aquatic plants. In toxicity tests with duckweed (Lemma gibba) EC50s based on nominal concentrations were all far above the solubility limit of 1034 µg/L (Huang et al., 1993; Huang et al., 1995; McConkey et al., 1997).

There is no significant difference between the freshwater and marine acute toxicity data, although the variance in the freshwater data is larger than in the marine data (F-test 0.05, t-test 0.86). However, this is likely due to the inclusion of other taxonomic groups. Therefore, the datasets can be combined. There are no reliable toxicity data for fish or other vertebrates and for aquatic plants. However, from two fish species tested and one aquatic plant, these groups do not appear particularly sensitive. Therefore, the MACeco, water and the
MACeco, marine can be derived from a species sensitivity distribution (Figure 8). The HC5 of the acute toxicity data is 67 µg/L, which is above the lowest value of 41 µg/L for Chironomus riparius. The HC50 is 307 µg/L. The goodness-of-fit is accepted at all significance levels. The MACeco, water is derived from the HC5(acute), default by applying an assessment factor of 10. The number of toxicity data and the taxonomic diversity is high and the differences in species sensitivity are low, which is characteristic of narcotic effects. The MACeco, water should be protective of any acute effects. However, the values used in the SSD are 50% effective concentration. Therefore, an assessment is made between the 50% and 10% effective concentrations (EC50 and EC10). A direct comparison can be made for 8 species from 4 taxonomic groups (Table 39). The ratio between the EC50 and EC10 varies widely. Moreover, such data have not been generated for the most sensitive taxonomic group, which are the insects. Therefore, an assessment factor of 10 is applied to the HC5(acute) to derive the MACeco, water. The MACeco, water is thus 6.7 µg/L. Because of the number of marine data, including non standard species such as annelids and molluscs, an extra assessment factor for the MACeco, marine is not necessary. The MACeco, marine is 6.7 µg/L too.

![Figure 8: Species sensitivity distribution for the acute toxicity of phenanthrene to freshwater and marine species](image)

Selected chronic toxicity data for freshwater species are shown in Table 40. Insects, which were the most sensitive species tested in acute toxicity tests, are not among the selected data. For the two most sensitive species tested in acute tests some data are available. In a 28-d sediment test with Chironomus riparius overlying water concentrations were also measured (Bleeker et al., 2003). The LOEC for emergence was 43 µg/L, which is above most of the NOECs or EC10s in Table 40. Survival and immobility of Diporeia species was also tested in a 10-d and 28-d test (Landrum et al., 2003). The 10-d EC50 for immobility was 38 µg/L, while the 10-d and 28-d LC50 were 168 and 95 µg/L, respectively.
Although the latter values for lethality and immobility might be rather insensitive, these results are higher than most NOECs or EC10s in Table 40.

Table 39: Acute no effect levels (10% cut-off by means of EC10) versus 50% effect levels (EC50) for phenanthrene

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>EC50/EC10 or LC50/LC10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Pseudokirchneriella subcapitata</td>
<td>6.5-18</td>
</tr>
<tr>
<td>Algae</td>
<td>Scenedesmus vacuolatus</td>
<td>3.9</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Vibrio fischeri</td>
<td>3.7-24</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia magna</td>
<td>1.3-2.6</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia pulex</td>
<td>2.5</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Acartia tonsa</td>
<td>1.3</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Oithona davisae</td>
<td>2.1-2.7</td>
</tr>
<tr>
<td>Cyanophyta</td>
<td>Anabaena flos-aqua</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Table 40: Selected chronic toxicity data of phenanthrene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Nitzschia palea</td>
<td>870</td>
</tr>
<tr>
<td>Algae</td>
<td>Pseudokirchneriella subcapitata</td>
<td>15 a</td>
</tr>
<tr>
<td>Algae</td>
<td>Scenedesmus vacuolatus</td>
<td>150</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Ceriodaphnia dubia</td>
<td>13</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia magna</td>
<td>18 b</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia pulex</td>
<td>13 c</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Hyalella azteca</td>
<td>155</td>
</tr>
<tr>
<td>Pisces</td>
<td>Danio rerio</td>
<td>14 d</td>
</tr>
<tr>
<td>Pisces</td>
<td>Micropterus salmoides</td>
<td>11</td>
</tr>
<tr>
<td>Pisces</td>
<td>Oncorhynchus mykiss</td>
<td>23 d</td>
</tr>
<tr>
<td>Pisces</td>
<td>Oryzias latipes</td>
<td>93 e</td>
</tr>
</tbody>
</table>

Notes to Table 40

a Geometric mean of 10 and 24 µg/L for the growth rate (most relevant parameter) under optimal growth conditions (2 d, pH restricted to 7.0-7.3).
b Most sensitive parameter (reproduction) determined under most reliable exposure regime (intermittent flow).
c Most sensitive parameter (reproduction).
d Most sensitive parameter (weight).
e Most sensitive parameter (malformations).

Selected chronic toxicity data for marine species are shown in Table 41. The selected marine data are statistically higher than the freshwater data (F-test 0.67, t-test 0.04). This is most likely due to the fact that the taxonomic groups echinoderms and tunicates are not particularly sensitive. Therefore, both sets of data are still combined.

Because acute and chronic toxicity data are available for algae, Daphnia, and fish, an assessment factor can be applied to the lowest NOEC or EC10. This is the EC10 of 11 µg/L for Micropterus salmoides. The resulting MPCeco, water is 1.1 µg/L. Because chronic data are available for additional taxonomic groups for the marine environment, the same assessment factor can be applied for the MPCeco, marine, which is 1.0 µg/L too. The SRCeco, water is equal to the geometric mean of the chronic toxicity data and is 43 µg/L.
Table 41: Selected chronic toxicity data of phenanthrene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td>Acartia tonsa</td>
<td>69 (^a)</td>
</tr>
<tr>
<td>Echinodermata</td>
<td>Arbacia punctulata</td>
<td>164</td>
</tr>
<tr>
<td>Echinodermata</td>
<td>Paracentrotus lividus</td>
<td>105 (^b)</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Mytilus galloprovincialis</td>
<td>29 (^c)</td>
</tr>
<tr>
<td>Tunicata</td>
<td>Ciona intestinalis</td>
<td>262 (^b)</td>
</tr>
</tbody>
</table>

Notes to Table 41

\(^a\) Most sensitive parameter (recruitment) determined under most reliable exposure regime (intermittent flow).

\(^b\) Determined with a photoperiod 14:10 h light:dark by cool daylight lamps (380-780 nm, PAR) with an intensity of 70 µE/m²/s.

\(^c\) Determined in the dark.

3.5.3 Sediment

Selected toxicity data for benthic organisms are shown in Table 42, recalculated to standard sediment with 10% organic matter. The crustaceans Rhepoxynius abronius and Schizopera knabeni are marine species while the annelid Limnodrilus hoffmeisteri inhabits mostly brackish sediments. The rest of the species live in freshwater sediments.

Table 42: Selected chronic toxicity data of phenanthrene to benthic species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard sediment]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td>Limnodrilus hoffmeisteri</td>
<td>168 (^a)</td>
</tr>
<tr>
<td>Annelida</td>
<td>Lumbriculus variegatus</td>
<td>26</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Hyalella azteca</td>
<td>167 (^b)</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Rhepoxynius abronius</td>
<td>122 (^c)</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Schizopera knabeni</td>
<td>7.8 (^d)</td>
</tr>
<tr>
<td>Insecta</td>
<td>Chironomus riparius</td>
<td>91 (^e)</td>
</tr>
</tbody>
</table>

Notes to Table 42

\(^a\) Most sensitive parameter (sediment egestion).

\(^b\) Geometric mean of 339, 113, and 122 mg/kg\(_{\text{dw, standard sed}}\), recalculated to standard sediment with 10% organic matter, for the most sensitive parameter (length).

\(^c\) Geometric mean of 125 and 120 mg/kg\(_{\text{dw, standard sed}}\), recalculated to standard sediment with 10% organic matter.

\(^d\) Most sensitive parameter (reproduction).

\(^e\) Geometric mean of 84, 114, and 79 mg/kg\(_{\text{dw, standard sed}}\), recalculated to standard sediment with 10% organic matter for the parameter emergence/mortality in a 28-d study.

With 6 chronic data from 3 taxonomic groups equally distributed over freshwater and marine species, a minimum assessment factor of 10 can be applied to derive the MPC\(_{\text{eco, sediment}}\) and MPC\(_{\text{eco, marine sediment}}\). The resulting value is 0.78 mg/kg\(_{\text{standard sediment}}\). The SRC\(_{\text{eco, sediment}}\) is derived from the geometric mean of these benthic data and is 63 mg/kg\(_{\text{standard sediment}}\).

3.5.4 Soil

Also for phenanthrene concentrations in soil rapidly diminish. The recovery after the 21-d exposure period in a test with the earthworm Eisenia fetida was only 2.0-12% of the initial concentrations (Bowmer et al., 1993). The concentrations at the end of a 28-d experiment with the pot worm Enchytraeus crypticus and the springtail Folsomia candida were 5 to 35% of the actual initial concentrations.
In a similar test with the springtail *Folsomia fimetaria* the concentrations at the end of the 21-d experiment were 65 to 78% of the actual initial concentrations (Sverdrup et al., 2001). In a test with the isopods *Oniscus asellus* and *Porcellia scaber*, only 2.9% of the initial concentration was left in food substrate consisting of poplar leaves enriched with dog food after 6 days of exposure (Van Brummelen et al., 1996). In a test with the snail *Helix aspersa* the concentrations at the end of the 28-d experiment were only 4% of the actual initial concentrations (Sverdrup et al., 2006). On the other hand, the recovery at the beginning and end of a week exposure in a study with the springtail *Folsomia candida*, where the soil was renewed every week, ranged from 84 to 115% (Bowmer et al., 1993).

Time-weighted average concentrations for these studies were 33% over 21 days (Bowmer et al., 1993), 52% over 28 days (Bleeker et al., 2003; Droge et al., 2006), 30% over 28 days (Sverdrup et al., 2006), 85% over 21 days (Sverdrup et al., 2001), 29% over 1 week (Van Brummelen et al., 1996) and almost 100% over 1 week (Bowmer et al., 1993). It appears that the rate of disappearance varies considerably between the studies. However, because of the rapid disappearance of phenanthrene in some studies, time-weighted average concentrations are preferred to base the effect concentration upon. Studies that have only measured initial concentrations and especially studies, in which concentrations have not been verified should be used with caution.

Chronic toxicity data for phenanthrene in soil are available for annelids, collembola, terrestrial plants, and microbial processes. The EC10 for reproduction of *Eisenia fetida* (Bowmer et al., 1993) is the lowest EC10 or NOEC. This value is almost equal to the geometric mean of 33 and 41 mg/kgdw, standard soil for the springtail *Folsomia candida*. Because chronic data are available for 8 species and 1 terrestrial process, covering all trophic levels, an assessment factor of 10 can be applied to derive the MPCeco, soil. The MPCeco, soil is thus 3.6 mg/kgdw, standard soil. The SRCeco, soil is derived from the geometric mean of the data for the 8 species and is 90 mg/kgdw, standard soil.

### Table 43: Selected chronic toxicity data of phenanthrene to terrestrial species and processes

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard soil]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td><em>Eisenia fetida</em></td>
<td>36 a</td>
</tr>
<tr>
<td>Annelida</td>
<td><em>Eisenia veneta</em></td>
<td>92</td>
</tr>
<tr>
<td>Annelida</td>
<td><em>Enchytraeus crypticus</em></td>
<td>87 b</td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Folsomia candida</em></td>
<td>37 c</td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Folsomia fimetaria</em></td>
<td>72 b</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Sinapis alba</em></td>
<td>98 d</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Trifolium pretense</em></td>
<td>88 d</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Lolium perenne</em></td>
<td>645 d</td>
</tr>
<tr>
<td>Microbial process</td>
<td>nitrification</td>
<td>154</td>
</tr>
</tbody>
</table>

Notes to Table 43

a Most sensitive endpoint (total offspring) derived from presented data based on time weighted average concentrations.

b Most sensitive endpoint (reproduction) corrected for time weighted average concentrations.

c Geometric mean of 33 and 41 mg/kgdw, standard soil for most sensitive endpoint (reproduction) corrected for time weighted average concentrations.

d Most sensitive endpoint (fresh weight).
3.6 Anthracene

3.6.1 Substance identification and physicochemical properties

3.6.1.1 Identity

Figure 9: Structural formula of anthracene

Table 44: Identification of anthracene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Anthracene, paranaphthalene</td>
<td></td>
</tr>
<tr>
<td>Chemical name</td>
<td>Anthracene</td>
<td></td>
</tr>
<tr>
<td>CAS number</td>
<td>120-12-7</td>
<td></td>
</tr>
<tr>
<td>EC number</td>
<td>204-371-1</td>
<td></td>
</tr>
<tr>
<td>SMILES code</td>
<td>c12ccccccc1cc3cccccc3c2</td>
<td></td>
</tr>
</tbody>
</table>

3.6.1.2 Physicochemical properties

Table 45: Physicochemical properties of anthracene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>178.23</td>
<td>Geometric mean of thirteen values by the generator-column method</td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>47</td>
<td>Slow-stirring method</td>
</tr>
<tr>
<td>$\log K_{OW}$</td>
<td>[-]</td>
<td>4.68</td>
<td>Slow-stirring method</td>
</tr>
<tr>
<td>$\log K_{OC}$</td>
<td>[-]</td>
<td>4.47</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>0.0014</td>
<td>Geometric mean of nine values by the gas saturation method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>215.8</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>340</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa.m³/mol]</td>
<td>5.0</td>
<td>Geometric mean of five values by the gas stripping method, one by the headspace method and one by the wetted-wall method</td>
</tr>
</tbody>
</table>

3.6.2 Water

Many acute toxicity data for anthracene are available. Anthracene appears to be extremely phototoxic. Most of the selected toxicity data for freshwater species (Table 46) are conducted under UV light. These acute effects are observed when organisms exposed to anthracene are irradiated by a source of ultraviolet radiation for a relatively short period of time (e.g. half an hour). The strongest effects are observed for natural sunlight.

The UV intensity of sunlight on a clear day was measured to be 4245 µW/cm² (Allred and Giesy, 1985), with 484 µW/cm² UV-B (Oris et al., 1984). In this study, adult *Daphnia pulex* were exposed to anthracene in the dark for 24 hours. Then they were exposed to full sunlight for half an hour. A dose-response relationship can not be easily determined, because there is only one exposure concentration that did not result in 100% effect. For exposure to full sunlight, the LC50 is estimated to be 1.0 µg/L. Exposure on a partly clouded day or a completely clouded day, or with various UV filters, yielded EC50s ranging from 5.1 to 20 µg/L. From the presented figures it can be concluded that all treatments with different UV intensities result in very steep dose-response relationships. If first the LC50 is estimated and exposure concentrations are
expressed as a ration of this LC50 for each light intensity, then a clear dose-response relationship can be derived (see Figure 10).

Table 46: Selected acute toxicity data of anthracene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td><em>Pseudokirchneriella subcapitata</em></td>
<td>3.9 a</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Daphnia pulex</em></td>
<td>1.0 b</td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Aedes aegypti</em></td>
<td>27 c</td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Chironomus riparius</em></td>
<td>2.5 d</td>
</tr>
<tr>
<td>Mollusca</td>
<td><em>Utterbackia imbecilis</em></td>
<td>1.9 e</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Lepomis macrochirus</em></td>
<td>1.3 f</td>
</tr>
</tbody>
</table>

Notes to Table 46

a Most relevant parameter (growth rate), determined under constant lighting with ‘white fluorescent bulbs’ with a filter to eliminate UV-A+B (<390 nm) and UV-A produced by blacklights, with an intensity of 765 µW/cm²; UV-B radiation was filtered from the blacklight spectrum. Algae were preincubated with anthracene for 12 hours in the dark.

b Incubated for 24 hours followed by 30 minutes irradiation with natural sunlight on a clear day with a UV intensity of 4245 µW/cm².

c 24 hours exposure to anthracene in the dark, followed by 24 hours exposure under UV light regime from simulated sunlight with an UV-B intensity of 150 µW/cm².

d Illuminated with mercury light source 330–800 nm, including some UV-A.

e 4 hours exposure under ambient laboratory lighting (UV-A <2 µW/cm²) followed by 24 hours exposure with UV-A (320-400 nm) with an intensity of 70.0±0.5 µW/cm².

f 24 hours exposure to anthracene in the dark followed constant illumination with UV-A+B and visible light, spectrum 91% equal to natural sunlight; UV-A and UV-B intensities are 108 and 6.7 µW/cm²; total intensity approximately equal to 0.5 and 1 m depth in an eutrophic lake.

Figure 10: Dose-response curve for *D. pulex* exposed to anthracene (24 hours) and natural sunlight (½ hour), successively (Allred & Giesy, 1985)

The importance of exposure to UV light is illustrated by the data for *Daphnia magna* as well. The lowest acute value for immobility of *Daphnia magna* is the EC50 of 11 µg/L after exposure for 48 hours with a 16:8 light:dark photoperiod.
with visible, UV-A (320-400 nm) and UV-B (290-320 nm) with an intensities of 61, 4.4, and 0.45 µmol/m²/s. At similar intensities without the UV-B component, the EC50 was 20 µg/L (Lampi et al., 2006). However, in this study with Daphnia magna the concentrations were not verified. In another study with Daphnia magna under normal laboratory lighting, concentrations were verified, but the EC50 was higher than the highest tested concentration of 25 µg/L (Bisson et al., 2000).

The reported 24-h LC50 for 3rd-4th instar larvae of the midge Aedes aegypti, with 6 hours of exposure in the sunlight, was even lower than 1 µg/L (Borovsky et al., 1987). However, the exposure concentrations were not measured, which renders the study less reliable. Further, in the same study the closely related species Aedes taeniorhynchus showed a much higher LC50, which is far above the solubility limit. Under simulated sunlight a reliable study with Aedes aegypti resulted in an LC50 of 27 µg/L (Table 46), although the UV intensity is less than under full sunlight.

Also for marine species the most severe effects are observed under UV light (Table 47). The few marine species have a comparable sensitivity (F-test 0.28, t-test 0.19).

| Table 47: Selected acute toxicity data of anthracene to marine species |
|---------------------------------|-----------------|-----------------|
| Taxon                           | Species         | LC50 or EC50 [µg/L] |
| Crustacea                       | Mysidopsis bahia| 3.6 a           |
| Mollusca                        | Mulinea lateralis| 69 a           |

Notes to Table 47

a Test performed under ultraviolet light with 397±35.1 µW/cm² UV-A (365±36 nm) and 134±22.8 µW/cm² UV-B (310±34 nm) with a photoperiod of 16:8 hours light:dark.

Anthracene is very phototoxic and toxic effects (LC50s) are observed at concentrations lower or equal to the lowest chronic effect concentrations. Ultraviolet radiation in the most sensitive chronic toxicity studies was less harsh (Table 48). A clear effect of the phototoxicity of anthracene can be observed for the algae species Pseudokirchneriella subcapitata. Algae exposed under UV light yielded an EC10 for growth rate of 1.5 of µg/L (Gala and Giesy, 1992), while the same species had an EC10s for growth rate of 7.8 µg/L under normal laboratory lighting (Bisson et al., 2000), or low UV intensity (Gala and Giesy, 1992).

There are no selected chronic data for marine species. In two 48-h studies with fertilized eggs of the echinoderm Psammechinus miliaris and the mollusc Crassostrea gigas the development of the larvae was examined (AquaSense, 2005). No effects were observed for tested concentrations up to 2.8 µg/L. This value is far below the aqueous solubility but higher than the lowest effect levels. In a similar study with embryos of the mollusc Mulinea lateralis the EC50 for development was higher than 6.5 µg/L, under ultraviolet light with 397±35.1 µW/cm² UV-A (365±36 nm) and 134±22.8 µW/cm² UV-B (310±34 nm) with a photoperiod of 16:8 hours light:dark.

Because acute and chronic toxicity data are available for algae, Daphnia, and fish, an assessment factor of 10 could in principle be applied. However, the lowest reliable value is the EC50 for phototoxicity to Daphnia pulex. Therefore, the MPCeco, water is based on this value and becomes 0.1 µg/L. Because of the steepness of the dose-response relationship, it is still considered appropriate to apply an assessment factor of 10, although the EC50 is an effect level and not a NOEC.
Table 48: Selected chronic toxicity data of anthracene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Pseudokirchneriella subcapitata</td>
<td>1.5 \textsuperscript{a}</td>
</tr>
<tr>
<td>Algae</td>
<td>Scenedesmus vacuolatus</td>
<td>16</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia magna</td>
<td>1.9 \textsuperscript{b}</td>
</tr>
<tr>
<td>Pisces</td>
<td>Pimephales promelas</td>
<td>6.7 \textsuperscript{c}</td>
</tr>
</tbody>
</table>

Notes to Table 48

\textsuperscript{a} Most relevant parameter (growth rate), determined under constant lighting with ‘white fluorescent bulbs’ with a filter to eliminate UV-A+B (<390 nm) and UV-A produced by blacklights, with an intensity of 765 µW/cm\textsuperscript{2}; UV-B radiation was filtered from the blacklight spectrum. Algae were preincubated with anthracene for 12 hours in the dark.

\textsuperscript{b} Most sensitive parameter (reproduction) determined under UV radiation with an intensity of 117 µW/cm\textsuperscript{2} and a ratio UV-A:UV-B of 8:1, and visible light by ‘white fluorescent lamps’ with a light regime of 16 hours light and 8 hours dark.

\textsuperscript{c} Most sensitive parameter (hatching) determined under UV radiation with an intensity of 67.94±9.02 µW/cm\textsuperscript{2} at 365±36 nm (UV-A) and 6.71±0.81 µW/cm\textsuperscript{2} at 310±34 nm (UV-B), and fluorescent light with a light regime of 16 hours light and 8 hours dark.

Because chronic (limited tests, see above) and acute data are available for additional taxonomic of marine species, the MPC\textsubscript{eco, marine} is the same. Because acute toxic effects are the most sensitive effects, the MAC\textsubscript{eco, water} and MAC\textsubscript{eco, marine} are the same as well. The SRC\textsubscript{eco, water} is equal to the geometric mean of the chronic toxicity data and is 4.2 µg/L, which is in its turn only slightly lower than the geometric mean of the acute toxicity data.

3.6.3 Sediment

Selected toxicity data for benthic organisms are shown in Table 42, recalculated to standard sediment with 10% organic matter. Besides these two chronic values there is one 10-d LC50 for Hyalella azteca of 50 mg/kg\textsubscript{dw, standard sed}, recalculated to standard sediment with 10% organic matter (Hatch and Burton Jr., 1999).

Table 49: Selected chronic toxicity data of anthracene to benthic species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard sediment]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td>Lumbriculus variegatus</td>
<td>2.3</td>
</tr>
<tr>
<td>Insecta</td>
<td>Chironomus riparius</td>
<td>4.3 \textsuperscript{a}</td>
</tr>
</tbody>
</table>

Notes to Table 42

\textsuperscript{a} Most sensitive parameter (mortality/emergence).

With two chronic data from two taxonomic groups, an assessment factor of 50 can be applied to derive the MPC\textsubscript{eco, sediment} and MPC\textsubscript{eco, marine sediment}. The resulting value is 0.047 mg/kg\textsubscript{standard sediment}. No data are available for marine organisms, and therefore an extra factor of 10 has to be applied. The MPC\textsubscript{eco, marine sediment} is 0.0047 mg/kg\textsubscript{standard sediment}. SRC\textsubscript{eco, sediment} is derived from the geometric mean of these chronic benthic data and is 3.2 mg/kg\textsubscript{standard sediment}.

3.6.4 Soil

Many toxicity data with terrestrial species are available for anthracene. From several studies, it appears that anthracene concentrations are rather stable in the used test systems (Bleeker et al., 2003; Droge et al., 2006; Sverdrup et al.,
2002). Because nominal concentrations are retrieved in the test systems, this improves the reliability of the data in general.

Chronic toxicity data for anthracene in soil are available for annelids, collembola, terrestrial plants, and microbial processes. Only a few studies resulted in useful NOEC or EC10 values (Table 50). The lowest endpoint is for reproduction of *Folsomia fimetaria* (Sverdrup et al., 2002). A similar effect concentration for the related species *Folsomia candida* was not found (Bleeker et al., 2003; Droge et al., 2006). Effects were not observed in the highest tested concentration of 1739 mg/kgdw, standard soil, recalculated to a standard soil with 10% organic matter. However, due to the very low solubility of anthracene, pore water concentrations are possibly already saturated at concentrations around 75 mg/kgdw, standard soil. No effects were observed for the pot worm *Enchytraeus crypticus* as well (Bleeker et al., 2003; Droge et al., 2006).

Table 50: Selected chronic toxicity data of anthracene to terrestrial species and processes

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard soil]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td><em>Eisenia andrei</em></td>
<td>210 a</td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Folsomia fimetaria</em></td>
<td>17 b</td>
</tr>
</tbody>
</table>

Notes to Table 50

a Subchronic endpoint growth.
b Most sensitive endpoint (reproduction) corrected for time weighted average concentrations.

In most tests with terrestrial plants no effects on growth of seedlings are observed, i.e. for 4 species (Mitchell et al., 1988). Growth of seedlings of *Avena sativa* has a 14-d EC50 of 150 mg/kgdw, standard soil (Mitchell et al., 1988), while in another study no effect on the growth of the same species was found (Römbke et al., 1995; Römbke et al., 1994). Growth of seedlings of *Cucumis sativus* had a 14-d EC50 of 3600 mg/kgdw, standard soil (Mitchell et al., 1988). The NOEC for shoot and root growth of *Lolium perenne* exposed for 40 days (Leyval and Binet, 1998) appeared to be smaller than 392 mg/kgdw, standard soil, all values recalculated to a soil with 10% organic carbon. The latter study (Leyval and Binet, 1998) was performed with moderate visible light (PAR 400-700 nm at 130 µmol/m²/s). At the lowest concentration 22 to 41% reduction in growth was observed. From the presented data at the 3 tested concentrations a reliable EC10 could not be derived.

In the study by Mitchell et al., (1988), it can be deduced from the figure for percentage emergence of seeds that the LC10 for *Avena sativa* should be significantly lower than 500 mg/kgdw, standard soil. For the more sensitive effect of growth only the EC50 is presented. From the figure for time of emergence it is obvious that for 4 out of 6 plant species the NOEC lies below 50 mg/kgdw, standard soil (Mitchell et al., 1988). Results on dehydrogenase are the only available values for terrestrial processes. Although no dose-response relationships are available it can be concluded that concentrations of 33 mg/kgdw, standard soil, recalculated to a standard soil with 10% organic matter, may lead to 20-25% effect (Römbke et al., 1995).

In principle, an assessment factor of 10 could be applied to the lowest NOEC or EC10, because data are available for annelids, insects, plants (macrophyta), and processes. However, for several plant species the NOECs are lower than the lowest tested concentration. The effect concentrations from chronic studies with macrophyta are one order of magnitude or even less higher than the EC10 for *Folsomia fimetaria*. Because it can not be excluded that the NOEC or EC10 for some plant species is lower than that of *Folsomia fimetaria*, an assessment
factor of 50 instead of 10 will be applied to the lowest effect concentration of the two remaining trophic levels, which is the EC10 for *Folsomia fimetaria*. The MPC_{eco, soil} then becomes 0.34 mg/kg dw, standard soil. The SRC_{eco, soil} is calculated from the geometric mean of the two selected data and is 60 mg/kg dw, standard soil. NOECs for terrestrial plants might be below this value, while NOECs for invertebrates are mostly above this value. Therefore, the derived value seems to be a good representation of the HC50.

### 3.7 Pyrene

#### 3.7.1 Substance identification and physicochemical properties

##### 3.7.1.1 Identity

Figure 11: Structural formula of pyrene

![Pyrene Structural Formula](image)

**Table 51: Identification of pyrene**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Pyrene, benzo[def]phenanthrene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>Pyrene</td>
</tr>
<tr>
<td>CAS number</td>
<td>129-00-0</td>
</tr>
<tr>
<td>EC number</td>
<td>204-927-3</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c1ccc2ccc3ccccc4cc1c2c34</td>
</tr>
</tbody>
</table>

##### 3.7.1.2 Physicochemical properties

**Table 52: Physicochemical properties of pyrene.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>202.25</td>
<td>Geometric mean of 5 values by generator-column method</td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>124</td>
<td>Geometric mean of 5 values by generator-column method</td>
</tr>
<tr>
<td>Log (K_{OW})</td>
<td>[-]</td>
<td>4.96</td>
<td>Average of 4 values by shake-flask method</td>
</tr>
<tr>
<td>Log (K_{OC})</td>
<td>[-]</td>
<td>4.75</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>6.6·10^{-4}</td>
<td>Geometric mean of 2 values by gas saturation method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>150.6</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>404</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa m^{3}/mol]</td>
<td>1.2</td>
<td>Geometric mean of 6 values by gas stripping method and 1 value by wetted-wall method</td>
</tr>
</tbody>
</table>

##### 3.7.1.3 Water

Acute toxicity data for freshwater species tested with pyrene are available for algae, amphitans, crustaceans, cyanophytes, insects, plants, molluscs, and fish. However, only a few data can be considered as reliable, mostly because exposure concentrations were not verified or the solubility was exceeded in the test solutions. Also pyrene appears to be extremely phototoxic. This is not illustrated by all the data in Table 53, which are partly carried out under normal laboratory lighting.
Table 53: Selected acute toxicity data of pyrene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Scenedesmus vacuolatus</td>
<td>49</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia magna</td>
<td>25</td>
</tr>
<tr>
<td>Insecta</td>
<td>Chironomus riparius</td>
<td>38 (^a)</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Utterbackia imbecilis</td>
<td>2.6 (^b)</td>
</tr>
</tbody>
</table>

Notes to Table 53

\(^a\) Test with UV filter which blocked most radiation (75±14%) below 400 nm, test under mercury light was less toxic.

\(^b\) 4 hours exposure under ambient laboratory lighting (UV-A <2 µW/cm\(^2\)) followed by 24 hours exposure with UV-A (320-400 nm) with an intensity of 70.0±0.5 µW/cm\(^2\).

The lowest value for *Daphnia magna* was observed after exposure of neonates for 24 hours with 16:8 hour light:dark, then at an UV intensity of 370 ±20 µW/cm\(^2\) (295-365 nm; peak 340 nm) for 2 hours and 1 hour of recovery in the test medium. The EC50 for immobility was 1.38 µg/L (Wernersson, 2003). In a similar treatment (2 hours of recovery instead of 1, the EC50 for 4-d old daphnids was 5.7 µg/L (Wernersson and Dave, 1997). When exposed to UV-B radiation only (intensity 64 µW/cm\(^2\)) for 4 times 2 hours during 48 hours, the EC50 for immobility of neonates ranged from 1.8 to 20 µg/L at different hardness of the artificial test media and different concentrations of dissolved organic matter of natural waters (Nikkilä et al., 1999). The EC50s for *Daphnia magna* were 4.6 and 4.3 µg/L after exposure for 48 hours with a 16:8 light:dark photoperiod with visible, UV-A (320-400 nm) and UV-B (290-320 nm) light with intensities of 61, 4.4, and 0.45 µmol/m\(^2\)/s, respectively, and at similar intensities without the UV-B component, respectively (Lampi et al., 2006). In all these studies, no analysis of the compounds in water was performed. However, the EC50s are substantially lower than the EC50 determined under standard laboratory conditions (Bisson et al., 2000), which is presented in Table 53.

For the freshwater mollusc *Utterbackia imbecilis* the 24-h LC50 was 2.63 µg/L with UV-A radiation (320-400 nm) at an intensity of 70 µW/cm\(^2\) (Weinstein and Polk, 2001). The reported concentrations were analytically verified as well. The same test under laboratory lighting resulted in an EC50 higher than 28 µg/L. These results illustrate the importance of phototoxicity for pyrene.

The only available data for fish are an unreliable LC50 of 220 µg/L for fathead minnows (*Pimephales promelas*) (Kagan et al., 1985) and a study with larvae of the same species, performed to determine the median lethal time (Oris and Giesy Jr., 1987). In the latter study, 7-d old larvae were exposed to a measured concentration of 25.6 µg/L pyrene for an incubation period of 24 hours in the absence of UV radiation and thereafter exposed for 96 hours to UV light with an intensity of 20 µW/cm\(^2\) UV-B (290-336 nm) and 95 µW/cm\(^2\) UV-A (336-400 nm). After the incubation time of 24 hours, the medium was renewed every 12 hours. The median lethal time was 3.2 hours, which means that much more than 50% mortality occurred in the test period of 120 hours and the LC50 would be far below this value.

Acute toxicity data for marine species are available for algae, annelids, bacteria, crustaceans, molluscs and cnidaria. The selected values are reported in Table 54. Also in this case, the lowest values are obtained in the presence of UV light (see notes to Table 54). The freshwater and marine acute toxicity data are not significantly different (F-test 0.76, t-test 0.33). Both data sets are therefore combined.
Table 54: Selected acute toxicity data of pyrene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td>Acartia tonsa</td>
<td>28 ±a</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Callinectes sapidus</td>
<td>2.7 ±b</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Libinia dubia</td>
<td>4.9 ±b</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Mysidopsis bahia</td>
<td>0.89 ±c</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Oithona davisae</td>
<td>107 ±d</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Panopeus herbstii</td>
<td>11.4 ±b</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Mulinea lateralis</td>
<td>1.68 ±c</td>
</tr>
</tbody>
</table>

Notes to Table 54

- Exposure under UV light with an intensity of 8 µW/cm² (UV-A) and 11.9 µW/cm² (UV-B).
- After exposure for 1 hour, transferred to filtered sea water with exposure to UV (UV-A (320-400 nm) 1979-2098 µW/cm² and UV-B (280-320 nm) 276-325 µW/cm²) for 4 hours and 24 hours of recovery in filtered sea water for 24 hours in the dark.
- Test performed under ultraviolet light with 397±35.1 µW/cm² UV-A (365±36 nm) and 134±22.8 µW/cm² UV-B (310±34 nm) with a photoperiod of 16:8 hours light:dark.
- Most sensitive parameter (immobility).

When exposed for 2 hours in the dark followed by 1 hour with UV radiation (320-400 nm; peak 350 nm) at an intensity of 1300 µW/cm², the LC50 for nauplii of *Artemia salina* was 8 µg/L (Kagan et al., 1985; Kagan et al., 1987). When exposed for 2 hours in the dark followed by 8 hours with UV radiation (peak 312 nm) at an intensity of 975-1000 µW/cm², the LC50 for nauplii of *Artemia salina* was estimated from the presented figure to be 36 µg/L (Peachey and Crosby, 1996). The same treatment with sunlight (λ>290 nm) at an intensity of 407-1429 µW/cm² resulted in an EC50 of 3.4 µg/L (Peachey and Crosby, 1996). Although the reliability of these studies is limited, because concentrations were not verified, it could be concluded that the maximum intensity of the radiation is more important than the time of irradiation. Of the crustaceans *Mysidopsis bahia* was the most sensitive species. Under ultraviolet light with an intensity of 397 µW/cm² UV-A and 134 µW/cm² UV-B with a photoperiod of 16:8 hours light:dark the LC50 was 0.89 µg/L. Under the same conditions, the LC50 for embryos-larvae of *Mulinea lateralis* was 0.23 µg/L, while the LC50 for juveniles of 1 to 1.5 mm of the same species was 1.68 µg/L (Pelletier et al., 1997). The embryo-larval assay is a rather chronic study, because it also takes the abnormalities in development of this sensitive life-stage into account.

In a very similar study, the shell development of embryos-larvae of the mollusc *Crassostrea gigas* was monitored after an exposure of 48 hours under UV light with an intensity of 456 µW/cm² UV-A and 6.3 µW/cm² UV-B with a photoperiod of 12:12 hours light:dark. The NOEC was 0.5 µg/L (Lyons et al., 2002) and the EC10 derived from the data 0.93 µg/L. Although the exposure time of this study is rather short (48 hours), the endpoint is a chronic one (shell development/malformation). Therefore, in the risk assessment this study can be considered as a chronic study. However, concentrations were not analytically verified.

For the MACeco, water and MACeco, marine the short-term LC50s are used. Although the endpoint of the embryo-larval assays is rather chronic, the exposure time is short. The EC50 of 0.23 µg/L for the mollusc *Mulinea lateralis* under UV enhanced conditions is the most sensitive acute endpoint. For pyrene the base set is not complete, because the studies with *Pimephales promelas* are limited.
The LC50 is below 25 µg/L, but this value is still amply above the LC50s for crustaceans and molluscs. Moreover, for other PAHs phototoxicity to these species appear to be the most sensitive endpoints as well. Therefore, an assessment factor of 10 is deemed sufficient for the derivation of the MACeco. Data are available for marine species such as molluscs and crabs. The MACeco, water and MACeco, marine thus are 0.023 µg/L.

Chronic toxicity data for freshwater species are available for algae, cyanophyta, crustaceans, insects, aquatic plants, and fish. The selected data are presented in Table 55, but these have not been generated in the presence of UV light. At 26 µg/L (measured concentration) slight toxic responses (malformations) were found for larvae of zebrafish (Danio rerio) towards the end of 48-h experiment (Petersen and Kristensen, 1998).

**Table 55: Selected chronic toxicity data of pyrene to freshwater species**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Pseudokirchneriella subcapitata</td>
<td>1.2</td>
</tr>
<tr>
<td>Algae</td>
<td>Scenedesmus vacuolatus</td>
<td>21</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Ceriodaphnia dubia</td>
<td>2.1</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Hyalella azteca</td>
<td>26</td>
</tr>
</tbody>
</table>

For marine species, chronic data are available for bacteria, crustaceans, echinoderms, molluscs, fish, and tunicates. The selected data are presented in Table 56. Freshwater and marine chronic toxicity data are not significantly different (F-test 0.89, t-test 0.92). Both sets can therefore be combined. For the tunicate Ciona intestinalis, no effects were observed up to the aqueous solubility, both under dark conditions and with a photoperiod 14:10 hours light:dark by cool daylight lamps (380-780nm, PAR) with an intensity of 70 µE/m²/s (Bellas et al., 2008). Slight toxic responses (malformations) were found towards the end of 48-h experiment as well at 24 and 47 µg/L for larvae the marine fish species herring (Clupea harengus) and Atlantic cod (Gadus morhua) (Petersen and Kristensen, 1998).

**Table 56: Selected chronic toxicity data of pyrene to marine species**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td>Acartia tonsa</td>
<td>1.7 a</td>
</tr>
<tr>
<td>Echinodermata</td>
<td>Paracentrotus lividus</td>
<td>23 b</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Mytilus galloprovincialis</td>
<td>8.3 b</td>
</tr>
</tbody>
</table>

**Taxon**  **Species**  **LC50 or EC50 [µg/L]**

| Mollusca | Mulinea lateralis | 0.23 c |

Notes to Table 56

a Exposure under UV light with an intensity of 8 µW/cm² (UV-A) and 11.9 µW/cm² (UV-B).
b Determined with a photoperiod 14:10 hours light:dark by cool daylight lamps (380-780nm, PAR) with an intensity of 70 µE/m²/s.
c Test performed under ultraviolet light with 397±35.1 µW/cm² UV-A (365±36 nm) and 134±22.8 µW/cm² UV-B (310±34 nm) with a photoperiod of 16:8 hours light:dark.

The lowest NOEC or EC10 for freshwater species is the EC10 of 1.2 µg/L for Pseudokirchneriella subcapitata, a value which is also below the lowest acute LC50 for freshwater species. The marine and freshwater acute toxicity data for molluscs and crustaceans do not differ significantly. The lowest value for marine species is the EC50 of 0.23 µg/L under UV enhanced conditions for survival/
development of normal larvae of the clam *Mulinea lateralis*. No NOEC or EC10 is presented but in a very similar study on shell abnormalities of embryos-larvae of the Japanese oyster *Crassostrea gigas* it appears that the dose-response curve is very steep for this type of effect, similar to what is observed for other phototoxic effects. Chronic data are available for many taxonomic groups including several additional groups for marine species. Although the tested fish species did not result in useful NOECs or EC10s, the slight effects are observed at concentrations that are well in excess of the NOEC and EC10s for crustaceans and molluscs. Also for other PAHs (anthracene, fluoranthene), this embryo-larval test belongs to the lowest values observed. Therefore, an assessment factor of 10 is considered sufficient. Because of the steepness of the dose-response relationship, it is still considered appropriate to apply an assessment factor of 10, although the EC50 is an effect level and not a NOEC. The MPC<sub>eco, water</sub> and MPC<sub>eco, marine</sub> are then 0.023 µg/L. These values are equal to the MAC<sub>eco, water</sub> and MAC<sub>eco, marine</sub>. The SRC<sub>eco, water</sub> is derived from the geometric mean of the chronic toxicity data including the EC50 value for *Mulinea lateralis*. The SRC<sub>eco, water</sub> is 4.2 µg/L.

### 3.7.2 Sediment

Toxicity studies with 2 freshwater oligochaetes are available. The lowest value for *Limnodrilus hoffmeisteri* is the EC10 from a 28-d reproduction study (Lotufo and Fleeger, 1996). However, this value was extrapolated from concentrations showing more than 40% effect. Therefore, the EC10 of 3.8 mg/kg<sub>dw</sub> (32 mg/kg<sub>dw, standard soil</sub>, recalculated to standard sediment with 10% organic matter) has a large uncertainty. Further, the reproduction falls rapidly with concentrations up to 210 mg/kg<sub>dw</sub> (1770 mg/kg<sub>dw, standard soil</sub>), but remains almost constant from 210 to 841 mg/kg<sub>dw</sub> (1770-7070 mg/kg<sub>dw, standard soil</sub>). It is plausible that the bioavailability of pyrene in the sediment is limited at the higher concentrations by the solubility in the pore water of sediment. Possibly, pore water concentrations are already saturated around 400 mg/kg<sub>dw, standard soil</sub>. If the 2 highest concentrations are omitted from the determination of EC10, the resulting value of 26 mg/kg<sub>dw</sub> (220 mg/kg<sub>dw, standard soil</sub>) in standard sediment is much higher. Further, the reported EC25 values determined by bootstrapping, are not in accordance with the log-logistic fit by which the EC10 is derived. The EC25 values reported by Lotufo and Fleeger (1996) for sediment egestion from a 10-d and a 5-d study and for reproduction from a 28-d study are 51.6, 58.9, and 59.1, respectively, for a sediment with 1.2% organic carbon. With the derived EC50, which is rather certain because it is not an extrapolated value and the reported EC25, EC10s can be derived with a log-logistic model. For the endpoints mentioned above, these EC10 values recalculated to sediment with 10% organic carbon are 222, 217, and 255 mg/kg<sub>dw</sub>, respectively. These values probably are more realistic.

The lowest reported endpoint for *Lumbriculus variegatus*, which is wet weight (Kukkonen and Landrum, 1994), has a much higher EC10 value. However, in this experiment, the worms were not fed, which resulted in weight loss during the experiment for all treatment groups, including the control. At high concentrations, sediment avoidance was observed, which resulted in an EC50 lower than the EC50 for wet weight. Therefore, the results of this test are not considered reliable, especially because at the EC10 values for wet weight and mortality (2300 and 3000 mg/kg<sub>dw, standard soil</sub>) pore water concentration are probably saturated as well.

For marine sediment only the species *Rhepoxynius abronius* was tested. The EC50 for reburial was lower than 25 mg/kg<sub>dw</sub> in standard sediment. The
organisms were irradiated with UV radiation before reburial was monitored (Boese et al., 1998). Because Rhepoxynius abronius is a subsurface burrower that typically does not extend body parts in overlying water (Swartz et al., 1990; Boese et al., 1997), this EC50 is not very useful in the risk assessment. Some 10-d experiments with Rhepoxynius abronius were performed (Swartz et al., 1997). The LC10s derived from the presented data are 45 and 154 mg/kg dw standard sediment, the confidence limits of these values are rather small.

Table 57: Selected chronic toxicity data of pyrene to benthic species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard sediment]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td>Limnodrilus hoffmeisteri</td>
<td>220 a</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Rhepoxynius abronius</td>
<td>84 b</td>
</tr>
</tbody>
</table>

Notes to Table 57

a Geometric mean of 217 and 222 mg/kg dw standard sediment for most sensitive parameter (sediment egestion).

b Geometric mean of 45 and 154 mg/kg dw standard sediment.

For freshwater sediment a reliable EC10 is available for oligochaetes (Table 57). For marine species one additional EC10 for a crustacean is available. This is the lowest value. Because chronic data for 2 different trophic levels are available, the assessment factor to derive the MPC_{eco, sediment} is 50, which results in an MPC_{eco, sediment} of 1.7 mg/kg dw standard sediment. Because 1 test is with a freshwater sediment species and 1 with a marine sediment species, the assessment factor to be applied to derive the MPC for marine sediment is 100 instead of 500. This results in a MPC_{eco, marine sediment} of 0.84 mg/kg dw standard sediment. The SRC_{eco, sediment} is calculated as the geometric mean of the 2 selected values and is 136 mg/kg dw standard sediment.

3.7.3 Soil

Many toxicity data with terrestrial species are available for pyrene. From several studies, it appears that pyrene concentrations are rather stable in the used test systems (Sverdrup et al., 2001; Sverdrup et al., 2006). Because nominal concentrations are retrieved in the test systems, this improves the reliability of the data in general. Many toxicity tests with species from five taxonomic groups and with terrestrial processes are available for pyrene. In the tests with the terrestrial algae species Chlorococcum meneghini the test was performed in quartz sand and normalization to organic matter is therefore not possible. The bioavailability of pyrene in this sand is high. The EC10 for cell number (optical density was 19 mg/kg dw (Chung et al., 2007). For the snail Helix aspersa no effects were observed as (Sverdrup et al., 2006). For ryegrass (Lolium perenne) a reliable EC10 could not be derived from the data (Sverdrup et al., 2003), this species showed also no toxicity in quartz sand (Chung et al., 2007). For the rest of the species and processes the selected data are presented in Table 58.

With data for annelids (3 species), springtails (2 species) terrestrial plants (2 species) and microbial processes an assessment factor of 10 can be applied to the lowest NOEC or EC10. A value of 1.8 mg/kgdw, standard soil is derived for the MPC_{eco, soil}. The SRC_{eco, soil} is calculated from the geometric mean of the 7 species and is 53 mg/kg dw, standard soil.
Table 58: Selected chronic toxicity data of pyrene to terrestrial species and processes

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard soil]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td><em>Eisenia veneta</em></td>
<td>140</td>
</tr>
<tr>
<td>Annelida</td>
<td><em>Enchytraeus crypticus</em></td>
<td>136 <em>a</em></td>
</tr>
<tr>
<td>Annelida</td>
<td><em>Lumbricus rubellus</em></td>
<td>55 <em>b</em></td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Folsomia candida</em></td>
<td>18 <em>c</em></td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Folsomia fimetaria</em></td>
<td>33 <em>d</em></td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Protaphorura armata</em></td>
<td>18 <em>e</em></td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Sinapis alba</em></td>
<td>101</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Trifolium pratense</em></td>
<td>55</td>
</tr>
<tr>
<td>Microbial process</td>
<td>nitrification</td>
<td>478</td>
</tr>
</tbody>
</table>

Notes to Table 58

*a* Geometric mean of 40 and 458 mg/kg dw standard soil for reproduction (most sensitive endpoint) based on EC10 and NOEC from 2 studies; NOEC and EC50 differed by a factor of 10.

*b* Most sensitive endpoint (cocoon production).

*c* Geometric mean of 1.6, 29 and 129 mg/kg dw standard soil for reproduction (number of juveniles).

*d* Most sensitive endpoint (reproduction) corrected for time weighted average concentrations.

*e* After 21 days exposure in soil, 2 days counting/extraction, followed by 7 days in drought chamber at 98.2% RH and 2 days at 100% RH.

3.8 Fluoranthene

3.8.1 Substance identification and physicochemical properties

3.8.1.1 Identity

![Figure 12: Structural formula of fluoranthene](image)

Table 59: Identification of fluoranthene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Fluoranthene, 1,2-benzacenaphthene, benzo[j,k]fluorene, benz[a]acenaphthylene, fluoranthenene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>1,2-benzacenaphthene</td>
</tr>
<tr>
<td>CAS number</td>
<td>206-44-0</td>
</tr>
<tr>
<td>EC number</td>
<td>205-012-4</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c12c3cccc1c4cccccc4c2ccc3</td>
</tr>
</tbody>
</table>
3.8.1.2 Physicochemical properties

Table 60: Physicochemical properties of fluoranthene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>202.25</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>227</td>
<td>Geometric mean of 7 values by generator-column method</td>
</tr>
<tr>
<td>log ( K_{ow} )</td>
<td>[-]</td>
<td>5.18</td>
<td>Average of 3 values by slow-stirring method</td>
</tr>
<tr>
<td>log ( K_{oc} )</td>
<td>[-]</td>
<td>4.97</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>0.00123</td>
<td>Gas saturation method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>110.2</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>384</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa.m³/mol]</td>
<td>1.1</td>
<td>Geometric mean of 3 values by gas stripping method</td>
</tr>
</tbody>
</table>

3.8.2 Water

Many toxicity data with fluoranthene are available. In a lot of the studies the concentrations have been verified, which makes the number of reliable data considerable. The selected acute toxicity data are presented in Table 61. It appears that fluoranthene is very phototoxic as well. The lowest values in Table 61 are consequently performed in the presence of UV light. If lighting conditions were not representative for the species, these data have not been taken into account.

Also for marine species many data are available. The selected acute toxicity data are presented in Table 62. Again, the lowest values were obtained under UV lighting, but these values have only been selected if the lighting conditions are relevant for the species.

The sensitivity of acute toxicity data for freshwater and marine species appears to be equal (F-test 0.96, t-test 0.53). Therefore, all data from both tables are combined in a species sensitivity distribution for acute toxicity (Figure 13). A reduced goodness-of-fit can be anticipated, because results are included both from tests with strong phototoxic effects and from tests with less UV exposure or species that are not sensitive to phototoxicity. The goodness-of-fit is accepted at all levels by the Kolmogorov-Smirnov test included in ETX, but not at the 0.025 significance level and higher by the Anderson-Darling test and 0.05 and higher for the Cramer von Mises test. The value of 0.1 µg/L for the marine fish species winter flounder (Pleuronectus americanus) (Spehar et al., 1999) deviates from the rest, but is just not a significant outlier (P > 0.05). The HC5 of the distribution is 0.99 µg/L. The LC50 for the winter flounder is the only value that is below the HC5. The HC50 of this distribution is 23 µg/L.

Many chronic toxicity data are available as well. The selected data for freshwater species are presented in Table 63. Also in this case the lowest NOEC or EC10 values were obtained in the presence of UV light, although the UV intensity is less harsh in most of these studies. For marine species several studies are available too (Table 64). The chronic data sets are very similar too (F-test 0.40, t-test 0.41). The marine data complement the freshwater data and also for the chronic data a species sensitivity distribution can be performed. This distribution is shown in Figure 14. Goodness-of-fit is accepted by all tests at all significance levels. The HC5 of this distribution is 0.60 µg/L. There are no NOECs or EC10 values below the HC5. The HC50 is 12 µg/L.

The species sensitivity distributions for chronic and acute data are very similar, with a factor 2 to 3 difference between the 2 curves. In general, the MACeco would be derived from from the HC5 for acute LC50 and EC50 values by applying a factor of 10. This results in a value of 0.099 µg/L. The MPCeco would
be derived by applying a factor of 1-5 to the HC5 for chronic NOEC or EC10 values. Due to the very low values of the phototoxic effects, the uncertainty is high. The lowest LC50 for winter flounder is 0.1 µg/L. Except from the LC50 for the winter flounder and the NOEC for the crustacean *Mysidopsis bahia* (Spehar et al., 1999), a few other studies report effect concentrations between 0.1 and 1 µg/L (i.e. a factor of 10 above the lowest value).

In a study with the marine benthic annelid *Monopylephorus rubroniveus* an LC50 of 0.7 µg/L (measured concentrations) was observed under exposure with UV-A (320-400 nm) with an intensity of 64.0 µW/cm² (Weinstein et al., 2003). However, this species is a sediment burrower and is under natural conditions not exposed to UV light. An EC10 of 0.80 µg/L was derived from the data for marine algae, exposed under a combination of visible and UV-A (~785 µW/cm²) light, continuosuly (Southerland and Lewitus, 2004). Concentrations in this study were not verified.

Under ultraviolet light with an intensity of 397 µW/cm² UV-A and 134 µW/cm² UV-B with a photoperiod of 16:8 hours light:dark the LC50 for embryos-larvae of *Mulinea lateralis* was 1.09 µg/L, while the LC50 for juveniles of 1 to 1.5 mm of the same species was 1.8 µg/L (Pelletier et al., 1997). The embryo-larval assay is a rather chronic study, because it also takes the abnormalities in development of this sensitive life-stage into account.

To take into account the uncertainties surrounding photoxicity, a maximum factor of 5 should be applied to the HC5 for chronic data. This also results in a value around 0.1 µg/L. For this reason the MACeco, water, MACeco, marine, MPCeco, water and MPCeco, marine are all set to 0.12 µg/L. The SRCeco, water is derived from the geometric mean of the chronic toxicity data and is 12 µg/L.

![Figure 13: Species sensitivity distribution for the acute toxicity of fluoranthene to freshwater and marine species](image-url)
<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Scenedesmus vacuolatus</td>
<td>35 (^a)</td>
</tr>
<tr>
<td>Amphibia</td>
<td>Rana catesbeiana</td>
<td>111</td>
</tr>
<tr>
<td>Amphibia</td>
<td>Rana pipiens</td>
<td>2.0 (^b)</td>
</tr>
<tr>
<td>Amphibia</td>
<td>Xenopus laevis</td>
<td>193</td>
</tr>
<tr>
<td>Annelida</td>
<td>Lumbriculus variegates</td>
<td>1.2 (^c)</td>
</tr>
<tr>
<td>Cnidaria</td>
<td>Hydra americana</td>
<td>2.2 (^c)</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Ceriodaphnia dubia</td>
<td>45</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Daphnia magna</td>
<td>1.6 (^d)</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Gammarus pseudolimnaeus</td>
<td>108</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Hyalella azteca</td>
<td>183 (^e)</td>
</tr>
<tr>
<td>Insecta</td>
<td>Chironomus tentans</td>
<td>176</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Physella virgata</td>
<td>82 (^d)</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Utterbackia imbecilis</td>
<td>2.4 (^f)</td>
</tr>
<tr>
<td>Pisces</td>
<td>Lepomis macrochirus</td>
<td>12 (^d)</td>
</tr>
<tr>
<td>Pisces</td>
<td>Oncorhynchus mykiss</td>
<td>7.7 (^d)</td>
</tr>
<tr>
<td>Pisces</td>
<td>Pimephales promelas</td>
<td>9.2 (^g)</td>
</tr>
</tbody>
</table>

Notes to Table 61:

\(^a\) Geometric mean of 36 and 34 µg/L.
\(^b\) 48 hours exposure followed by 48 hours continuous irradiation with 782-829 µW/cm² UV-A and 130-153 µW/cm² UV-B.
\(^c\) Exposure under laboratory ultraviolet light with 783-850 µW/cm² UV-A and 104 µW/cm² UV-B and a photoperiod of 12:12 hours light:dark.
\(^d\) Exposure under laboratory ultraviolet light with 359-587 µW/cm² UV-A and 63-80 µW/cm² UV-B and a photoperiod of 12:12 hours light:dark.
\(^e\) Gold light (0.17 µW/cm² UV-B, 0.09 µW/cm² UV-A, 167.72 µW/cm² visible); 16:8 hours light:dark. Gold light was considered most representative for this bottom dwelling organisms; geometric mean of 188.7 and 177 µg/L.
\(^f\) Exposure with UV-A (320-400 nm), intensity 69.0±1.0 µW/cm² for 24 hours; renewal every 8 hours; 4 hours pre-exposed under ambient laboratory lighting; Geometric mean of 2.90, 2.44, and 2.00 µg/L.
\(^g\) Geometric mean of 9.46, 6.83, and 12.2 µg/L. Exposure under laboratory ultraviolet light with 359-587 µW/cm² UV-A and 63-80 µW/cm² UV-B and a photoperiod of 12:12 hours light:dark or exposure under laboratory fluorescent light with UV radiation very similar to sunlight.
Table 62: Selected acute toxicity data of fluoranthene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td>Neanthes arenaceodentata</td>
<td>258</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Acartia tonsa</td>
<td>120</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Ampelisca abdita</td>
<td>67</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Callinectes sapidus</td>
<td>18 a</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Corophium insidiosum</td>
<td>20 b</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Emerita analoga</td>
<td>73 b</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Grandidierella japonica</td>
<td>19 b</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Homarus americanus</td>
<td>317</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Leptocheirus plumulosus</td>
<td>20 b</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Libinia dubia</td>
<td>17 c</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Menippe adina</td>
<td>39 d</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Mysisidopsis bahia</td>
<td>1.4 e</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Oithona davisae</td>
<td>133</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Palaemonetes spec.</td>
<td>142</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Panopeus herbstii</td>
<td>25.3 f</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Rhepoxynius abronius</td>
<td>63 g</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Macomona liliana</td>
<td>25 h</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Mullinea lateralis</td>
<td>1.8 i</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Mytilus edulis</td>
<td>80</td>
</tr>
<tr>
<td>Pisces</td>
<td>Pleuronectus americanus</td>
<td>0.1 j</td>
</tr>
</tbody>
</table>

Notes to Table 62:

a After exposure for 1 hour, transferred to filtered sea water with exposure to UV (UV-A (320-400 nm) 2.095 mW/cm² and UV-B (280-320 nm) 0.325 mW/cm²) for 4 hours and 24 hours of recovery in filtered sea water for 24 hours in the dark.

b After 96 hours exposure and 1 hour reburial, animals were transferred to uncontaminated seawater and irradiated for 1 hour with UV (UV-A 167 µW/cm² and UV-B 58 µW/cm²), reburial in sediment was measured for 1 hour after the 1 hour UV irradiation.

c After exposure for 1 hour, transferred to filtered sea water with exposure to UV (UV-A (320-400 nm) 2.098 mW/cm² and UV-B (280-320 nm) 0.313 mW/cm²) for 4 hours and 24 hours of recovery in filtered sea water for 24 hours in the dark.

d After exposure for 1 hour, transferred to filtered sea water with exposure to UV (UV-A (320-400 nm) 1.455 mW/cm² and UV-B (280-320 nm) 0.196 mW/cm²) for 4 hours and 24 hours of recovery in filtered sea water for 24 hours in the dark.

e Laboratory ultraviolet light with 465-724 µW/cm² UV-A and 68-109 µW/cm² UV-B and a photoperiod of 16:8 hours light:dark.

f After exposure for 1 hour, transferred to filtered sea water with exposure to UV (UV-A (320-400 nm) 1.979 mW/cm² and UV-B (280-320 nm) 0.276 mW/cm²) for 4 hours and 24 hours of recovery in filtered sea water for 24 hours in the dark.

After exposure in water for 96 hours, transfer to sediment with overlying water to measure reburial EC50 after 1 hour.

h Geometric mean of 12 and 51 µg/L. 16:8 light:dark photoperiod with fluorescent light, followed by 1 hour of UV exposure in clean seawater with 13 W/m² UV-A (320-400 nm) and 2.5 W/m² UV-B (290-330 nm). Sunny summer day in Hamilton NZ: 35 W/m² UV-A and 4.3 W/m² UV-B; at the end of the exposure period clams were transferred to beakers with fresh sediment.
1 Ultraviolet light with 397±35.1 µW/cm² UV-A (365±36 nm) and 134±22.8 µW/cm² UV-B (310±34 nm) with a photoperiod of 16:8 hours light:dark
2 Laboratory ultraviolet light with 465-724 µW/cm² UV-A and 68-109 µW/cm² UV-B and a photoperiod of 16:8 hours light:dark

Table 63: Selected chronic toxicity data of fluoranthene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td><em>Pseudokirchneriella subcapitata</em></td>
<td>8.6</td>
</tr>
<tr>
<td>Algae</td>
<td><em>Scenedesmus vacuolatus</em></td>
<td>14</td>
</tr>
<tr>
<td>Amphibia</td>
<td><em>Ambystoma maculatum</em></td>
<td>125</td>
</tr>
<tr>
<td>Amphibia</td>
<td><em>Rana pipiens</em></td>
<td>25</td>
</tr>
<tr>
<td>Amphibia</td>
<td><em>Xenopus laevis</em></td>
<td>25</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Ceriodaphnia dubia</em></td>
<td>1.17</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Daphnia magna</em></td>
<td>1.4</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Diporeia spp.</em></td>
<td>6.5</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Hyalella azteca</em></td>
<td>1.1</td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Chironomus tentans</em></td>
<td>14</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Lemna gibba</em></td>
<td>130</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Danio rerio</em></td>
<td>18</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Pimephales promelas</em></td>
<td>1.4</td>
</tr>
</tbody>
</table>

Notes to Table 63

a Photoperiod 16:8 hours light:dark at less than 500 lux.
b Laboratory ultraviolet light with 283 µW/cm² UV-A and 47 µW/cm² UV-B and a photoperiod of 12:12 hours light:dark.
c Longest exposure duration of 28 days.
d Low intensity of UV enhanced light (7.54 µW/cm² UV-B, 102.08 µW/cm² UV-A, 289.24 µW/cm² visible) with a photoperiod of 16:8 hours light:dark.
e Geometric mean of 13 and 15 µg/L. Performed in the presence of a sand substrate, gold light was used (0.17 µW/cm² UV-B, 0.09 µW/cm² UV-A, 167.72 µW/cm² visible) with an intensity of 16:8 hours light:dark.
f Most sensitive parameter (length), EC10 was calculated from presented data.
g Laboratory ultraviolet light was used with 612 µW/cm² UV-A and 82 µW/cm² UV-B and a photoperiod of 12:12 hours light:dark.

Table 64: Selected chronic toxicity data of fluoranthene to marine species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td><em>Acartia tonsa</em></td>
<td>41</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Mysidopsis bahia</em></td>
<td>0.6</td>
</tr>
<tr>
<td>Echinodermata</td>
<td><em>Paracentrotus lividus</em></td>
<td>21</td>
</tr>
<tr>
<td>Mollusca</td>
<td><em>Mytilus galloprovincialis</em></td>
<td>34</td>
</tr>
<tr>
<td>Tunicata</td>
<td><em>Ciona intestinalis</em></td>
<td>242</td>
</tr>
</tbody>
</table>

Notes to Table 64

a Most sensitive parameter (hatching).
b Performed under laboratory ultraviolet light with 465-724 µW/cm² UV-A and 68-109 µW/cm² UV-B and a photoperiod of 16:8 hours light:dark.
c Lighting by cool daylight lamps (380-780nm, PAR) with an intensity of 70 µE/m²/s and a photoperiod of 14:10 hours light:dark.
3.8.3 Sediment

For fluoranthene benthic toxicity data are available for both freshwater and marine benthic species. Selected data are shown in Table 65.

Table 65: Selected chronic toxicity data of fluoranthene to benthic species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard sed]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td>Stylaria lacustris</td>
<td>112</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Corophium sporicorne</td>
<td>108</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Hyalella azteca</td>
<td>73 (^a)</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Rhepoxynius abronius</td>
<td>135 (^b)</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Schizopera knabeni</td>
<td>41 (^c)</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Coullana spec.</td>
<td>157 (^d)</td>
</tr>
<tr>
<td>Insecta</td>
<td>Chironomus tentans</td>
<td>58</td>
</tr>
<tr>
<td>Insecta</td>
<td>Chironomus riparius</td>
<td>166 (^e)</td>
</tr>
</tbody>
</table>

Notes to Table 65

- \(^a\) Geometric mean of 8.8 and 600 mg/kg\(_{dw\, standard\, sed}\) for mortality.
- \(^b\) Geometric mean of 58, 113, 83, 117, 235, 173, 218, 188, and 141 mg/kg\(_{dw\, standard\, sed}\) for mortality.
- \(^c\) Longest exposure duration (14-d) for most sensitive, relevant parameter (reproduction).
- \(^d\) Most sensitive, relevant parameter (mortality).
- \(^e\) NOEC for longest test duration (28-d emergence); 10-11 d LC50s range between 43 and 330-461 (four values) mg/kg\(_{dw\, standard\, sed}\) in two different studies.

Further several LC50s have been reported without a NOEC or EC10. Some 30-d tests with Diporeia species were carried out. At trace concentrations
(<1 mg/kgdw standard sed) no effect was observed, at higher concentrations mortality was significantly different from controls (430-530 mg/kgdw, standard sed) (Kane Driscoll et al., 1997a). These sediments had low organic matter content (0.37 and 0.53%). In a sediment with higher organic carbon (1.9%) (Kane Driscoll and Landrum, 1997), the concentrations normalised to a sediment with 10% organic matter up to 3000 mg/kgdw, standard sed showed no significant mortality. From these studies it can be estimated that the LC10 must lie in this range of tested concentrations.

Several tests with *Hyalella azteca* are available. Results of these studies vary widely. When recalculated to a sediment with 10% organic matter, LC50s (Kane Driscoll and Landrum, 1997; Hatch and Burton Jr., 1999; Suedel et al., 1993; Verrhiest et al., 2001; Wilcoxen et al., 2003) varied from 15 to 3800 mg/kgdw standard sed and NOECs for mortality (Kane Driscoll and Landrum, 1997; Kane Driscoll et al., 1997a; Verrhiest et al., 2001; Suedel and Rodgers Jr., 1996) varied from 8.8 to 600 mg/kgdw standard sed. Studies are performed with a different percentage organic matter of the sediment ranging from 0.37 to 3.4% as well as with different exposure times ranging from 10 to 30 days. However, both parameters could not explain the large differences in toxicity.

Two chironomid species were tested. 10-d LC50 values for *Chironomus tentans* (Suedel et al., 1993) ranged from 40 to 102 mg/kgdw, recalculated to a sediment with 10% organic matter. For *Chironomus riparius*, exposed for 10 or 11 days to fluoranthene in sediment (Stewart and Thompson, 1995; Verrhiest et al., 2001), these values ranged from 43 to 461 mg/kgdw standard sed. For this species total emergence, emergence time and onset of emergence from a 28-d study were not more sensitive as endpoint as mortality (Stewart and Thompson, 1995). The NOEC for mortality and growth during a 10-d study (Verrhiest et al., 2001) was lower than 8.8 mg/kgdw standard sed, recalculated to a sediment with 10% organic matter. Fluoranthene was also tested in a mixture together with phenanthrene and benzo[k]fluoranthene, with each compound comprising one third of the total PAH concentration. For this mixture, data are presented from which a clear dose-response relationship can be deduced. If the LC10 is determined with a log-logistic relationship, this value is 5.6 mg/kgdw standard sed, on basis of the fluoranthene concentrations in this mixture, and normalised to sediment with 10% organic matter. Because of the additivity of the PAHs in this mixture (Verrhiest et al., 2001), the LC10 for fluoranthene alone will be higher than this value. All sediment concentrations were verified. Because the measured concentrations were higher than 77% of the nominal concentrations, the data by Verrhiest et al. (2001) are based on nominal concentrations.

For marine sediment toxicity studies have been performed with 1 species of annelids (*Arenicola marina*), 5 species of crustaceans (*Corophium volutator, Corophium spinicorne, Rhepoxynius abronius, Schizopera knabeni, Coullana spec.*), 1 mollusc (*Abra alba*), and 1 echinodermata species (*Echinocardium cordata*). Most species are tested with exposure times of 10 days. The test endpoints are often mortality. For *Corophium volutator* (Bowmer, 1994) a geometric mean of 10-d LC50 of 220 mg/kgdw standard sed was calculated for sediment with 10% organic matter. For *Corophium spinicorne* (Swartz et al., 1990) the 10-d LC50 was 160 mg/kgdw standard sed or higher. For the studies with *Rhepoxynius abronius* (Swartz et al., 1988; Swartz et al., 1997; Swartz et al., 1990; Boese et al., 1998; Cole et al., 2000; DeWitt et al., 1992) a geometric mean for the 10-d LC50 of about 270 mg/kgdw can be derived when calculated for a sediment with 10% organic matter. An EC50 for reburial was reported aswell which, transferred to a sediment with 10% organic matter, is smaller than 39 mg/kgdw standard sed (Boese et al., 1998). Reburial is considered to be a better endpoint for chronic toxicity than mortality. In this case, after 10 days of exposure, the organisms were irradiated with UV radiation (UV-A (321-400 nm))
315±36 µW/cm²; UV-B (280-320 nm) 128±12 µW/cm²; visible light (401-700 nm) 3400±278 µW/cm²) before reburial was monitored. However, in contrast to several other crustaceans, *Rhepoxynius abronius* is a subsurface burrower that typically does not extend body parts in overlying water (Swartz et al., 1990; Boese et al., 1997). Therefore, this EC50 is not very useful in the risk assessment. In contrast, the EC10 for mortality for this species is very useful, because from a comparison with data for reburial (Boese et al., 1997), it appears that mortality is almost equally sensitive as reburial under normal conditions.

For the *Schizopera knabeni* the LC50 decreases with increasing exposure times. Recalculated to a sediment with 10% organic matter, the 4-d LC50 (Lotufo, 1997) is larger than 8200 mg/kgdw standard sed and the 10-d LC50 (Lotufo, 1998) is 820 mg/kgdw standard sed. For reproduction, the same effect was observed, only this parameter is more sensitive than mortality. The 10-d EC50 (Lotufo, 1998) is 210 mg/kgdw standard sed; the 14-d EC50 is 150 mg/kgdw standard sed. The EC10s are 58 and 41 mg/kgdw standard sed respectively. Another sensitive endpoint is the grazing rate of algae cells by this organism. From a 6-h study (Lotufo, 1997), an EC10 for grazing rate can be derived with a log-logistic model. Recalculated to sediment with 10% organic matter, this EC10 is 9.2 mg/kgdw standard sed. For a *Coullana* species the grazing rate was determined in the same way (Lotufo, 1998). The EC10 calculated from the results for this species was 39 mg/kgdw standard sed. Reproduction and mortality from a 10-d study appeared to be less sensitive endpoints, but these parameters are considered environmentally more relevant.

Tests were also performed with the marine mollusc *Abra alba* and the echinoderm *Echinocardium cordatum*. The EC50 for defecation varied from 16.3 to >625 mg/kgdw in organic rich muddy sediment (Bowmer, 1994). For *Echinocardium cordatum* the 10-d LC50s varied from 33 to 116 mg/kgdw standard sed in muddy fine sand (Bowmer, 1994). When possible, recalculation to sediment with 10% organic matter leads to LC50s of 1100 to 1700 mg/kgdw standard sed. It appears that the tested marine species are equally sensitive as freshwater species. The lowest effect concentration for fluoranthene in sediment was found for mortality and growth of *Chironomus riparius*. This was a LOEC and not a NOEC and no effect percentage was given. However, results for the same species vary widely. The lowest selected value is the EC10 for reproduction of the marine crustacean *Schizopera knabeni*. Also for this species a more sensitive endpoint was found (grazing after 1 day exposure) but this did apparently not affect reproduction in a longer exposure duration of 14 days. Therefore, reproduction is chosen as most sensitive of the relevant parameters. The MPCeco, sediment is based on this value. Because data are available for annelids, crustaceans, and insects, an assessment factor of 10 can be applied to this value. The MPCeco, sediment for fluoranthene in sediment then becomes 4.1 mg/kgdw standard sed. For marine sediment, chronic studies are available for annelids, crustaceans and echinoderms. Therefore, the MPCeco, marine sediment has the same value of 4.1 mg/kgdw standard sed. The SRCeco, sediment is equal to the geometric mean of the selected data and is 96 mg/kgdw standard sed.

### 3.8.4 Soil

For fluoranthene several toxicity data in soil are available. For the earthworm *Eisenia fetida* (Schaub and Achazi, 1996) and the snail *Helix aspersa* (Sverdrup et al., 2006) no effects were observed. Also for the processes respiration and
dehydrogenase no effects were observed (Eschenbach et al., 1991). For the rest of the species and processes the selected data are shown in Table 66.

**Table 66: Selected chronic toxicity data of fluoranthene to terrestrial species and processes**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg standard soil]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td><em>Eisenia veneta</em></td>
<td>415</td>
</tr>
<tr>
<td>Annelida</td>
<td><em>Enchytraeus crypticus</em></td>
<td>55</td>
</tr>
<tr>
<td>Insecta</td>
<td><em>Folsomia fimetaria</em></td>
<td>127 a</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Sinapsis alba</em></td>
<td>1411 b</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Trifolium pratense</em></td>
<td>199 b</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Lolium perenne</em></td>
<td>1067 b</td>
</tr>
<tr>
<td>Microbial process</td>
<td>nitrification</td>
<td>48</td>
</tr>
</tbody>
</table>

**Notes to Table 66**

a Most sensitive endpoint (reproduction) corrected for time weighted average concentrations.
b Most sensitive endpoint (fresh weight).

Selected data are available for all trophic levels. The MPC_{eco, soil} can therefore be derived by applying an assessment factor of 10 to the lowest NOEC or EC10, which is the EC10 for the process of nitrification. The resulting MPC_{eco, soil} is 4.8 mg/kg_{dw standard soil}.

For the SRC_{eco, soil} the geometric mean of the data for the 6 selected species could be chosen. This is 310 mg/kg_{dw standard soil}. It must be noted that for 2 species no effects were observed, the highest tested concentration for the earthworm was however below this value of 310 mg/kg_{dw standard soil}.

At the same time, the lowest value for terrestrial processes and enzymatic activity is much lower, but for 2 other processes or enzymatic activities no effects were observed up to the highest tested concentration of 1400 mg/kg_{dw standard soil}, normalized to standard soil with 10% organic matter. In this study (Eschenbach et al., 1991), concentrations were not verified but from several other studies it appears that fluoranthene is rather stable in terrestrial test systems (Sverdrup et al., 2001; Sverdrup et al., 2006). Therefore, the geometric mean of the terrestrial processes and enzymatic activities is higher than the value for species. The SRC_{eco, soil} is thus 310 mg/kg_{dw standard soil}.

### 3.9 Chrysene

#### 3.9.1 Substance identification and physicochemical properties

#### 3.9.1.1 Identity

![Figure 15: Structural formula of chrysene](image-url)
Table 67: Identification of chrysene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Chrysene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>Chrysene</td>
</tr>
<tr>
<td>CAS number</td>
<td>218-01-9</td>
</tr>
<tr>
<td>EC number</td>
<td>205-923-4</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c12ccccccc1c3ccc4cccccc4c3cc2</td>
</tr>
</tbody>
</table>

3.9.1.2 Physicochemical properties

Table 68: Physicochemical properties of chrysene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>228.29</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>1.61</td>
<td>Geometric mean of 6 values by generator-column method</td>
</tr>
<tr>
<td>log $K_{OW}$</td>
<td>[-]</td>
<td>5.81</td>
<td>Slow-stirring method</td>
</tr>
<tr>
<td>log $K_{OC}$</td>
<td>[-]</td>
<td>5.60</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>$2.11 \cdot 10^{-6}$</td>
<td>Gas saturation method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>255.5</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>448</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa.m³/mol]</td>
<td>0.24</td>
<td>Geometric mean of 1 value by gas stripping method and 1 value by headspace method</td>
</tr>
</tbody>
</table>

3.9.2 Water

Reliable chronic toxicity studies were performed with algae (Bisson et al., 2000), daphnids (both *Daphnia magna* (Hooftman, 1991) and *Ceriodaphnia dubia* (Bisson et al., 2000)) and fish (Hooftman and Evers-de Ruiter, 1992b), but no significant effects were observed for any species in a regular toxicity experiment around or below the aqueous solubility. The only study, that showed a considerable effect of chrysene, was a determination of the median lethal time for neonates of *Daphnia magna* (Newsted and Giesy, 1987). In this experiment, the daphnids were exposed to one concentration of chrysene (measured concentration of 0.7 µg/L). The test was performed as a static-renewal acute toxicity test. After 24 hours of exposure with a 16:8 light:dark photoperiod, the animals were exposed to UV light with an intensity of $25 \pm 3 \mu W/cm²$ UV-B (310±36 nm), $120 \pm 5 \mu W/cm²$ UV-A (365±36 nm), and $680 \pm 10 \mu W/cm²$ visible light (400 to 700 nm). The median lethal time after UV radiation started was 24 hours. Thus, after 48 hours, of which the last 24 hours were with UV radiation, 50% mortality of the daphnids occurred at 0.7 µg/L. For marine species acute toxicity studies were performed with bacteria, annelids and crustaceans. No significant effects at or below the aqueous solubility were observed in any of these toxicity studies as well. Moreover, only one study with the luminescent bacterium species *Vibrio fischeri* can be considered as reliable (Loibner et al., 2004).

No acute toxicity data for algae and fish are available. However, for algae the EC10 and thus the EC50 for growth of *Pseudokirchneriella subcapitata* is higher than 1 µg/L. Due to the limited solubility of chrysene, no acute effects are expected for fish either. Besides that, an ELS study with the zebrafish *Brachydanio rerio* is available. Chronic studies were performed with algae, daphnids (2 species) and fish. Therefore an assessment factor of 10 to the lowest NOEC or EC10 can be applied. However, no effects were observed at all, although in the test with *Ceriodaphnia dubia* the highest tested measured concentration was 0.09 µg/L, which means that this species was not tested up to the water solubility of chrysene. The only study with a significant effect below
the aqueous solubility was 50% mortality after 48 hours at 0.7 µg/L. In this study, toxicity of chrysene was enhanced by irradiation with UV light, although the intensity was considerably less than natural sunlight. Sunlight or UV light comparable with sunlight was also used in the case of the lowest effect concentrations for anthracene and fluoranthene. Similar to these compounds an assessment factor of 10 is applied to the lowest effect concentration. The resulting \( \text{MPC}_{\text{eco, water}} \) is thus 0.07 µg/L. No additional chronic toxicity data for typically marine species are available. Therefore, an assessment factor of 100 will be applied to derive the \( \text{MPC}_{\text{eco, marine}} \). This \( \text{MPC}_{\text{eco, marine}} \) thus is 0.007 µg/L. Because the MPC values are based on an acute study with \textit{Daphnia} and no further information is available, the \( \text{MAC}_{\text{eco, water}} \) and \( \text{MAC}_{\text{eco, marine}} \) are set equal to their corresponding MPC values. Because no toxicity was observed up to the solubility in chronic studies, the \( \text{SRC}_{\text{eco, water}} \) is set equal to the aqueous solubility. The \( \text{SRC}_{\text{eco, water}} \) thus is 1.6 µg/L.

3.9.3 Sediment

No data for benthic organisms are available. Therefore, the ERLs are derived by means of equilibrium partitioning. The \( \text{MPC}_{\text{eco, sediment}} \) is 1.6 mg/kg\text{dw}, standard sed, the \( \text{MPC}_{\text{eco, marine sediment}} \) is 0.16 mg/kg\text{dw}, standard sed, and the \( \text{SRC}_{\text{eco, sediment}} \) is 38 mg/kg\text{dw}, standard sed.

3.9.4 Soil

For soil 2 studies with 3 species are available. No effects were observed in a 14-d study with the earthworm \textit{Eisenia fetida} (Bowmer et al., 1993), a 21-d study with the springtail \textit{Folsomia candida} (Bowmer et al., 1993), and a 28-d study with the springtail \textit{Folsomia fimetaria} (Sverdrup et al., 2002). However, pore water concentrations are possibly already saturated below 50 mg/kg\text{dw} standard soil. Therefore, the ERLs are derived by means of equilibrium partitioning. The \( \text{MPC}_{\text{eco, soil}} \) is 1.6 mg/kg\text{dw}, standard soil, and the \( \text{SRC}_{\text{eco, soil}} \) is 38 mg/kg\text{dw}, soil.

3.10 Benz[a]anthracene

3.10.1 Substance identification and physicochemical properties

3.10.1.1 Identity

![Figure 16: Structural formula of benz[a]anthracene](image)

\begin{table}[
\centering
\caption{Identification of benz[a]anthracene} 
\begin{tabular}{|l|l|}
\hline
\textbf{Parameter} & \textbf{Value} \\
\hline
Common/trivial/other name & Benz[a]anthracene, 1,2-benzanthracene, 2,3-benzophenanthrene, naphanthracene, tetraphene \\
Chemical name & 1,2-benzanthracene \\
CAS number & 56-55-3 \\
EC number & 200-280-6 \\
SMILES code & c12cccc1cc3c4cccccc4ccc3c2 \\
\hline
\end{tabular}
\end{table}
3.10.1.2 Physicochemical properties

Table 70: Physicochemical properties of benz[a]anthracene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>228.29</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>10.2</td>
<td>Geometric mean of 7 values by generator-column method</td>
</tr>
<tr>
<td>log $K_{OW}$</td>
<td>[-]</td>
<td>5.91</td>
<td>Slow-stirring method</td>
</tr>
<tr>
<td>log $K_{OC}$</td>
<td>[-]</td>
<td>5.70</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>2.71·10^{-5}</td>
<td>Gas saturation method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>160.5</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>438</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa·m^3/mol]</td>
<td>0.47</td>
<td>Geometric mean of 2 values by gas stripping method and 1 value by headspace method</td>
</tr>
</tbody>
</table>

3.10.2 Water

Selected acute toxicity data for benz[a]anthracene are shown in Table 71. For algae a 24-h EC50 based on cell number is available (Altenburger et al., 2004). The lowest acute value for immobility of *Daphnia magna* is the EC50 of 0.96 µg/L after exposure for 48 hours with a 16:8 light:dark photoperiod with visible light, UV-A (320-400 nm) and UV-B (290-320 nm) with an intensities of 61, 4.4, and 0.45 µmol/m²/s. At similar intensities without the UV-B component, the EC50 was 1.48 µg/L (Lampi et al., 2006). In this study with *Daphnia magna* the concentrations were not verified, and therefore, this study is not included in Table 71. In another study with *Daphnia magna* concentrations were verified, but the highest tested concentration was 9.1 µg/L and no toxicity was observed (Bisson et al., 2000). In a study with *Daphnia pulex* in which the concentrations were verified as well, the EC50 was 10 µg/L (Trucco et al., 1983).

For fish, no standard acute toxicity data are available. A study with larvae of fathead minnows (*Pimephales promelas*) was performed to determine the median lethal time (Oris and Giesy Jr., 1987). 7-d old larvae were exposed to a measured concentration of 1.8 µg/L benz[a]anthracene for an incubation period of 24 hours in the absence of UV radiation and thereafter exposed for 96 hours to UV light with an intensity of 20 µW/cm² UV-B (290-336 nm), 95 µW/cm² UV-A (336-400 nm). After the incubation time of 24 hours, the medium was renewed every 12 hours. The median lethal time was 65 hours, which means that more than 50% mortality occurred in the test period of 120 hours.

Table 71: Selected acute toxicity data of benz[a]anthracene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td><em>Scenedesmus vacuolatus</em></td>
<td>14</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Daphnia pulex</em></td>
<td>10</td>
</tr>
</tbody>
</table>

In tests with marine algae (Boney and Corner, 1962) and bacteria (El-Alawi et al., 2002; Johnson and Long, 1998; Loibner et al., 2004) adverse effects were only observed at concentrations far above the aqueous solubility, but in all these studies concentrations were not verified or experimental details about solubility in test media are missing. Consequently, no marine data have been selected. From the tests with *Daphnia magna* and the test with *Pimephales promelas*, it can be concluded that benz[a]anthracene is more toxic in the presence of UV light than is reflected by the selected data in Table 71. EC50s in the presence of UV light are more likely in the order of 1 µg/L.
Reliable chronic toxicity studies with freshwater species are available for algae and crustaceans. However, for *Ceriodaphnia dubia* no toxicity was observed up to 9.1 µg/L and the 7-d EC10 is thus higher than this value (Bisson et al., 2000). The selected chronic data for the two algae species are shown in Table 72. The rest of the chronic toxicity data are well above the aqueous solubility and concentrations were not verified. In an ELS test with rice fish (*Oryzias latipes*) benz[a]anthracene was tested in glass bottles with Teflon lined caps (Rhodes et al., 2005). No analysis of the substance was however performed and the EC10 was 79 µg/L, which is far above the aqueous solubility. This study can therefore not be considered as reliable. Moreover, in the acute test with fathead minnows, more than 50% mortality occurred at 1.8 µg/L.

Table 72: Selected chronic toxicity data of benz[a]anthracene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td><em>Pseudokirchneriella subcapitata</em></td>
<td>1.2</td>
</tr>
<tr>
<td>Algae</td>
<td><em>Scenedesmus vacuolatus</em></td>
<td>8.0</td>
</tr>
</tbody>
</table>

The determination of the lethal time for *Pimephales promelas* is an acute fish toxicity study, which completes the base-set, although no LC50 can be derived from the study. Chronic toxicity data are available for algae and crustaceans. Fish are possibly the most sensitive species of the base-set in acute toxicity tests. Therefore, an assessment factor of 100 should be applied to derive the MPC_{eco, water}. The lowest NOEC or EC10 is the EC10 of 1.2 µg/L for *Pseudokirchneriella subcapitata*. The MPC_{eco, water} for freshwater is 0.012 µg/L. Because no studies with additional marine species are available, the MPC_{eco, marine} is derived by applying an assessment factor of 1000. The MPC_{eco, marine} is 0.0012 µg/L.

Two acute EC50s have been selected. However, from other not selected acute toxicity studies, it is clear that for fish and daphnids acute toxic effects due to phototoxicity occur at concentrations that lie in the same range as the chronic effects, which is about one order of magnitude below the selected acute toxicity data. Phototoxicity can be considered as a very sensitive acute effect. An assessment factor of 100 on the lowest selected acute value seems to be protective for the phototoxic effects on fish and daphnids as well. The MAC_{eco, water} then becomes 0.10 µg/L. Because there are no reliable marine data, an additional factor of 10 is applied. The resulting MAC_{eco, marine} is 0.010 µg/L. The value of the SRC_{eco, water} could be taken equal to the geometric mean of the two available NOECs and is 3.1 µg/L. The SRC_{eco, water} should represent the HC50. With fish probably being the most sensitive taxonomic group and crustaceans showing no effects up to (almost) the water solubility, the geometric mean of the two algae species seems a good representative for the HC50.

### 3.10.3 Sediment

The only available study with benthic organisms is a 10-d study with the marine crustacean *Rhepoxynius abronius* (Boese et al., 1998). No effects on reburial and mortality were observed up to concentrations of 64 mg/kg_{dw, standard sed} normalized to standard sediment with 10% organic matter. Therefore, the ERLs are derived by means of equilibrium partitioning. The MPC_{eco, sediment} is 0.35 mg/kg_{dw, standard sed}. For the marine environment, this number is a factor of 10 lower. The MPC_{eco, marine sediment} is 0.035 mg/kg_{dw, standard sed}. The SRC_{eco, sediment} is 91 mg/kg_{dw, standard sed}. 

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3.10.4 Soil

Toxicity tests with 5 terrestrial species from 3 taxonomic groups are available for benz[a]anthracene. In the tests with the pot worm *Enchytraeus crypticus* (Droge et al., 2006; Bleeker et al., 2003) and the springtails *Folsomia candida* (Droge et al., 2006; Bleeker et al., 2003) and *Folsomia fimetaria* (Sverdrup et al., 2002) no effects were observed on reproduction and mortality at measured concentrations of 2400 mg/kg\(_{\text{dw, standard soil}}\), normalized to standard soil with 10% organic matter. Pore water concentrations are possibly already saturated at concentrations around 300 mg/kg\(_{\text{dw}}\). At the levels used in the test increasing or decreasing the concentrations has no effect anymore on the uptake of the substance from pore water. Also for the isopod *Porcellio scaber*, exposed through contaminated litter (Van Brummelen et al., 1996), no effects were observed up to concentrations normalized to 10% organic matter of 26 mg/kg\(_{\text{dw, standard soil}}\). Only for the isopod *Oniscus asellus*, also exposed through contaminated litter (Van Brummelen et al., 1996), significant effects were observed. The NOEC normalized to 10% organic matter was 1.0 mg/kg\(_{\text{dw, standard soil}}\) for the growth of females. From the presented data a reliable EC\(_{10}\) can be derived as well. Taking account of loss of the substance in between renewal of the food, the EC\(_{10}\) is 1.9 mg/kg\(_{\text{dw, standard soil}}\) and still slightly higher than the NOEC reported in the study, based on initial concentrations. This value has been selected (Table 73).

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC(<em>{10}) [mg/kg(</em>{\text{standard soil}})]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td><em>Oniscus asellus</em></td>
<td>1.9 (^a)</td>
</tr>
</tbody>
</table>

Notes to Table 73

\(^a\) Most sensitive parameter (growth of females).

Although there are data for 5 species, all species are invertebrates. They can be considered as primary consumers (springtails) and decomposers. Therefore, an assessment factor of 50 should be applied in principle. However, given the fact that 5 species are tested and *Oniscus asellus* appears to be a very sensitive species, an assessment factor of 10 seems justified. A value of 0.19 mg/kg\(_{\text{dw, standard soil}}\) is derived for the MPC\(_{\text{eco, soil}}\). Of the 5 species tested, 3 showed no signs of toxicity up to concentrations that may be assumed to correspond with saturated pore water concentrations. It seems not justified to base the SRC\(_{\text{eco, soil}}\) on one very sensitive species, because the SRC\(_{\text{eco, soil}}\) should represent the HC\(_{50}\). Therefore, the SRC\(_{\text{eco, soil}}\) is derived by equilibrium partitioning and is 91 mg/kg\(_{\text{dw, standard soil}}\).

3.11 Benzo[k]fluoranthene

3.11.1 Substance identification and physicochemical properties

3.11.1.1 Identity

![Figure 17: Structural formula of benzo[k]fluoranthene](image)
Table 74: Identification of benzo[k]fluoranthene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Benzo[k]fluoranthene, 8,9-benzofluoranthene, 11,12-benzofluoranthene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>8,9-benzofluoranthene</td>
</tr>
<tr>
<td>CAS number</td>
<td>207-08-9</td>
</tr>
<tr>
<td>EC number</td>
<td>205-916-6</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c1ccc2cccc3c4cc5ccccc5ccc4c1c23</td>
</tr>
</tbody>
</table>

3.11.1.2 Physicochemical properties

Table 75: Physicochemical properties of benzo[k]fluoranthene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>252.31</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>0.93</td>
<td>Geometric mean of 2 values by generator-column method</td>
</tr>
<tr>
<td>log K_{OW}</td>
<td>[-]</td>
<td>6.11</td>
<td>Slow-stirring method</td>
</tr>
<tr>
<td>log K_{OC}</td>
<td>[-]</td>
<td>5.90</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>1.29·10^{-7}</td>
<td>Method not clear, Antoine equation 363-430 K</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>217</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>480</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa.m^3/mol]</td>
<td>0.059</td>
<td>Gas stripping method</td>
</tr>
</tbody>
</table>

3.11.2 Water

Acute toxicity data for benzo[k]fluoranthene are only available for *Daphnia magna*. However, in the two available studies no effects were observed. In one study the substance was analysed (Bisson et al., 2000), in the second study (Verrhiest et al., 2001) concentrations were not verified. In this study the effect of exposure to UV light was studied by placing the daphnids under UV-A (365 nm, 247 µW/cm²) for 2 hours. This had no effect on the toxicity of benzo[k]fluoranthene. In both tests, benzo[k]fluoranthene was tested up to the solubility limit (1.0-1.1 µg/L). In a test with the marine bacterium species *Vibrio fischeri* (Loibner et al., 2004) no adverse effects were observed at concentrations up to the aqueous solubility too. Due to the low solubility of benzo[k]fluoranthene of about 1 µg/L, acute effects are not anticipated. Reliable chronic toxicity studies with freshwater species are available for algae, crustaceans and fish. In the 72-h study with *Pseudokirchneriella subcapitata* the EC10 for growth is larger than 1.0 µg/L (Bisson et al., 2000). For *Ceriodaphnia dubia* no toxicity was observed as well up to 1.1 µg/L and the 7-d EC10 is thus higher than this value (Bisson et al., 2000). In another test with daphnids (*Daphnia magna*) concentrations were tested up to 2.2 µg/L and no effects were observed (AquaSense, 2005). In two studies, the effects of benzo[k]fluoranthene in an ELS test with zebra fish (*Danio rerio*) were examined. In the first study one concentration of 0.58 µg/L was tested. At this concentration 52% mortality occurred (Hooftman and Evers-de Ruiter, 1992b). In a second study a dose-response relationship was examined (Hooftman and Evers-de Ruiter, 1992c). The mentioned concentrations here are based on measured concentrations per concentration and not on average recovery times the nominal concentration as given in the report. The LC50 estimated from the presented data with a log-logistic relationship is 0.65 µg/L. From the data for weight and length EC10s are derived of 0.31 and 0.17 µg/L. Due to the good fit of the log-logistic equation, these estimates have a low uncertainty. Two studies with marine species are available. In two 48-h studies with fertilized eggs of the
echinoderm *Psammechinus miliaris* and the mollusc *Crassostrea gigas* the development of the larvae was examined (AquaSense, 2005). No effects were observed for tested concentrations up to 2.6 µg/L. In conclusion, six species were tested but only for one species effects were observed below the water solubility Table 76.

*Table 76: Selected chronic toxicity data of benzo[k]fluoranthene to freshwater species*

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pisces</td>
<td><em>Danio rerio</em></td>
<td>0.17 a</td>
</tr>
</tbody>
</table>

Notes to Table 76

* Most sensitive parameter (length).

The base-set for benzo[k]fluoranthene is not complete, because acute data are missing for fish. Acute toxicity was tested for algae, bacteria (*Vibrio*) and crustaceans, the latter also with inclusion of phototoxicity. Due to the high hydrophobicity of benzo[k]fluoranthene it is not likely that species from other taxonomic groups will show acute toxic effects. Chronic toxicity data are available for algae, crustaceans, fish, echinoderms and molluscs. Fish are the most sensitive species. Therefore, an assessment factor of 10 could be applied to derive the MPCeco, water. The lowest NOEC or EC10 is the EC10 of 0.17 µg/L for zebra fish. The MPCeco, water for freshwater is 0.017 µg/L. Because studies with two additional marine species are available, the MPCeco, marine is equal to the freshwater value. No acute toxic effects have been observed, even under influence of UV light, while phototoxicity can be considered as very sensitive acute effects. Therefore, no MACeco, water can be derived. The value of the SRCeco, water could be taken equal to water solubility, because only 1 out of 5 species showed effects at concentrations below the solubility. The SRC thus is 0.93 µg/L.

### 3.11.3 Sediment

Two benthic organisms were tested for benzo[k]fluoranthene (Verrhiest et al., 2001). The crustacean *Hyalella azteca* was tested in a 14-d study and the midge larvae (*Chironomus riparius*) in a 10-d study. No effects on mortality and growth were observed up to concentrations of 880 mg/kgdw, standard sed, normalized to standard sediment with 10% organic matter. Therefore, the ERLs are derived by means of equilibrium partitioning. The MPCeco, sediment is 0.79 mg/kgdw, standard sed. The MPCeco, marine sediment for the marine environment is the same. The SRCeco, sediment is 44 mg/kgdw, standard sed.

### 3.11.4 Soil

Toxicity tests with two species of springtails are available for benzo[k]fluoranthene, one with *Folsomia candida* (Bowmer et al., 1993) and *Folsomia fimetaria* (Sverdrup et al., 2002). In both studies no effects were observed on reproduction and mortality at measured concentrations up to 180 mg/kgdw, standard soil for *Folsomia candida* and 2100 mg/kgdw, standard soil for *Folsomia fimetaria*, normalized to standard soil with 10% organic matter. Pore water concentrations are possibly already saturated at concentrations below 50 mg/kgdw. At the levels used in the test increasing or decreasing the concentrations has no effect anymore on the uptake of the substance from pore water. Because there is no value that can be used for terrestrial species, the MPC has to be derived by equilibrium partitioning. A value of 0.79 mg/kgdw, standard soil is derived for the MPCeco, soil. Also the SRCeco, soil is
derived by equilibrium partitioning and is 44 mg/kg\text{dw, standard soil}. This value is based on saturated pore water concentrations.

3.12 Benzo[b]fluoranthene

3.12.1 Substance identification and physicochemical properties

3.12.1.1 Identity

![Structural formula of benzo[b]fluoranthene]

*Figure 18: Structural formula of benzo[b]fluoranthene*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Benzo[b]fluoranthene, 2,3-benzofluoranthene, 3,4-benzofluoranthene, benz[e]acephenanthrylene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>2,3-benzofluoranthene</td>
</tr>
<tr>
<td>CAS number</td>
<td>205-99-2</td>
</tr>
<tr>
<td>EC number</td>
<td>205-911-9</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c1c2cccc2c3ccc4c5ccccc5c1c34</td>
</tr>
</tbody>
</table>

3.12.1.2 Physicochemical properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>252.31</td>
<td>Geometric mean of 2 values by generator-column method</td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>1.28</td>
<td>Geometric mean of 2 values by generator-column method</td>
</tr>
<tr>
<td>log $K_{OW}$</td>
<td>[-]</td>
<td>6.124</td>
<td>Calculated ClogP</td>
</tr>
<tr>
<td>log $K_{OC}$</td>
<td>[-]</td>
<td>5.914</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>5·10^{-8}</td>
<td>Method not clear, Antoine equation 363-430 K</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>217</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>480</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa.m^3/mol]</td>
<td>0.067</td>
<td>Gas stripping method</td>
</tr>
</tbody>
</table>

3.12.2 Water

Acute toxicity data for benzo[b]fluoranthene are only available for *Daphnia magna*. However, in the two available studies no effects were observed below the water solubility in the absence of UV light. In the first study the substance was analysed (Bisson et al., 2000), in the second study (Wernersson and Dave, 1997) concentrations were not verified. In this study the effect of exposure to UV light was studied by placing the daphnids under UV-A (295-365 nm; peak 340 nm; intensity 370±20 µW/cm²) for 2 hours. Whereas benzo[b]fluoranthene was not toxic to daphnids in the absence of UV light, even in concentration far above the aqueous solubility, the toxicity increased after irradiation with UV light, resulting in an EC50 of 4.2 µg/L, which is still amply above the water solubility. In a test with the marine bacterium species *Vibrio fischeri* (Loibner et al., 2004) no adverse effects were observed at concentrations up to the aqueous solubility too. Due to the low solubility of benzo[b]fluoranthene of about 1 µg/L, acute effects are not anticipated.
Reliable chronic toxicity studies with freshwater species are available for algae and crustaceans. In the 72-h study with *Pseudokirchneriella subcapitata* the EC10 for growth is larger than 1.0 µg/L (Bisson et al., 2000). For *Ceriodaphnia dubia* no toxicity was observed as well up to 1.1 µg/L and the 7-d EC10 is thus higher than this value (Bisson et al., 2000). In conclusion, no EC50, EC10, or NOEC value is available to base the environmental risk limits upon. The base-set for benzo[b]fluoranthene is not complete, because acute data are missing for fish. Chronic data for fish are missing as well. This is the only trophic level that showed the adverse effects below the water solubility for benzo[k]fluoranthene. For this reason, the MPCeco, water and MPCeco, marine for benzo[b]fluoranthene were taken equal to the risk limits for benzo[k]fluoranthene, which has very similar properties (see section 3.11). The SRCeco, water for benzo[b]fluoranthene is derived in a similar way to benzo[k]fluoranthene as well by taking the solubility limit of 1.3 µg/L.

3.12.3 Sediment

The only available study with benthic organisms is a 10-d study with the marine crustacean *Rhepoxynius abronius* (Boese et al., 1998). No effects on reburial and mortality were observed up to concentrations of 105 mg/kgdw, standard sed normalized to standard sediment with 10% organic matter. Therefore, the MPCs are taken equal to the values for benzo[k]fluoranthene. The MPCeco, sediment is 0.79 mg/kgdw, standard sed. The MPCeco, marine sediment for the marine environment is the same. The SRCeco, sediment is derived by equilibrium partitioning and is 62 mg/kgdw, standard sed.

3.12.4 Soil

One toxicity test with springtails (*Folsomia fimetaria*) is available for benzo[b]fluoranthene (Sverdrup et al., 2002). No effects were observed on reproduction and mortality at measured concentrations up to 1300 mg/kgdw, standard soil for *Folsomia fimetaria*, normalized to standard soil with 10% organic matter. Pore water concentrations are possibly already saturated at concentrations slightly above 50 mg/kgdw. At the levels used in the test increasing or decreasing the concentrations has no effect anymore on the uptake of the substance from pore water. Because there is no value that can be used for terrestrial species, the MPC has to be derived by equilibrium partitioning. Because the risk limits for the aquatic compartment are equal to those for benzo[k]fluoranthene, the MPCeco, soil is taken equal to the value for benzo[k]fluoranthene as well, which was 0.79 mg/kgdw, standard soil (see section 3.11). The SRCeco, soil is derived by equilibrium partitioning and is 62 mg/kgdw, standard soil. This value is based on saturated pore water concentrations, which is slightly higher than the value for benzo[k]fluoranthene due to the higher solubility.

3.13 Benzo[a]pyrene

3.13.1 Substance identification and physicochemical properties

3.13.1.1 Identity

![Structural formula of benzo[a]pyrene](image)

*Figure 19: Structural formula of benzo[a]pyrene*
Table 79: Identification of benzo[a]pyrene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Benzo[a]pyrene, 3,4-benzopyrene, benzo[def]chrysene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>3,4-benzopyrene</td>
</tr>
<tr>
<td>CAS number</td>
<td>50-32-8</td>
</tr>
<tr>
<td>EC number</td>
<td>200-028-5</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c12c3c4cccc3ccc1cc5cccc5c2cc4</td>
</tr>
</tbody>
</table>

3.13.1.2 Physicochemical properties

Table 80. Physicochemical properties of benzo[a]pyrene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>252.31</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>1.5</td>
<td>Geometric mean of 6 values by the generator-column method</td>
</tr>
<tr>
<td>log $K_{OW}$</td>
<td>[-]</td>
<td>6.13</td>
<td>Slow-stirring method</td>
</tr>
<tr>
<td>log $K_{OC}$</td>
<td>[-]</td>
<td>5.92</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>1.39·10⁻⁸</td>
<td>Effusion method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>181.1</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>495</td>
<td></td>
</tr>
<tr>
<td>Henry's law constant</td>
<td>[Pa.m³/mol]</td>
<td>0.059</td>
<td>Geometric mean of 1 value by the gas stripping method and 1 value by the wetted-wall method</td>
</tr>
</tbody>
</table>

3.13.2 Water

Acute toxicity data for benzo[a]pyrene with freshwater species are available for algae, amphibians, cyanophyta, bacteria, crustaceans including *Daphnia*, insects and fish. For marine species data are available for algae, annelids, bacteria, and crustaceans. However, most data cannot be considered reliable, mostly because they are performed at concentrations far above the aqueous solubility, and sometimes due to the excessive use of co-solvent. Further, in many experiments concentrations are not experimentally verified.

The lowest effect observed for algae is the EC10 for *Pseudokirchneriella subcapitata* of 0.78 µg/L (Bisson et al., 2000). This test was performed with a light intensity of 6000 to 8000 lux (~2000 µW/cm² with cool white fluorescent lamps). Concentrations were measured. For the same species, the EC10 and EC50 can be estimated from the data presented by Cody et al. (1984). The EC10 under cool white fluorescent light was 10 µg/L, which is above the aqueous solubility. However, under black light with intensities of 0.00032 µW/cm² at 670 nm, 0.0019 µW/cm² at 550 nm and 5.7 µW/cm² at 380 nm, the EC50 was 2.8 µg/L and the EC10 0.96 µg/L. Here, reported concentrations are nominal. Although the light intensities are given at single wavelengths, from the presented spectra it is estimated that the total light intensity is less than 50 µW/cm² in all cases. Therefore, the light intensity may play an important role in the lower EC10 from the study by Bisson et al. (2000).

The lowest acute value for immobility of *Daphnia magna* is the EC50 of 0.98 µg/L after exposure for 48 hours with a 16:8 light:dark photoperiod with visible, UV-A (320-400 nm) and UV-B (290-320 nm) with an intensities of 61, 4.4, and 0.45 µmol/m²/s. At similar intensities without the UV-B component, the EC50 was 1.62 µg/L (Lampi et al., 2006). After exposure for 24 hours with a 16:8 light:dark photoperiod, then 2 hours exposure to UV (295-365 nm; peak 340 nm) with an intensity of 370±20 µW/cm² for 2 hours, followed by 1 hour of recovery in the test medium, the EC50 for immobility of *Daphnia magna* was
1.16 µg/L (Wernersson, 2003). In an earlier study with similar exposure except from the fact the recovery period was 1 hour instead of 2 hours, the EC50 was 8.6 µg/L (Wernersson and Dave, 1997). However, in these 3 studies with Daphnia magna the concentrations were not verified. In another study with Daphnia magna concentrations were verified, but the highest tested concentration was 2.7 µg/L and no toxicity was observed (Bisson et al., 2000). In a study with Daphnia pulex in which the concentrations were verified as well, the EC50 was 5 µg/L (Trucco et al., 1983), although this value is above the aqueous solubility of 1.5 µg/L in pure water. It can be concluded that the lowest acute toxic effects are observed in combination with exposure to UV light, although in none of these studies the concentrations were verified, which reduces the reliability.

A study with larvae of fathead minnows (Pimephales promelas) was performed to determine the median lethal time (Oris and Giesy Jr., 1987). 7-d old larvae were exposed to a measured concentration of 5.6 µg/L benzo[a]pyrene for an incubation period of 24 hour in the absence of UV radiation and thereafter exposed for 96 hours to UV light with an intensity of 20 µW/cm² UV-B (290-336 nm), 95 µW/cm² UV-A (336-400 nm). After the incubation time of 24 hours, the medium was renewed every 12 hours. The median lethal time was 40 hours, which means that more than 50% mortality occurred in the test period of 120 hours. Although also this concentration was above the water solubility, the concentration in the test medium was verified analytically and no cosolvent was used to prepare the solution.

The selected acute toxicity data are presented in Table 81.

Table 81: Selected acute toxicity data of benzo[a]pyrene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>LC50 or EC50 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td>Daphnia pulex</td>
<td>5</td>
</tr>
</tbody>
</table>

Chronic toxicity data are available for freshwater algae, amphibians, crustaceans, plants, fish, and protozoans and marine algae, bacteria, crustaceans, echinoderms, molluscs, and fish. However, also for the chronic data, most studies must be considered unreliable due to the used concentrations that exceed the water solubility.

The 72-h EC10 for growth of Pseudokirchneriella subcapitata is 0.78 µg/L and the 7-d EC10 for reproduction of Ceriodaphnia dubia is 0.5 µg/L (Bisson et al., 2000). Concentrations were measured. Two ELS studies with Danio rerio were performed. No significant effects were observed for mortality, hatchability, length, and weight up to measured concentrations of 4.0 µg/L in a 42-d study (Hooftman and Evers-de Ruiter, 1992b) and no effects on malformations were observed in a 7-d study at concentrations up to 0.44 µg/L (Petersen and Kristensen, 1998).

In a 36-d ELS study with Oncorhynchus mykiss solutions were renewed every 7 to 10 days and water concentrations were measured every 5 days. Aqueous concentrations appeared to be rather constant. It appeared that mortality and hatching were not dose-response related in a range of measured concentrations ranging from 0.08 to 3.0 µg/L (Hannah et al., 1982). Only at 2.4 µg/L a significant difference in mortality was observed. The length of alevins was significantly reduced at all benzo[a]pyrene concentrations. However, a dose-response relationship was completely lacking and the effect percentage did not exceed 8% at all concentrations. At 0.21, 2.4, and 3.0 µg/L significantly more abnormalities were observed. However, at intermediate concentrations of 0.37 and 1.5 µg/L no significant effects were observed. Therefore, the NOEC for abnormalities is 1.5 µg/L. If the presented data are evaluated with a log-logistic
relationship, an EC10 of 2.9 µg/L is derived. Due to the absence of dose-response relationships for mortality, hatching, and length, this EC10 for abnormalities is considered as most critical endpoint for *Oncorhynchus mykiss*.

### Table 82: Selected chronic toxicity data of benzo[a]pyrene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td><em>Pseudokirchneriella subcapitata</em></td>
<td>0.78</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Ceriodaphnia dubia</em></td>
<td>0.503</td>
</tr>
<tr>
<td>Pisces</td>
<td><em>Oncorhynchus mykiss</em></td>
<td>2.9 <em>a</em></td>
</tr>
</tbody>
</table>

Notes to Table 82

*a* Most sensitive endpoint (malformations).

A method for evaluating pollutant genotoxicity, embryotoxicity and teratogenicity using sea urchin (*Strongylocentrotus purpuratus*) embryos was developed and tested using benzo[a]pyrene (Hose et al., 1983; Hose, 1985). In this 48-h study with eggs and sperm of the echinoderm *Strongylocentrotus purpuratus* no significant effects were observed on fertilisation success of eggs. After 48 hours however, the embryos exposed to a nominal concentration of 1.0 µg/L benzo[a]pyrene and higher showed a significantly higher percentage abnormalities of the gastrulae. Only the nominal concentration of 0.5 µg/L was not significantly different from the solvent (ethanol) control. All treatments, including the solvent control were significantly different from the sea water control. The percentage effect shows a dose-response relationship in the nominal concentrations of 0.5, 1, and 5 µg/L. At higher concentrations, i.e. above the aqueous solubility, the effect percentage remains rather constant. The concentrations were measured and initial concentrations were within 10% of the nominal values. After 48 hours all concentrations had declined to about 0.5 µg/L except from the highest concentrations of 50 µg/L, which had declined to 2 µg/L. In a 48-h study with fertilized eggs of the echinoderm *Psammechinus miliaris* the development of the larvae was examined (AquaSense, 2005). No effects were observed for tested concentrations up to 1.6 µg/L. Concentrations were verified in this study.

The shell development of embryos of the mollusc *Crassostrea gigas* was investigated in a 48-h study (Lyons et al., 2002). Under UV lacking fluorescent laboratory lighting with a photoperiod of 12:12 hours light:dark, the NOEC for abnormal shells is 1 µg/L. With a log-logistic relationship, the derived EC10 from the presented data is 1.1 µg/L. When UV irradiation with an intensity of 456.2±55 µW/cm² UV-A and 6.3±0.1 µW/cm² UV-B with a photoperiod of 12:12 hours light:dark was used, the NOEC reduced to 0.5 µg/L. The presented data show a clear dose-response relationship and the EC10 derived from these data with a log-logistic equation is 0.22 µg/L. Concentrations were not verified in this study.

In 2 48-h studies with fertilized eggs of the same species (*Crassostrea gigas*) the development of the larvae was examined (AquaSense, 2005). No effects were observed for measured concentrations up to 1.6 µg/L. However, no UV light was used in this study.

In a 7-d ELS study with the marine fish *Fundulus heteroclitus* mild deformities were observed in the benzo[a]pyrene treatment groups ranging from 0.25 to 10 µg/L, while these effects were not observed in the controls (Wassenberg et al., 2002). Concentrations were not verified. The percentage effect ranged from 0 to 43% but a dose-response relationship was completely missing. In the second lowest concentration of 0.5 µg/L 0% deformities were observed. Therefore, no useable endpoint can be derived from this study.
In a 6-d ELS study with the marine flatfish *Psettichthys melanostichus* the only tested concentration of 0.1 µg/L resulted in significantly reduced hatching success (on the fifth day of the study) and in 5% of the embryos deformities were found (Hose et al., 1982). However, in the control group only 57.0% hatched on average, with a range from 21.6 to 89.6%. In the treated group the average hatching success was 28.1% with a range of 7% to 67.6%. The meaning of these results can therefore be questioned, especially because after 120 hours the percentage hatching was almost equal. The exposure concentration in this study was verified.

The only study that resulted in a useable NOEC for marine species is given in Table 83.

**Table 83: Selected chronic toxicity data of benzo[a]pyrene to marine species**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echinodermata</td>
<td><em>Strongylocentrotus purpuratus</em></td>
<td>0.5</td>
</tr>
</tbody>
</table>

Acute toxicity data are available for algae, daphnids and fish. In the chronic studies the lowest reliable values (i.e. with verification of the exposure concentrations) were 0.50 µg/L for the freshwater daphnid *Ceriodaphnia dubia* and the marine echinid *Strongylocentrotus purpuratus*. However, phototoxicity is not included in these data. The EC50 for daphnids in the presence of UV light was as low as nominal concentrations of 1 µg/L. The NOEC for the mollusc *Crassostrea gigas* was 0.5 µg/L, based on nominal concentrations, while the calculated EC10 was even as low as 0.22 µg/L. Because exposure concentrations of benzo[a]pyrene are not rather stable in aquatic test systems, actual concentrations might even have been lower in these systems. An assessment factor of 10 is therefore not justified in this case. Instead an assessment factor of 50 is used. Because data are available for several typical marine species, the same factor can be applied for the marine environment. The MPCeco, water and MPCeco, marine is therefore 0.010 µg/L.

Phototoxic effects are effects that are very acute of nature. Phototoxicity has been observed for algae, daphnids, fish and molluscs. A MACeco, water and a MACeco, marine are therefore useful parameters. Given the fact that the lowest observed effects are phototoxicity to larvae of molluscs, which have an EC10 based on nominal concentrations that is only 22 times as high as the MPC, the MACeco, water and the MACeco, marine can be taken equal to their respective MPC values.

The SRCeco is based on the geometric mean of the chronic data. As there are species that show effects below the lowest selected NOEC (*Crassostrea gigas*) as well as above the solubility (*Danio rerio* and *Psammechinus miliaris*), the geometric of the selected toxicity data seems a good representative of the HC50. The SRCeco is thus 0.87 µg/L.

### Sediment

No data for benthic organisms are available. Therefore, the ERLs are derived by means of equilibrium partitioning. The MPCeco, sediment and MPCeco, marine sediment are the same: 0.49 mg/kgdw, standard sed. The SRCeco, sediment is 42 mg/kgdw, standard sed.

### Soil

Many toxicity data with terrestrial species are available for benzo[a]pyrene. From several studies, it appears that benzo[a]pyrene concentrations are stable in the used test systems (Bleeker et al., 2003; Droge et al., 2006; Van Straalen and Verweij, 1991; Van Brummelen and Stuijfzand, 1993; Van Brummelen et
Because nominal concentrations are retrieved in the test systems, this improves the reliability of the data in general. Due to the low solubility of benzo[a]pyrene, pore water concentrations are possibly already saturated at concentrations well below 100 mg/kg_{dw}. Indeed, for several species no effects have been observed, while on the other hand a few NOECs are well above this level of 100 mg/kg_{dw}. For the earthworm *Eisenia andrei*, the mite *Hypoaspis aculeifer*, the springtails *Folsomia candida* and *Folsomia fimetaria*, the terrestrial plants *Avena sativa*, *Brassica rapa*, *Sinapsis alba* and *Trifolium pratense*, and the terrestrial processes respiration and dehydrogenase no effects were observed at a concentration of 69 mg/kg_{dw, standard soil} and mostly much higher. For the species and processes for which a NOEC or EC10 could be derived, the selected data are presented in Table 84.

**Table 84: Selected chronic toxicity data of benzo[a]pyrene to terrestrial species and processes**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC/EC10 [mg/kg_{standard soil}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td><em>Eisenia f. fetida</em></td>
<td>26 (^a)</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Oniscus asellus</em></td>
<td>8.1 (^b)</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Porcellio scaber</em></td>
<td>1.6</td>
</tr>
<tr>
<td>Macrophyta</td>
<td><em>Lolium perenne</em></td>
<td>307</td>
</tr>
<tr>
<td>Microbial process</td>
<td>nitrification</td>
<td>1046</td>
</tr>
</tbody>
</table>

Notes to Table 84

\(^a\) Most sensitive endpoint (cocoon production).
\(^b\) Most sensitive endpoint (fresh weight).

In one study with the pot worm *Enchytraeus crypticus* a concentration of 26 mg/kg_{dw, standard soil}, recalculated to a soil with 10% organic matter, caused 24% reduction in reproduction. This concentration is referred to as threshold concentration (Achazi et al., 1995). This concentration is probably referring to significant effects. The concentration below this threshold concentration was 2.6 mg/kg_{dw, standard soil}. The reliability of the results with *Eisenia fetida* from the same study have been classified as unassignable, because two batches of seemingly similar benzo[a]pyrene yielded different results. The values mentioned in this study with *Eisenia fetida* showed markedly more toxicity than the values in a similar, later study from the same group (Schaub and Achazi, 1996). However, in its turn these values from the latter study with *Eisenia fetida* have been reevaluated as well, because the control for benzo[a]pyrene yielded much higher reproduction values (about twice as high) than the control for fluoranthene and all low concentrations for both compounds, resulting in significant effects mentioned in the study at the lowest concentrations for benzo[a]pyrene.

Because of the large data set for benzo[a]pyrene, which covers all trophic levels and includes 14 species from 4 taxonomic groups and 3 terrestrial processes, a minimum assessment factor of 10 should be used to derive the MPC_{eco, soil}. This MPC_{eco, soil} thus becomes 0.16 mg/kg_{dw, standard soil}. With this data set the use of a species sensitivity distribution seems justified, but the method to deal with the studies resulting in no effects is not available at this moment. Because for most species effects are not observed up to the level of the aqueous solubility in pore water, the SRC_{eco, soil} is derived by equilibrium partitioning from the aqueous solubility and is 76 mg/kg_{dw, standard soil}. 
3.14 Benzo[ghi]perylene

3.14.1 Substance identification and physicochemical properties

3.14.1.1 Identity

![Figure 20: Structural formula of benzo[ghi]perylene](image)

Table 85: Identification of benzo[ghi]perylene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Benzo[ghi]perylene, 1,12-benzoperylene, benzoperylene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>1,12-benzoperylene</td>
</tr>
<tr>
<td>CAS number</td>
<td>191-24-2</td>
</tr>
<tr>
<td>EC number</td>
<td>205-883-8</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c16cccc2ccc3ccc4ccc5cccc6c5c4c3c12</td>
</tr>
</tbody>
</table>

3.14.1.2 Physicochemical properties

Table 86: Physicochemical properties of benzo[ghi]perylene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>276.33</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>0.31</td>
<td>Geometric mean of 2 values by the generator-column method</td>
</tr>
<tr>
<td>log $K_{OW}$</td>
<td>[-]</td>
<td>6.22</td>
<td>Slow-stirring method</td>
</tr>
<tr>
<td>log $K_{OC}$</td>
<td>[-]</td>
<td>6.01</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>$1.39 \times 10^{-8}$</td>
<td>Effusion method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>272.5</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>525</td>
<td></td>
</tr>
<tr>
<td>Henry’s law constant</td>
<td>[Pa.m³/mol]</td>
<td>0.034</td>
<td>Gas stripping method</td>
</tr>
</tbody>
</table>

3.14.2 Water

For algae no EC50 is presented. However, in the 72-h study with *Pseudokirchneriella subcapitata* the EC10 for growth is higher than 0.16 µg/L (Bisson et al., 2000) and hence the EC50 must also be higher than this value. The lowest acute value for immobility of *Daphnia magna* is the EC50 of 0.13 µg/L after exposure for 48 hours with a 16:8 light:dark photoperiod with visible, UV-A (320-400 nm) and UV-B (290-320 nm) with an intensities of 61, 4.4, and 0.45 µmol/m²/s. At similar intensities without the UV-B component, the EC50 was 1.04 µg/L (Lampi et al., 2006). However, in this study with *Daphnia magna* the concentrations were not verified. Besides that, the solubility of benzo[ghi]perylene is amply below 1 µg/L, while the EC50 determined without UV-B illumination is above 1 µg/L. In another study with *Daphnia magna* concentrations were verified, but the highest tested concentration was 0.2 µg/L and no toxicity was observed (Bisson et al., 2000).

For fish, no standard acute toxicity data are available. A study with larvae of *Pimephales promelas* was performed to determine the median lethal time (Oris and Giesy Jr., 1987). 7-d old larvae were exposed to a measured concentration of 0.15 µg/L benzo[ghi]perylene for an incubation period of 24 hours in the
absence of UV radiation and thereafter exposed for 96 hours to UV light with an intensity of 20 µW/cm² UV-B (290-336 nm), 95 µW/cm² UV-A (336-400 nm). After the incubation time of 24 hours, the medium was renewed every 12 hours. After 120 hours, of which the last 96 hours were with UV radiation, less than 20% mortality of the fish larvae occurred at 0.15 µg/L.

Reliable chronic toxicity studies with freshwater species are available for algae, crustaceans and fish. The 72-h EC10 for the growth rate of *Pseudokirchneriella subcapitata* (Bisson et al., 2000) and the 42-d NOEC in an ELS test with *Danio rerio* (Hooftman and Evers-de Ruiter, 1992b) were higher than 0.16 µg/L. The EC10 in a 7-d study with *Ceriodaphnia dubia* was 0.082 µg/L. In both the test with *C. dubia* and *P. subcapitata* and the test with *D. rerio* concentrations were measured. In further tests with duckweed (Huang et al., 1997a) and marine bacteria (El-Alawi et al., 2002; Loibner et al., 2004) no adverse effects were observed, but in all these studies concentrations were not verified or experimental details about solubility in test medium are missing. The only reliable study with a value that can be used for risk assessment is therefore the EC10 for *C. dubia* (Table 87).

**Table 87: Selected chronic toxicity data of benzo[ghi]perylene to freshwater species**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td><em>Ceriodaphnia dubia</em></td>
<td>0.082</td>
</tr>
</tbody>
</table>

The determination of the lethal time for *Pimephales promelas* can be considered as an acute fish study and hence the base-set can be considered as complete, although no reliable EC50 values are available, mostly due to the fact that without UV illumination benzo[ghi]perylene is not toxic up to the water solubility. Chronic toxicity data are available for algae, crustaceans and fish. Therefore, an assessment factor of 10 should be applied to derive the MPCeco, water. The lowest NOEC or EC10 is the EC10 of 0.082 µg/L for *Ceriodaphnia dubia*. The MPCeco, water for freshwater is 0.0082 µg/L. Because no studies with additional marine species are available, the MPCeco, marine is derived by applying an assessment factor of 100. The MPCeco, marine is 0.00082 µg/L. No acute EC50s have been selected due to the shortcomings of the studies described above. However, from these studies, it is clear that for daphnids acute toxic effects due to phototoxicity occur at nominal concentrations that lie in the same range as the chronic effects. The MACeco, water and the MACeco, marine can therefore be taken equal to their respective MPC values. Because of the 3 valid chronic toxicity studies, only the value for crustaceans is below the water solubility and the value for algae and fish did not result in effects up to concentrations of 0.16 µg/L, the SRCeco, water could be taken equal to this limit value to reflect the HC50.

### 3.14.3 Sediment

No data for benthic organisms are available. Therefore, the ERLs are derived by means of equilibrium partitioning. The MPCeco, sediment is 0.49 mg/kgdw, standard sed. For the marine environment, this number is a factor of 10 lower. The MPCeco, marine sediment is 0.049 mg/kgdw, standard sed. The SRCeco, sediment is 9.6 mg/kgdw, standard sed.

### 3.14.4 Soil

Only one toxicity test with terrestrial species is available for benzo[ghi]perylene (Bowmer et al., 1993). In this test with the springtail *Folsomia candida* no effects were observed on reproduction and mortality up to measured
concentrations of 180 mg/kg<sub>dw</sub> in a soil with 10% organic matter. Pore water concentrations are possibly already saturated at concentrations well below 100 mg/kg<sub>dw</sub>. At the levels used in the test increasing or decreasing the concentrations has no effect anymore on the uptake of the substance from pore water. Because there is no value that can be used for terrestrial species, the MPC has to be derived by equilibrium partitioning. A value of 0.49 mg/kg<sub>dw</sub>, standard soil is derived for the MPC<sub>eco</sub>, soil. Also the SRC<sub>eco</sub>, soil is derived by equilibrium partitioning and is 9.6 mg/kg<sub>dw</sub>, standard soil.

3.15 Dibenz[a,h]anthracene
3.15.1 Substance identification and physicochemical properties
3.15.1.1 Identity

![Figure 21: Structural formula of dibenz[a,h]anthracene](image)

Table 88. Identification of dibenz[a,h]anthracene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Dibenz[a,h]anthracene, 1,2,5,6-dibenzanthracene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>Dibenz[a,h]anthracene</td>
</tr>
<tr>
<td>CAS number</td>
<td>53-70-3</td>
</tr>
<tr>
<td>EC number</td>
<td>200-121-8</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c12ccccc1ccc3cc4c5cccccc5ccc4cc23</td>
</tr>
</tbody>
</table>

3.15.1.2 Physicochemical properties

Table 89. Physicochemical properties of dibenz[a,h]anthracene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>278.34</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>0.91</td>
<td>Geometric mean of 3 values by the shake-flask method</td>
</tr>
<tr>
<td>log K&lt;sub&gt;OW&lt;/sub&gt;</td>
<td>[-]</td>
<td>6.55</td>
<td>Average of two values determined by the shake-flask method</td>
</tr>
<tr>
<td>log K&lt;sub&gt;OC&lt;/sub&gt;</td>
<td>[-]</td>
<td>6.29</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>3.7·10&lt;sup&gt;-10&lt;/sup&gt;</td>
<td>Effusion method</td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>269.5</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td>524</td>
<td></td>
</tr>
<tr>
<td>Henry's law constant</td>
<td>[Pa m&lt;sup&gt;3&lt;/sup&gt;/mol]</td>
<td>0.035</td>
<td>Calculated from vapour pressure and solubility</td>
</tr>
</tbody>
</table>

3.15.2 Water

For algae no EC50 is presented. However, in the 72-h study with *Pseudokirchneriella subcapitata* the EC10 for growth is 0.14 µg/L (Bisson et al., 2000) and hence the EC50 must be higher than this value.

The lowest acute value for immobility of *Daphnia magna* is the EC50 of 0.55 µg/L after exposure for 48 hours with a 16:8 light:dark photoperiod with
visible, UV-A (320-400 nm) and UV-B (290-320 nm) with an intensities of 61, 4.4, and 0.45 µmol/m²/s. At similar intensities without the UV-B component, the EC50 was 1.56 µg/L (Lampi et al., 2006). An EC50 of 1.8 µg/L was observed for Daphnia magna after exposure for 24 hours with a 16:8 light:dark photoperiod, then 2 hours exposure under UV irradiation (295-365 nm; peak 340 nm) with an intensity of 370±20 µW/cm² for 2 hours, followed by 1 hour of recovery in the test medium (Wernersson, 2003). In an earlier study with similar exposure except from the fact that the recovery period was 1 hour instead of 2 hours, the EC50 was 4.6 µg/L (Wernersson and Dave, 1997). While in the first study a co-solvent was used, solutions in the latter two studies were prepared by coating the substance on the bottom of a glass vessel. However, in none of these studies with Daphnia magna the concentrations were verified. Besides that, the solubility of dibenz[a,h]anthracene is below 1 µg/L. In another study with Daphnia magna concentrations were verified, but the highest tested concentration was 0.34 µg/L and no toxicity was observed (Bisson et al., 2000).

For fish, no standard acute toxicity data are available. A study with larvae of Pimephales promelas was performed to determine the median lethal time (Oris and Giesy Jr., 1987). 7-d old larvae were exposed to a measured concentration of 0.15 µg/L dibenz[a,h]anthracene for an incubation period of 24 hours in the absence of UV radiation and thereafter exposed for 96 hours to UV light with an intensity of 20 µW/cm² UV-B (290-336 nm), 95 µW/cm² UV-A (336-400 nm). After the incubation time of 24 hours, the medium was renewed every 12 hours. After 120 hours, of which the last 96 hours were with UV radiation, no mortality of the fish larvae occurred at 0.15 µg/L.

Reliable chronic toxicity studies with freshwater species are available for crustaceans and algae. No effect was observed at concentrations up to 0.032 µg/L in a 7-d study with Ceriodaphnia dubia. The 72-h EC10 for the growth rate of Pseudokirchneriella subcapitata was 0.14 µg/L (Bisson et al., 2000). In both the test with C. dubia and P. subcapitata concentrations were measured. In further tests with duckweed (Huang et al., 1997a) and marine bacteria (El-Alawi et al., 2002; Loibner et al., 2004), algae (Boney and Corner, 1962) and annelids (Rossi and Neff, 1978) no adverse effects were observed, but in all these studies concentrations were not verified or experimental details about solubility in test medium are missing. The only reliable study with a value that can be used for risk assessment is therefore the EC10 for P. subcapitata (Table 90).

Table 90: Selected chronic toxicity data of dibenz[a,h]anthracene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Pseudokirchneriella subcapitata</td>
<td>0.14</td>
</tr>
</tbody>
</table>

The determination of the lethal time for Pimephales promelas can be considered as an acute fish study and hence the base-set can be considered as complete, although no reliable EC50 values are available, mostly due to the fact that without illumination with UV light no toxic effects were observed up to the water solubility. Chronic toxicity data are available for algae and crustaceans but not for fish. Because the concentration that was tested with Pimephales promelas at which no mortality occurred is as low as the EC10 for algae, fish might be the most sensitive species of the base-set. Further, the highest tested concentration for Ceriodaphnia dubia was four times lower than the EC10 for Pseudokirchneriella subcapitata. Therefore, an assessment factor of 100 should be applied to derive the MPCeco, water. The lowest NOEC or EC10 is the EC10 of 0.14 µg/L for growth of Pseudokirchneriella subcapitata. The MPCeco, water for...
freshwater is 0.0014 µg/L. Because no studies with additional marine species are available, the $\text{MPC}_{\text{eco, marine}}$ is derived by applying an assessment factor of 1000. The $\text{MPC}_{\text{eco, marine}}$ is 0.00014 µg/L. No acute EC50s have been selected due to the shortcomings of the studies described above. However, from these studies, it is clear that for daphnids acute toxic effects due to phototoxicity occur at nominal concentrations that lie in the same range as the chronic effects for algae. However, because phototoxicity is a very sensitive acute effect, assessment factors of 100 and 1000 seem not justified for the $\text{MAC}_{\text{eco, water}}$ and the $\text{MAC}_{\text{eco, marine}}$. Instead, the $\text{MAC}_{\text{eco, water}}$ and the $\text{MAC}_{\text{eco, marine}}$ can therefore be taken equal to their respective MPC values multiplied by a factor of 10, i.e. 0.014 µg/L and 0.0014 µg/L, respectively. The value of the $\text{SRC}_{\text{eco, water}}$ could be taken equal to the only available NOEC of 0.14 µg/L, because no information is available for fish and the EC10 for daphnids could be higher than this NOEC but a factor of 4 lower as well.

3.15.3 Sediment
No data for benthic organisms are available. Therefore, the ERLs are derived by means of equilibrium partitioning. The $\text{MPC}_{\text{eco, sediment}}$ is 0.18 mg/kgdw, standard sed. For the marine environment, this number is a factor of 10 lower. The $\text{MPC}_{\text{eco, marine sediment}}$ is 0.018 mg/kgdw, standard sed. The $\text{SRC}_{\text{eco, sediment}}$ is 18 mg/kgdw, standard sed.

3.15.4 Soil
Only one toxicity test with terrestrial species is available for dibenz[a,h]anthracene (Sverdrup et al., 2002). In this test with the springtail Folsomia fimetaria no effects were observed on reproduction and mortality up to measured concentrations of 2870 mg/kgdw normalized to standard soil with 10% organic matter. Pore water concentrations are possibly already saturated at about 100 mg/kgdw. At the levels used in the test increasing or decreasing the concentrations has no effect anymore on the uptake of the substance from pore water. Because there is no value that can be used for terrestrial species, the MPC has to be derived by equilibrium partitioning. The resulting $\text{MPC}_{\text{eco, soil}}$ is 0.18 mg/kgdw, standard soil is derived. Also the $\text{SRC}_{\text{eco, soil}}$ is derived by equilibrium partitioning and is 18 mg/kgdw, standard soil.

3.16 Indeno[1,2,3-cd]pyrene
3.16.1 Substance identification and physicochemical properties
3.16.1.1 Identity

Figure 22: Structural formula of indeno[1,2,3-cd]pyrene
Table 91: Identification of indeno[1,2,3-cd]pyrene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common/trivial/other name</td>
<td>Indeno[1,2,3-cd]pyrene, 2,3-o-phenylenepyrene</td>
</tr>
<tr>
<td>Chemical name</td>
<td>Indeno[1,2,3-cd]pyrene</td>
</tr>
<tr>
<td>CAS number</td>
<td>193-39-5</td>
</tr>
<tr>
<td>EC number</td>
<td>205-893-2</td>
</tr>
<tr>
<td>SMILES code</td>
<td>c1ccc2c(c1)c3ccc4ccc5ccc6cc2c3c4c56</td>
</tr>
</tbody>
</table>

3.16.1.2 Physicochemical properties

Table 92: Physicochemical properties of indeno[1,2,3-cd]pyrene

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>[g/mol]</td>
<td>276.33</td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>[µg/L]</td>
<td>0.19</td>
<td>Generator-column method</td>
</tr>
<tr>
<td>log $K_{OW}$</td>
<td>[-]</td>
<td>6.584</td>
<td>Calculated ClogP</td>
</tr>
<tr>
<td>log $K_{OC}$</td>
<td>[-]</td>
<td>6.374</td>
<td>QSAR</td>
</tr>
<tr>
<td>Vapour pressure</td>
<td>[Pa]</td>
<td>1.0·10^-8</td>
<td></td>
</tr>
<tr>
<td>Melting point</td>
<td>[°C]</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>Boiling point</td>
<td>[°C]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Henry's law constant</td>
<td>[Pa·m^3/mol]</td>
<td>0.035</td>
<td>Gas stripping method</td>
</tr>
</tbody>
</table>

3.16.2 Water

Very few data are available for indeno[1,2,3-cd]pyrene. In the acute toxicity study 48-h with *Daphnia magna*, concentrations were measured (Bisson et al., 2000). No toxicity was observed but the test range was up to 357 µg/L, which is far above the solubility limit. In a study with the luminescent marine bacterium *Vibrio fischeri* no inhibition of the bioluminescence was observed up to the level of the water solubility. However, the solubility was not reported (Loibner et al., 2004). Two chronic studies are available in which the aqueous concentrations were measured (Bisson et al., 2000). These values are presented in Table 93.

Table 93: Selected chronic toxicity data of indeno[1,2,3-cd]pyrene to freshwater species

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>NOEC or EC10 [µg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td><em>Pseudokirchneriella subcapitata</em></td>
<td>1.5</td>
</tr>
<tr>
<td>Crustacea</td>
<td><em>Ceriodaphnia dubia</em></td>
<td>0.27</td>
</tr>
</tbody>
</table>

The base-set is not complete for indeno[1,2,3-cd]pyrene. However, due to the hydrophobicity acute toxic effects are not expected to occur. With the EC10 for reproduction of *Ceriodaphnia dubia* and growth rate of *Pseudokirchneriella subcapitata* 2 sensitive endpoints are covered that are among the lowest effect concentrations for 6 other PAHs. Therefore, an assessment factor of 100 is applied to the lowest EC10, despite the fact that the base-set is not complete. The resulting MPCeco,water is 0.0027 µg/L.

No suitable chronic toxicity data are available for marine species. The assessment factor for marine water is 1000 in this case. The MPCeco,marine is 0.00027 µg/L. Because of the absence of acute toxicity, a MACeco,water can not be derived. The SRCeco,water is equal to the geometric mean of the two chronic data and is 0.64 µg/L.

3.16.3 Sediment

No data for benthic organisms are available. Therefore, the ERLs are derived by means of equilibrium partitioning. The MPCeco, sediment is 0.38 mg/kgdw, standard sed.
For the marine environment, this number is a factor of 10 lower. The MPC_{eco, marine sediment} is 0.038 mg/kg_{dw, standard sed}. The SRC_{eco, sediment} is 89 mg/kg_{dw, standard sed}.

3.16.4 Soil

Only one toxicity test with terrestrial species is available for indeno[1,2,3-cd]pyrene (Sverdrup et al., 2002). In this test with the springtail *Folsomia fimetaria* no effects were observed on reproduction and mortality up to measured concentrations of 3350 mg/kg_{dw, normalized to standard soil with 10% organic matter}. Pore water concentrations are possibly already saturated below 100 mg/kg_{dw}. At the levels used in the test increasing or decreasing the concentrations has no effect anymore on the uptake of the substance from pore water. Because this value can not be used, the MPC for terrestrial species has to be derived by equilibrium partitioning. For the MPC_{eco, soil} a value of 0.38 mg/kg_{dw, standard soil} is derived. Also the SRC_{eco, soil} is derived by equilibrium partitioning and is 89 mg/kg_{dw, standard soil}. 


Summary and analysis of data

4.1 Overview of derived risk limits
An overview of the derived risk limits is given in Table 94.

For comparison, the formerly derived ecotoxicological MPC values (Kalf et al., 1995) are shown in Table 95. It can be concluded that the new values for the MPC are generally lower than the formerly derived values (Kalf et al., 1995), especially for the higher PAHs. It has to be noted that for several of the higher PAHs the ecotoxicological values were derived from QSAR calculations without a further assessment factor. In the revision of the first tranche Intervention Values, new MPC values were derived on the basis of the same data as well (Verbruggen et al., 2001). For the values that were derived from QSARs (chrysene, benzo[ghi]perylene, and indeno[1,2,3-cd]pyrene) an additional assessment factor of 10 was applied. For several of the other substances a higher assessment factor was applied, in accordance with the methodology that has been followed since that time as documented in the Technical Guidance Document (European Commission, 2003) and the guidance for the Water Framework Directive (Lepper, 2005). These lower values are generally lower than the values derived in the current evaluation, which are based on more data with mostly a lower assessment factor.

For almost all PAHs the values for soil and sediment were solely based on the equilibrium partitioning method. In the current evaluation more and more reliable data for these higher PAHs were available and QSARs were not applied anymore. Many reliable studies for benthic and especially terrestrial species have been found, which made it possible to base the ERLs for soil and sediment on direct toxicity instead of equilibrium partitioning.

In Table 96, a comparison of the new SRC_{eco} values with the formerly derived ecotoxicological and human toxicological SRC values (Lijzen et al., 2001) is made. A comparison of the SRC values shows that the newly derived ecotoxicological values are generally somewhat higher than the ecotoxicological values derived in the revision of the first tranche Intervention Values (Verbruggen et al., 2001; Lijzen et al., 2001). However, the ecotoxicological values are especially for the lower PAHs much lower than the human toxicological values (Lijzen et al., 2001), while these values are in the same order of magnitude for the higher PAHs.

The derived values can also be compared with the Environmental Quality Standards that are set under the Water Framework Directive for priority substances under Directive 2008/105/EC. This comparison is shown in Table 97. Although the number of data included in the derivation is generally lower, the Environmental Quality Standards from the Water Framework Directive are mostly higher than the values derived in this report. This is remarkable for several reasons. First, in most cases the lowest assessment factors have been used in this report for the MAC_{eco} values. This means that the lowest reliable values have not been considered in the derivation of the quality standards for the Water Framework Directive. For fluoranthene, it should be noted that the MAC_{eco, water} is at the level of the HC5 for acute data derived in this report (L(E)C50 data and no NOECs or EC10s). The extra assessment factor for the marine environment is applied in this report, because no reliable data for additional marine taxonomic groups were available for the higher PAHs. These
data were not available for the derivation of the quality standards under the WFD as well, but still the same assessment factor has been applied as for freshwater. Further, it is remarkable that Directive 2008/105/EC clearly states that each individual EQS is applicable, which means that the toxic unit approach should not be applied, which differs from the proposed values in this report, because concentration addition should be considered to apply to the mixture of PAHs.
Table 94: Overview of the derived risk limits for each PAH individually. Concentrations in water are in µg/L, concentrations in soil and sediment in mg/kg dw standard soil/sed containing 10% organic matter.

<table>
<thead>
<tr>
<th>Compound</th>
<th>MAC_{eco, water}</th>
<th>MAC_{eco, marine}</th>
<th>MAC_{eco, water}</th>
<th>MAC_{eco, marine}</th>
<th>SRC_{eco, water}</th>
<th>SRC_{eco, marine}</th>
<th>SRC_{eco, water}</th>
<th>SRC_{eco, marine}</th>
<th>SRC_{eco, water}</th>
<th>MAC_{eco, soil}</th>
<th>SRC_{eco, soil}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>130</td>
<td>130</td>
<td>2.0</td>
<td>2.0</td>
<td>518</td>
<td>0.16</td>
<td>0.16</td>
<td>42</td>
<td>0.69</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>33</td>
<td>3.3</td>
<td>1.3</td>
<td>0.13</td>
<td>72</td>
<td>0.17</td>
<td>0.017</td>
<td>9.5</td>
<td>0.17</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>3.8</td>
<td>0.76</td>
<td>3.8</td>
<td>0.38</td>
<td>102</td>
<td>0.97</td>
<td>0.10</td>
<td>31</td>
<td>0.68</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Fluorene</td>
<td>34</td>
<td>6.8</td>
<td>1.5</td>
<td>0.30</td>
<td>117</td>
<td>0.83</td>
<td>0.17</td>
<td>64</td>
<td>1.6</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>6.7</td>
<td>6.7</td>
<td>1.1</td>
<td>1.1</td>
<td>43</td>
<td>0.78</td>
<td>0.78</td>
<td>63</td>
<td>3.6</td>
<td>90</td>
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</tr>
<tr>
<td>Anthracene</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>4.2</td>
<td>0.047</td>
<td>0.0047</td>
<td>3.2</td>
<td>0.34</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Pyrene</td>
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<td>0.023</td>
<td>0.023</td>
<td>0.023</td>
<td>4.2</td>
<td>1.67</td>
<td>0.84</td>
<td>136</td>
<td>1.8</td>
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</tr>
<tr>
<td>Fluoranthene</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>12</td>
<td>4.11</td>
<td>4.11</td>
<td>96</td>
<td>4.8</td>
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<tr>
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<td>0.0070</td>
<td>0.070</td>
<td>0.0070</td>
<td>1.6</td>
<td>1.64</td>
<td>0.16</td>
<td>38</td>
<td>1.6</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Benz[a]anthracene</td>
<td>0.10</td>
<td>0.010</td>
<td>0.012</td>
<td>0.0012</td>
<td>3.1</td>
<td>0.35</td>
<td>0.04</td>
<td>91</td>
<td>0.19</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
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<td>0.017</td>
<td>0.93</td>
<td>0.79</td>
<td>0.79</td>
<td>0.44</td>
<td>0.79</td>
<td>44</td>
<td>0.79</td>
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</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td>0.017</td>
<td>0.017</td>
<td>1.3</td>
<td>0.79</td>
<td>0.79</td>
<td>0.44</td>
<td>0.79</td>
<td>62</td>
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<tr>
<td>Benzo[a]pyrene</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
<td>0.010</td>
<td>0.87</td>
<td>0.49</td>
<td>0.49</td>
<td>42</td>
<td>0.16</td>
<td>76</td>
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<tr>
<td>Benzo[gh]perylenede</td>
<td>0.0082</td>
<td>0.00082</td>
<td>0.0082</td>
<td>0.00082</td>
<td>0.16</td>
<td>0.49</td>
<td>0.49</td>
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<td>0.49</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Dibenzo[a,h]anthracene</td>
<td>0.014</td>
<td>0.0014</td>
<td>0.0014</td>
<td>0.00014</td>
<td>0.14</td>
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<td>0.018</td>
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<td>0.18</td>
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</tr>
<tr>
<td>Indeno[1,2,3-cd]pyrene</td>
<td>0.0027</td>
<td>0.00027</td>
<td>0.64</td>
<td>0.38</td>
<td>0.038</td>
<td>89</td>
<td>0.38</td>
<td>89</td>
<td>0.38</td>
<td>89</td>
<td></td>
</tr>
</tbody>
</table>
Table 95: Comparison of the formerly derived MPCs for PAHs with the values derived in this report. Concentrations in water are in µg/L, concentrations in soil and sediment in mg/kg dw standard soil/sed containing 10% organic matter

<table>
<thead>
<tr>
<th>Reference</th>
<th>MPC&lt;sub&gt;eco&lt;/sub&gt;, water</th>
<th>MPC&lt;sub&gt;eco&lt;/sub&gt;, water</th>
<th>MPC&lt;sub&gt;eco&lt;/sub&gt;, water</th>
<th>MPC&lt;sub&gt;eco&lt;/sub&gt;, sediment</th>
<th>MPC&lt;sub&gt;eco&lt;/sub&gt;, sediment</th>
<th>MPC&lt;sub&gt;eco&lt;/sub&gt;, sediment</th>
<th>MPC&lt;sub&gt;eco&lt;/sub&gt;, soil</th>
<th>MPC&lt;sub&gt;eco&lt;/sub&gt;, soil</th>
<th>MPC&lt;sub&gt;eco&lt;/sub&gt;, soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>2.0</td>
<td>2.1</td>
<td>1.2</td>
<td>0.16</td>
<td>0.12</td>
<td>0.14</td>
<td>0.69</td>
<td>0.12</td>
<td>0.14</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>1.3</td>
<td></td>
<td></td>
<td>0.17</td>
<td></td>
<td></td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>3.8</td>
<td></td>
<td></td>
<td>0.97</td>
<td></td>
<td></td>
<td>0.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluorene</td>
<td>1.5</td>
<td></td>
<td></td>
<td>0.83</td>
<td></td>
<td></td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>1.1</td>
<td>3.2</td>
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<td>0.78</td>
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<td>3.6</td>
<td>3.3</td>
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</tr>
<tr>
<td>Anthracene</td>
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<td>0.07</td>
<td>0.05</td>
<td>0.039</td>
<td>0.12</td>
<td>0.34</td>
<td>0.039</td>
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</tr>
<tr>
<td>Pyrene</td>
<td>0.023</td>
<td></td>
<td></td>
<td>1.67</td>
<td></td>
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<td>1.8</td>
<td></td>
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</tr>
<tr>
<td>Fluoranthene</td>
<td>0.12</td>
<td>0.12</td>
<td>0.30</td>
<td>4.11</td>
<td>1.0</td>
<td>2.6</td>
<td>4.8</td>
<td>1.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Chrysene</td>
<td>0.070</td>
<td>0.28</td>
<td>0.34</td>
<td>1.64</td>
<td>8.1</td>
<td>10.7</td>
<td>1.6</td>
<td>8.1</td>
<td>10.7</td>
</tr>
<tr>
<td>Benzo[a]anthracene</td>
<td>0.012</td>
<td>0.010</td>
<td>0.01</td>
<td>0.35</td>
<td>0.025</td>
<td>0.36</td>
<td>0.19</td>
<td>0.49</td>
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</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
<td>0.017</td>
<td>0.0036</td>
<td>0.04</td>
<td>0.79</td>
<td>0.38</td>
<td>2.4</td>
<td>0.79</td>
<td>0.38</td>
<td>2.4</td>
</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td>0.017</td>
<td></td>
<td></td>
<td>0.79</td>
<td></td>
<td></td>
<td>0.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>0.010</td>
<td>0.0050</td>
<td>0.05</td>
<td>0.49</td>
<td>0.052</td>
<td>2.7</td>
<td>0.16</td>
<td>0.19</td>
<td>0.26</td>
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<td>Benzo[ghi]perylenne</td>
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<td>0.0031</td>
<td>0.03</td>
<td>0.49</td>
<td>0.57</td>
<td>7.5</td>
<td>0.49</td>
<td>0.57</td>
<td>7.5</td>
</tr>
<tr>
<td>Dibenz[a,h]anthracene</td>
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<td></td>
<td></td>
<td>0.18</td>
<td></td>
<td></td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indeno[1,2,3-cd]pyrene</td>
<td>0.0027</td>
<td>0.00061</td>
<td>0.04</td>
<td>0.38</td>
<td>0.031</td>
<td>5.9</td>
<td>0.38</td>
<td>0.031</td>
<td>5.9</td>
</tr>
</tbody>
</table>

a This report.
b Verbruggen (2001).
Table 96: Comparison of the formerly derived SRCs for PAHs with the values derived in this report. Concentrations in water are in µg/L, concentrations in soil and sediment in mg/kg dw standard soil/sed containing 10% organic matter

<table>
<thead>
<tr>
<th>SRC</th>
<th>$SRC_{eco, water}$</th>
<th>$SRC_{eco, water}$</th>
<th>$SRC_{human, gw}$</th>
<th>$C_{max\ in\ drinking\ water}$</th>
<th>$SRC_{eco, sediment}$</th>
<th>$SRC_{eco, sediment}$</th>
<th>$SRC_{human, sediment}$</th>
<th>$SRC_{eco, soil}$</th>
<th>$SRC_{eco, soil}$</th>
<th>$SRC_{human, soil}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>a</td>
<td>b</td>
<td>c</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>518</td>
<td>290</td>
<td>15,600</td>
<td>1260</td>
<td>42</td>
<td>17</td>
<td>120</td>
<td>14</td>
<td>17</td>
<td>870</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>72</td>
<td>4010</td>
<td>1570</td>
<td>9.5</td>
<td>170</td>
<td>9.4</td>
<td>26,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>102</td>
<td>2570</td>
<td>15,700</td>
<td>31</td>
<td>47,000</td>
<td>31</td>
<td>&gt;100,000</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Fluorene</td>
<td>117</td>
<td>1320</td>
<td>1260</td>
<td>64</td>
<td>210</td>
<td>82</td>
<td>23,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>43</td>
<td>30</td>
<td>850</td>
<td>1260</td>
<td>63</td>
<td>31</td>
<td>440</td>
<td>90</td>
<td>31</td>
<td>23,000</td>
</tr>
<tr>
<td>Anthracene</td>
<td>4.2</td>
<td>1.4</td>
<td>71</td>
<td>1260</td>
<td>3</td>
<td>1.6</td>
<td>4200</td>
<td>60</td>
<td>1.6</td>
<td>25,500</td>
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<tr>
<td>Pyrene</td>
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<td>106</td>
<td>15,700</td>
<td>136</td>
<td>60,000</td>
<td>53</td>
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<td></td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>11</td>
<td>30</td>
<td>201</td>
<td>1570</td>
<td>96</td>
<td>260</td>
<td>1600</td>
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<td>35</td>
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<td>38</td>
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</tr>
<tr>
<td>Benz[a]anthracene</td>
<td>3.1</td>
<td>1.0</td>
<td>12</td>
<td>157</td>
<td>91</td>
<td>49</td>
<td>290</td>
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</tr>
<tr>
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<td>44</td>
<td>38</td>
<td>560</td>
<td>44</td>
<td>38</td>
<td>3200</td>
</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td>1.3</td>
<td></td>
<td>17</td>
<td>157</td>
<td>62</td>
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<td>0.84</td>
<td>16</td>
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<tr>
<td>Benzo[ghi]perylene</td>
<td>0.16</td>
<td>0.18</td>
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<td>942</td>
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<td>18</td>
<td>70</td>
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<tr>
<td>Indeno[1,2,3-cd]pyrene</td>
<td>0.64</td>
<td>0.036</td>
<td>0.26</td>
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<td>89</td>
<td>1.9</td>
<td>580</td>
<td>89</td>
<td>1.9</td>
<td>3200</td>
</tr>
</tbody>
</table>

a This report.
b Formerly derived ecotoxicological values (Verbruggen et al., 2001).
c Risk value used for deriving serious soil and groundwater contamination (Lijzen et al., 2001).
d Direct consumption of groundwater as drinking water for the derivation of the overall SRC$_{gw}$, recalculated values are slightly different from earlier reported values (Lijzen et al., 2001).
Table 97: Comparison of the Environmental Quality Standards for PAHs under the Water Framework Directive (2008/105/EC) with the values derived in this report. Concentrations in water are in µg/L

<table>
<thead>
<tr>
<th>ERL</th>
<th>MAC&lt;sub&gt;eco, water&lt;/sub&gt;</th>
<th>MAC&lt;sub&gt;eco, water&lt;/sub&gt;</th>
<th>MAC&lt;sub&gt;eco, marine&lt;/sub&gt;</th>
<th>MAC&lt;sub&gt;eco, marine&lt;/sub&gt;</th>
<th>MPC&lt;sub&gt;eco, water&lt;/sub&gt;</th>
<th>MPC&lt;sub&gt;eco, water&lt;/sub&gt;</th>
<th>MPC&lt;sub&gt;eco, marine&lt;/sub&gt;</th>
<th>MPC&lt;sub&gt;eco, marine&lt;/sub&gt;</th>
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</thead>
<tbody>
<tr>
<td>Reference</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>Naphthalene</td>
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<td>n.a.</td>
<td>130</td>
<td>n.a.</td>
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<td>2.4</td>
<td>2.0</td>
<td>1.2</td>
</tr>
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<td>Acenaphthylene</td>
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<td>3.3</td>
<td>1.3</td>
<td>0.13</td>
<td></td>
<td></td>
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<tr>
<td>Acenaphthene</td>
<td>3.8</td>
<td>0.76</td>
<td>3.8</td>
<td>0.38</td>
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<td></td>
<td></td>
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<tr>
<td>Fluorene</td>
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<td>1.5</td>
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<td>0.023</td>
<td>0.023</td>
<td>0.023</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Fluoranthene</td>
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<tr>
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<td>0.0012</td>
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<tr>
<td>Benzo[k]fluoranthene</td>
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<td></td>
<td>0.017</td>
<td>0.03</td>
<td>0.017</td>
<td>0.03</td>
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</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td></td>
<td></td>
<td>0.017</td>
<td>0.03</td>
<td>0.017</td>
<td>0.03</td>
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<td></td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
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<td>0.1</td>
<td>0.05</td>
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<tr>
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<td>0.00082</td>
<td>0.0082</td>
<td>0.00082</td>
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<td>0.0014</td>
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<td>0.002</td>
<td>0.00027</td>
<td>0.0002</td>
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<sup>a</sup> This report.
<sup>b</sup> WFD (2008/105/EC).
4.2 Environmental risk limits on the basis of internal lipid residues

The derived risk limits appear to be rather different from each other. However, a closer look at the data shows that the difference is largely explained by the differences in hydrophobicity if the risk limits for water are considered, while the risk limits for soil and sediment are more or less constant at least for the SRCeco, soil and SRCeco, sediment. This is more prominent, when instead of the risk limits the individual selected data are considered. In Figure 23 all selected acute toxicity data for both freshwater and marine species are presented as a function of the log $K_{ow}$ of each PAH. Although there is a trend with log $K_{ow}$ it appears that the most phototoxic PAHs (anthracene, pyrene, and fluoranthene in the middle of the figure) lead to very low values in comparison with the other PAHs.

A clearer picture is created if the chronic toxicity data are considered. These data are presented in Figure 24. It appears that the toxicity, expressed as a band width of species sensitivity, increases with increasing hydrophobicity. This reflects the increasing bioconcentration of PAHs with increasing hydrophobicity, at least in invertebrates and young fish that do mostly not metabolize PAHs to a significant content.

When soil and sediment are considered, not only bioaccumulation into terrestrial and benthic organisms exposed via the pore water phase is hydrophobicity dependent, but the sorption to organic matter in the soil and sediment as well. This results in more or less constant toxicity with increasing hydrophobicity. Indeed this is observed. No clear relationship of the toxicity with hydrophobicity is found for both terrestrial species (Figure 25) and benthic species (Figure 26).

![Figure 23: Acute toxicity of PAHs to freshwater and marine aquatic species as a function of hydrophobicity](image-url)
Figure 24: Chronic toxicity of PAHs to freshwater and marine aquatic species as a function of hydrophobicity.

Figure 25: Chronic toxicity of PAHs to terrestrial species as a function of hydrophobicity.
Figure 26: Chronic toxicity of PAHs to benthic species as a function of hydrophobicity

Because of this evidence of the mainly equilibrium partitioning driven toxicity of PAHs, it could be considered to follow a similar approach for PAHs as has been developed for total petroleum hydrocarbons (TPH) (Verbruggen et al., 2008). Several assumptions are evaluated again for PAHs, because they form the basis for successfully applying the internal body burden approach. The first assumption is that toxic effects are directly related to the internal residue of the substance. If the parent substance is extensively metabolized in the organisms, this assumption could be erroneous. Photoinduced toxicity is a mode of toxic action that is not caused by the parent compound but by a photoactivated reaction product. However, for phototoxicity it has been shown that this process is dependent on the amount of the parent substance that has been accumulated by the organisms. The difference with metabolism is that metabolism is caused by metabolic processes within the body of the organisms themselves, while for photoactivation the process takes place in the organisms but is induced by ultraviolet radiation applied from outside the body. Especially for vertebrates it has been shown that metabolized PAHs are mutagenic and carcinogenic and thus causing toxicity. In such a case, not the residue of the parent substance in the organism but the throughput of the parent substance to the toxic metabolite would be of importance. The selected toxicity data are from studies with either invertebrates, which mostly lack the capability to metabolize PAHs, or with early life stages of fish and amphibians. For early life stages of fish, it appeared that metabolism is very limited (Petersen and Kristensen, 1998). Because most ecotoxicity studies are performed with early life stages, which lack the metabolic capacity of older organisms, it is assumed that metabolism generally plays only a minor role in the selected toxicity data. Nevertheless, for the amphipod *Hyalella azteca* it was shown that PAHs were substantially metabolized, especially naphthalene (Lee et al., 2002b). Moreover, toxicity could not simply be attributed to the accumulated amount of PAH in the amphipods (as would be so for narcosis), because lethal concentrations still decreased in time, when the bioaccumulation process had already reached an equilibrium. To describe time-dependent toxicity more complex models than the
critical body residue approach for narcotic substances were developed. Examples of these models are the damage assessment model (DAM) from Lee et al. (2002a) or the threshold damage model (TDM) from Ashauer et al. (2007). These models take account of both toxicokinetics (uptake and depuration) and toxicodynamics (damage and repair). However, damage is related to the accumulated amount, and the parameters to describe the toxicodynamics are relatively constant for the selected PAHs (Lee et al., 2002a). As a result, the incipient (i.e. chronic) effect concentrations are still linearly related to the accumulated amount of the substance.

Further, it can be reasoned (Lee and Landrum, 2006; Ashauer et al., 2007) that the concept of damage addition is equivalent to concentration addition, if it is assumed that in the toxicokinetics and toxicodynamics no interaction occurs between the compounds. Therefore, the concept of concentration addition still applies and the toxic unit approach can be used. This is an important observation, because the mode of toxic action could be different and independent action would be assumed to apply instead of concentration addition.

A second assumption is that the accumulation behaviour from the aqueous phase to both organic matter of soil and sediment as well as to biological membranes that are considered the target for narcosis, is hydrophobicity dependent. For sorption to organic matter this has been evaluated before (European Commission, 2008; Verbruggen et al., 2008). For bioconcentration into lipids this is generally true if the relationship between bioconcentration and hydrophobicity is not confounded by metabolism. Despite the metabolism of naphthalene in *Hyalella azteca*, it appeared that the bioconcentration factor of the parent compound was not necessarily lower compared to that what was expected based on the hydrophobicity of the substance. Moreover, there still is a perfect relationship between the LC50 based on external water concentrations and the log $K_{ow}$, which implies that toxicity is mainly hydrophobicity dependent (Lee et al., 2002b). It appears that there is a good correlation between bioconcentration and hydrophobicity for e.g. *Daphnia magna* (Newsted and Giesy, 1987) and fish early life stages (zebrafish larvae) (Petersen and Kristensen, 1998). In both cases the slope of this equation is slightly less than unity (0.87 and 0.92, respectively), similar to what was assumed for the derivation of the environmental risk limits for total petroleum hydrocarbons (Verbruggen et al., 2008). The values used within this reference were based on partitioning to artificial membranes (Verbruggen et al., 2000) as well as on estimations from QSAR modeling (Di Toro et al., 2000).

Consequently, the used methodology as well as the equations from the derivation of the ERLs for total petroleum hydrocarbons (Verbruggen et al., 2008) can be adopted to derive environmental risk limits for the PAHs. For this goal, all individual chronic toxicity data were recalculated to internal lipid residues. Residues were expressed on a molar basis. For aquatic toxicity, internal residues were calculated directly by multiplying with the membrane water partition coefficient. For soil and sediment, data were first transferred to pore water concentrations by dividing by the partition coefficient, after which the internal residues were derived in the same way. If for one species data were available for several PAHs, the geometric mean of the internal residues was used.

The membrane water partition coefficients were estimated from a polynomial fit (Verbruggen et al., 2008). Earlier work for TPH used a straight line up to a log $K_{ow}$ of 5.5, based on a QSAR approach (Di Toro et al., 2000), for which recently a slightly revised equation ($\log K_{m}=0.936*\log K_{ow}$) was presented (McGrath and Di Toro, 2009). However, the assumption that the intercept in this equation is 0, is not necessarily true. For artificial membrane-water partition...
coefficients, that underlie the polynomial fit, an almost equal slope of 0.92±0.05, but a different intercept of 0.33±0.14 was found (Verbruggen et al., 2000). It appears that the experimental values for critical body burdens, after application of chemical class corrections (Di Toro et al., 2000), correspond much better with the derived critical target lipid body burdens (CTLBBs) if this intercept is taken into account. For this reason, only the polynomial fit on the experimentally determined membrane-water partition coefficients was used. However, differences in the final results are very small.

Next to the method described above, a similar exercise as was performed by Di Toro et al. (2000) can be made with the selected chronic toxicity data. In this case, the chronic toxicity data are expressed as concentrations in water as well, similar to the methodology described above. The concentrations are then plotted on a molar basis as a function of \( \log K_{ow} \). A linear regression analysis is made in which the intercept is calculated for each species individually, but the slope of the regression is shared over all species.

Reliable chronic toxicity data (no observed effect residue – NOER or 10% effective residue – ER10) were available for 34 aquatic species, containing 3 algae, 2 amphibians, 1 tunicate, 8 crustaceans, 4 echinoderms, 3 insects, 1 aquatic plant, 1 mollusc, and 10 fish species. For bentic species there were reliable chronic toxicity data for 10 species, containing 2 freshwater and 1 marine annelid, 1 freshwater and 4 marine crustaceans, and 2 freshwater insects. The freshwater species were both tested in water only exposure and a water-sediment system. The internal residue for these species was based on both types of tests by calculating the pore water concentration from the sediment concentrations. For terrestrial species, reliable chronic toxicity data were available for 13 species, containing 5 annelids, 2 crustaceans, 3 insects, and 3 terrestrial plants. In total the data set for freshwater, marine water, freshwater sediment, marine sediment, and soil contains 54 species (Table 98). The results of both methods (i.e. Verbruggen et al., 2008; Di Toro et al., 2000) are discussed below. The methods result in a set of 54 internal residues for different species. Although the spread in data for the different PAHs can be considerable, this is assumed to be random variation. Based on the calculations with membrane-water partition coefficients, the internal residues for *Pseudokrichneriella subcapitata*, for example, range from 0.29 to 61 mmol/kg\textsubscript{lipid}. Fluorene has the highest internal residue, but is not necessarily an outlier if it is assumed that the data are log-normal distributed (which underlies the use of the geometric mean instead of the average for multiple data). Nevertheless, the NOERs for the rest of the 11 PAHs for which data are available range from 0.29 for anthracene to 3.7 mmol/kg\textsubscript{lipid} for fluoranthene. For *Ceriodaphnia dubia* a similar situation is observed. The lowest value is 0.12 mmol/kg\textsubscript{lipid} for benzo[gh]perylene and the highest value 7.5 mmol/kg\textsubscript{lipid} for naphthalene. The NOERs for the rest of the 10 PAHs range from 0.51 mmol/kg\textsubscript{lipid} for fluoranthene to 1.9 mmol/kg\textsubscript{lipid} for acenaphthene. For *Hyalella azteca* the lowest value observed of 0.48 mmol/kg\textsubscript{lipid} can be explained by the specific phototoxicity of fluoranthene in combination with the experimental lighting conditions applied in the water-only test. It should be noted that the same species and compound tested in a water-sediment system resulted in a calculated NOER of 5.8 mmol/kg\textsubscript{lipid}. However, for many species the spread in NOER is less than a factor of 10. Therefore, taking the geometric mean of the internal residues seems to be justified, as no apparent differences were observed. In Table 98 the log of the NOER data is presented for all species, including the average, standard deviation, minimum, maximum, and the number of data.
With the method of Di Toro et al. (2000), a regression is made of all chronic toxicity data on a molar basis as a function of log $K_{ow}$, including the terrestrial and benthic toxicity data that were first expressed as pore water concentration. The general slope of the data is $-1.024 \pm 0.06112$ (95% confidence intervals -1.146 to -0.9027). With only the aquatic toxicity data a similar result is obtained $(-1.030 \pm 0.08100$ with 95% confidence intervals -1.193 to -0.8676). This slope is considerably steeper than the original value of -0.945 from the target lipid model (Di Toro et al., 2000) or the updated version of -0.936±0.015 (McGrath and Di Toro, 2009).

The bioaccumulation studies with daphnids and fish early life-stages show a slope that is much more similar to this universal slope of 0.936 for narcosis than to the value of 1.024 obtained by the latter method, which is similar but considers only chronic toxicity of PAHs instead of acute values. Therefore, further analysis has been performed with the values obtained from the membrane-water partitioning coefficients based on experimental values for $K_m$, which show a similar slope as the universal slope for narcosis and the BCF values for PAHs in daphnids and fish early-life stages. By applying the steeper shared slope of 1.024 risk limits for smaller PAHs would be higher, while those for 5- to 6-ring PAHs would be lower.

The dataset meets the criteria for goodness of fit at all significance levels for the Anderson-Darling, Kolmogorov-Smirnov, and Cramer von Mises tests, calculated with the computer program ETX (Van Vlaardingen et al., 2004). It appears that there is no significant difference in the both the variance (F-test) and the mean (t-test) between any of the compartments or subsets (e.g. water vs. sediment, water vs. soil, sediment vs. soil, or fresh vs. marine). This is another argument to combine all data into one species sensitivity distribution. The species sensitivity distribution is shown in Figure 27. The HC5 of this distribution is 0.39 mmol/Llipid (90% CI: 0.22-0.63 mmol/Llipid), and the HC50 is 4.7 mmol/Llipid (90% CI: 3.3-6.6 mmol/Llipid).

These values for the HC5 and HC50 are very comparable to the values earlier derived for TPH based on the results of toxicity tests with 6 benthic species in sediment freshly spiked with 2 types of oil (Verbruggen et al., 2008). For TPH, an HC5 of 0.41 mmol/Llipid (90% CI: 0.01-1.88 mmol/Llipid) and HC50 of 8.7 mmol/Llipid (90% CI: 2.1–36.5 mmol/Llipid) were derived. The values for PAHs are only slightly lower than the values for TPH. This is similar to what was observed for acute toxicity of PAHs compared to other substances that are assumed to act by narcosis. The effect concentrations of PAHs were estimated to be 0.546 times lower than the general values for baseline toxicity (Di Toro et al., 2000). With application of this factor, the values for PAHs derived from the HC5 and HC50 of TPH would become 0.22 and 4.7 mmol/Llipid. Together with the rather steep slope of the species sensitivity distribution (i.e. relatively low interspecies variability), the main mode of toxic action seems to be narcosis.
Table 98: Overview of selected data for chronic toxicity of PAHs based on internal residues. If for one species several PAHs were tested, statistics of the distribution are presented

<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
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<td></td>
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<td></td>
<td>log NOER Average</td>
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<td>log NOER</td>
<td>log NOER</td>
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<td>Average  Standard deviation</td>
<td>Minimum  Maximum</td>
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<tr>
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<td>Corophium spinicorne</td>
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<td>-0.22 0.57</td>
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<tr>
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<td>1.04 0.52</td>
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<td>0.09 0.43</td>
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<td>1.58 0.55</td>
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<td>1.18 0.52</td>
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<td>0.42 0.54</td>
</tr>
<tr>
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<td>log NOER</td>
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<td>Standard deviation</td>
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<td>freshwater</td>
<td>Oryzias latipes</td>
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<td>freshwater</td>
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<td>pisces</td>
<td>marine water</td>
<td>Gadus morhua</td>
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</tr>
<tr>
<td>pisces</td>
<td>marine water</td>
<td>Oncorhynchus gorbuscha</td>
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<tr>
<td>tunicata</td>
<td>marine water</td>
<td>Ciona intestinalis</td>
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<td>0.54</td>
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</table>
Figure 27: Species sensitivity distribution of all species in different compartments based on internal residues of individual PAHs

The values of the HC5 and HC50 can be recalculated to concentrations for the individual PAHs in water, sediment, and soil. These values are remarkably higher than the values derived with the deterministic approach (assessment factors). When applying the SSD method to derive risk limits, an assessment factor of 1 to 5 should be applied to the HC5 to derive the MPC in accordance with the European methodology (Van Vlaardingen and Verbruggen, 2007). For TPH this factor has been set to 1, mainly because the mixtures are supposed to act by narcosis and a rather thorough validity check of the method has been performed. However, the PAHs have several modes of toxic action. For some of the PAHs phototoxicity is leading to very low acute effect concentrations. Examples are the acute toxicity of anthracene to algae (Gala and Giesy, 1992), daphnids (Allred and Giesy, 1985), insects (Bleeker et al., 2003), and marine amphipods (Pelletier et al., 1997), pyrene to marine amphipods (Pelletier et al., 1997) and fluoranthene to juvenile flatfish (Spehar et al., 1999). Recalculated to internal lipid residues, these L(E)C50s are all equal to or lower than the HC5. Among the most sensitive species are many crustaceans. Two of them are the terrestrial isopods exposed to benz[a]anthracene and benzo[a]pyrene in food (Van Brummelen and Stuijfzand, 1993; Van Brummelen et al., 1996; Van Straalen and Verweij, 1991). Another two are the marine crustaceans Dungeness crab exposed to naphthalene (Caldwell et al., 1977) and the amphipod Mysidopsis bahia exposed to fluoranthene (Spehar et al., 1999).

These four species are at or below the HC5. Also the freshwater daphnids (Daphnia magna and Ceriodaphnia dubia) belong to the most sensitive species. It is therefore considered necessary to apply a maximum value of 5 to the HC5 to be protective for the most sensitive species (crustaceans) and the most sensitive acute toxic effects (phototoxicity, where crustaceans, but also insects and early life stages of molluscs and fish are at risk). The resulting values of this exercise are shown in Table 99. The levels of the MPC\textsubscript{eco} and SRC\textsubscript{eco} are also
shown in Figure 23 to 26 by means of the lower and higher lines, respectively. It can be seen that the lines follow the data rather well, taking note of the observation made above on phototoxicity and sensitive groups of species. Additionally, it should be noted that for several of the higher PAHs the $SRC_{eco}$ is at the level of the solubility in water, which means that effect concentrations above this line will not be observed.

In conclusion it can be stated that this exercise is a reconfirmation, at least for these substances, that the equilibrium partitioning method is a useful method in setting quality standards. The large number of data used here shows that the variability is mostly due to individual studies, but that on average there is no difference between the different compartments. Because the variability due to inhomogenous datasets has been reduced and no different and sometimes high assessment factors have been used, the risk limits for PAHs derived in this way are considered to be more coherent with each other. Because toxicity is driven by equilibrium partitioning, monitoring of these PAHs could be focused on measuring free water concentrations, e.g. in pore water, with solid phase extraction techniques. An advantage of such a measurement would be that reduced bioavailability in soil or sediment, for example due to the presence of black carbon, is taken into account.
Table 99: Comparison of the risk limits based on internal residues calculated from membrane water partition coefficients and the SSD approach and the risk limits derived for each PAH individually with the deterministic approach. Concentrations in water are in µg/L, concentrations in soil and sediment in mg/kg dw standard soil/sed containing 10% organic matter.

<table>
<thead>
<tr>
<th>Risk limit</th>
<th>MPC_{eco, water}</th>
<th>MPC_{eco, water}</th>
<th>SRC_{eco, water}</th>
<th>SRC_{eco, water}</th>
<th>MPC_{eco, soil and sediment}</th>
<th>MPC_{eco, soil}</th>
<th>SRC_{eco, soil and sediment}</th>
<th>SRC_{eco, soil}</th>
<th>SRC_{eco, sediment}</th>
<th>SRC_{eco, sediment}</th>
<th>SRC_{eco, soil}</th>
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<td>Method</td>
<td>HC5/5 AF</td>
<td>HC50 geom</td>
<td>HC5/5 AF</td>
<td>HC50 geom</td>
<td>HC50 geom</td>
<td>HC50 geom</td>
<td>SRC_{eco, soil and sediment}</td>
<td>SRC_{eco, soil}</td>
<td>SRC_{eco, sediment}</td>
<td>SRC_{eco, sediment}</td>
<td>SRC_{eco, soil}</td>
</tr>
<tr>
<td>Data</td>
<td>All PAHs</td>
<td>Single PAH</td>
<td>All PAHs</td>
<td>Single PAH</td>
<td>All PAHs</td>
<td>Single PAH</td>
<td>All PAHs</td>
<td>Single PAH</td>
<td>Single PAH</td>
<td>Single PAH</td>
<td>Single PAH</td>
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<td>Naphthalene</td>
<td>5.4 2.0</td>
<td>324 518</td>
<td>0.43 0.16</td>
<td>0.69</td>
<td>26 42</td>
<td>14</td>
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<tr>
<td>Acenaphthylene</td>
<td>4.0 1.3</td>
<td>236 72</td>
<td>0.51 0.17</td>
<td>0.17</td>
<td>30 9.5</td>
<td>9.4</td>
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<tr>
<td>Acenaphthene</td>
<td>1.7 3.8</td>
<td>104 102</td>
<td>0.53 0.97</td>
<td>0.68</td>
<td>31 31</td>
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</tr>
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<td>63 117</td>
<td>0.58 0.83</td>
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<td>35 64</td>
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<td>0.67 0.78</td>
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<td>40 63</td>
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<td>Anthracene</td>
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<td>24 4.2</td>
<td>0.71 0.05</td>
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<td>42 3</td>
<td>60</td>
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<tr>
<td>Pyrene</td>
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<td>16 4.2</td>
<td>0.89 1.67</td>
<td>1.8</td>
<td>53 136</td>
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<tr>
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<td>11 11</td>
<td>0.99 4.11</td>
<td>4.8</td>
<td>59 96</td>
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<td>1.7 1.64</td>
<td>1.6</td>
<td>103 38</td>
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<tr>
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<td>0.064 0.012</td>
<td>3.8 3.1</td>
<td>1.9 0.35</td>
<td>0.19</td>
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<td>3.2 0.93</td>
<td>2.5 0.79</td>
<td>0.79</td>
<td>151 44</td>
<td>44</td>
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<tr>
<td><em>Benz[b]fluoranthene</em></td>
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<td>3.2 1.3</td>
<td>2.6 0.79</td>
<td>0.79</td>
<td>153 62</td>
<td>62</td>
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<tr>
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<td>2.6 0.49</td>
<td>0.16</td>
<td>154 42</td>
<td>76</td>
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<td><em>Benz[ghi]perylene</em></td>
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<td>3.1 0.16</td>
<td>3.1 0.49</td>
<td>0.49</td>
<td>186 10</td>
<td>10</td>
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<td><em>Dibenzo[a,h]anthracene</em></td>
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<td>4.7 0.18</td>
<td>0.18</td>
<td>279 18</td>
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<td><em>Indeno[1,2,3-cd]pyrene</em></td>
<td>0.035 0.0027</td>
<td>2.1 0.64</td>
<td>4.9 0.38</td>
<td>0.38</td>
<td>289 89</td>
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</table>

Note: a except for fluoranthene, where the SSD approach was applied for water.
References


Achazi RK, Chroszcz G, Düker C, Henneken M, Rothe B, Schaub K, Steudel I. 1995. The effect of fluoranthene (Fla), benzo(a)pyrene (BaP) and cadmium (Cd) upon survival rate and life cycle parameter of two terrestrial annelids in laboratory test systems. Newslett Enchytraeidae 4: 7-14.


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Sverdrup LE, Krogh PH, Nielsen T, Kjaer C, Stenersen J. 2003. Toxicity of eight polycyclic aromatic compounds to red clover (Trifolium pratense), ryegrass (Lolium perenne), and mustard (Sinapsis alba). Chemosphere 53: 993-1003.


## Appendix. Detailed ecotoxicity data

### Table 100: Legend to the tables in the Appendix

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<thead>
<tr>
<th>Legend to data tables</th>
<th>species properties</th>
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<tbody>
<tr>
<td>A</td>
<td>Test water analysed Yes/No</td>
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<tr>
<td>Test type</td>
<td>S = static; R = renewal; F = flow-through</td>
</tr>
<tr>
<td>Test water</td>
<td>am = artificial medium; dtw = dechlorinated tap water; dw = de-ionised/dechlorinated/distilled water; nw = natural water; rw = reconstituted (sea)water; rtw = reconstituted tap water; tw = tap water</td>
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<tr>
<td>Ri</td>
<td>Reliability index, see section 2.2</td>
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### Table 101: Acute toxicity of naphthalene (CASnr. 91-20-3) for freshwater organisms

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO3 [mg/L]</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<td><strong>Algae</strong></td>
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<td></td>
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</tr>
<tr>
<td>Chlamydomonas angulosa</td>
<td>5*10^4 cells/ml</td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>6.5</td>
<td>19</td>
<td>3</td>
<td></td>
<td>EC50</td>
<td>photosynthesis/assimilation 14C</td>
<td>9600</td>
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<td>25, 106, 231</td>
<td>Hutchinson et al., 1980</td>
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<tr>
<td>Chlorella vulgaris</td>
<td>20*10^4 cells/ml</td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>6.5</td>
<td>19</td>
<td>3</td>
<td></td>
<td>EC50</td>
<td>photosynthesis/assimilation 14C</td>
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<td>3</td>
<td>25, 106, 231</td>
<td>Hutchinson et al., 1980</td>
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</tr>
<tr>
<td>Chlorella vulgaris</td>
<td>3-10*10^4 cells/ml</td>
<td>N</td>
<td>S</td>
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<td>7.6</td>
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<td>Y</td>
<td>S</td>
<td>am</td>
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<td>Pseudokirchneriella subcapitata</td>
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<td>N</td>
<td>S</td>
<td>rg</td>
<td>am</td>
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<td>Pseudokirchneriella subcapitata</td>
<td>10*5 cells/ml</td>
<td>N</td>
<td>S</td>
<td>rg</td>
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<td></td>
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<td>S</td>
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<td>Scenedesmus subspicatus</td>
<td>10*4 cells/ml</td>
<td>N</td>
<td>S &gt;98%</td>
<td>am</td>
<td>25±1</td>
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<td>203</td>
<td>Djomo et al., 2004</td>
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<td>Scenedesmus vacuolatus</td>
<td>7.5*10^4 cells/ml</td>
<td>Y</td>
<td>Sc</td>
<td>99%</td>
<td>6.9±0.2</td>
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<td>Crit. Endpoint</td>
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<td>&lt; 24 h</td>
<td>N Sc ≥97%</td>
<td>nw</td>
<td>7.6±0.2</td>
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<td>&lt; 24 h</td>
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<td>Wernersson 2003</td>
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<td>8.0</td>
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<td>N Sc ≥80%</td>
<td>nw</td>
<td>7.4-9.4</td>
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<td>173</td>
<td>48 h</td>
<td>NOEC</td>
<td>mortality</td>
<td>600</td>
<td>3</td>
<td>LeBlanc 1980</td>
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<td><em>Daphnia pulex</em></td>
<td>&lt; 24 h</td>
<td>N Sc ≥96%</td>
<td>nw</td>
<td>7.5</td>
<td>15±2</td>
<td>96 h</td>
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<td>mortality</td>
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<td><em>Daphnia pulex</em></td>
<td>&lt; 24 h</td>
<td>N Sc ≥96%</td>
<td>nw</td>
<td>20</td>
<td>160-180</td>
<td>48 h</td>
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<td>160-180</td>
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<td><em>Daphnia pulex</em></td>
<td>1.9-2.1 mm</td>
<td>Y Sc ACS grade</td>
<td>7.2 (6.8-7.5)</td>
<td>20±1</td>
<td>43 (43-48)</td>
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<td>LC50</td>
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<td>35, 80</td>
<td>Geiger &amp; Buikema, 1981, 1982</td>
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<td>7.2 (6.8-7.5)</td>
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<td>43 (43-48)</td>
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<td>35, 80</td>
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<tr>
<td><strong>Diporeia spp.</strong></td>
<td>1-2 mm, 5-11 m, juvenile</td>
<td>Y R &gt;98%</td>
<td>nw</td>
<td>8.1-8.3</td>
<td>4</td>
<td>165-250</td>
<td>5 d</td>
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<td>Exp. time</td>
<td>Crit. Endpoint</td>
<td>Value [µg/L]</td>
<td>Ri</td>
<td>Notes</td>
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<td>Y</td>
<td>Sc</td>
<td>nw</td>
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<td>48 h</td>
<td>LC50 mortality</td>
<td>3930</td>
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<tr>
<td>Anabaena flos-aqua</td>
<td>2*10^5 cells/ml</td>
<td>Y</td>
<td>S a.g.</td>
<td>am</td>
<td>29</td>
<td>2 h</td>
<td>NOEC nitrogen fixation</td>
<td>&lt;2100</td>
<td>2</td>
<td>210</td>
<td>Bastian &amp; Toetz, 1985</td>
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<td>2*10^5 cells/ml</td>
<td>Y</td>
<td>S a.g.</td>
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<td>29</td>
<td>2 h</td>
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<td>2 h</td>
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<td>Chironomus attenuatus</td>
<td>4th instar</td>
<td>N</td>
<td>S tw</td>
<td>7.9-8.3</td>
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<td>24 h</td>
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<td>80, 239</td>
<td>Darville &amp; Wilhm, 1984</td>
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<td>80, 239</td>
<td>Darville &amp; Wilhm, 1984</td>
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<td>S &gt;99% DSW</td>
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<td>96 h</td>
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<td>N</td>
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<td>CF nw</td>
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<td>43.9± 0.58</td>
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<td>44</td>
<td>96 h</td>
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<td>24.6±1.4</td>
<td>44.9 (42.4-46.6)</td>
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<td>LC50 mortality</td>
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<td>am</td>
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<td>2.8</td>
<td>48 h</td>
<td>LC50 mortality</td>
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Table 102: Chronic toxicity of naphthalene (CASnr. 91-20-3) for freshwater organisms

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<tr>
<th>Species</th>
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<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness [mg/L]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
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<td>S</td>
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<td>S</td>
<td>am</td>
<td>23</td>
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<td>NOEC</td>
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<td>215</td>
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<td>167</td>
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<td>14 d</td>
<td>EC10</td>
<td>standing crop</td>
<td>13000</td>
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<td>Scenedesmus subspicatus</td>
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<td>N</td>
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<td>7 d</td>
<td>EC10</td>
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<td>Geiger &amp; Buikema, 1982</td>
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<td>Scenedesmus vacuolatus</td>
<td>7.5*10^4 cells/ml</td>
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<td>Sc 99%</td>
<td>am</td>
<td>6.9±0.2</td>
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<td>24 h</td>
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<td>am</td>
<td>6.9±0.2</td>
<td>28±0.5</td>
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<td>EC10 cell number</td>
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<td>R</td>
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<td>R</td>
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### Table 103: Acute toxicity of naphthalene (CASnr. 91-20-3) for marine organisms

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### Table 104: Chronic toxicity of naphthalene (CASnr. 91-20-3) for marine organisms

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<th>Value [µg/L]</th>
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Table 105: Toxicity of naphthalene (CASnr. 91-20-3) to terrestrial organisms

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### Species properties

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### Microbial processes

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### Table 106: Toxicity of naphthalene (CASnr. 91-20-3) to benthic organisms

**Crustacea**

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### Table 107: Acute toxicity of acenaphthylene (CASnr: 208-96-8) to freshwater organisms.

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<td>S</td>
<td>30</td>
<td>24 h</td>
<td>EC50</td>
<td>growth</td>
<td>6300</td>
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<td>Yoshioka et al., 1986</td>
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### Table 108: Chronic toxicity of acenaphthylene (CASnr: 208-96-8) to freshwater organisms.

<table>
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<tr>
<th>Species</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time [h]</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<td>Value</td>
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<td>Y S</td>
<td>23±2</td>
<td>215</td>
<td>72 h</td>
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<td>growth</td>
<td>82</td>
<td>2</td>
<td>167</td>
<td>Bisson et al., 2000</td>
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<td>Test type</td>
<td>Purity [%]</td>
<td>Test water</td>
<td>pH</td>
<td>T [°C]</td>
<td>Hardness CaCO₃ [mg/L]</td>
<td>Exp. time</td>
<td>Crit. Endpoint</td>
<td>Value [µg/L]</td>
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<td>Ceriodaphnia dubia</td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>R</td>
<td>nw</td>
<td>8.1±0.4</td>
<td>25±2</td>
<td>240±40</td>
<td>7 d</td>
<td>EC10 reproduction</td>
<td>64</td>
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**Table 109: Acute toxicity of acenaphthylene (CASnr: 208-96-8) to marine organisms.**

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<th>Species properties</th>
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<th>Test water</th>
<th>pH [°C]</th>
<th>T [%]</th>
<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<td>Vibrio fischer</td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>7.2±0.1</td>
<td>20±1</td>
<td>15 min</td>
<td>EC50</td>
<td>bioluminescence</td>
<td>800</td>
<td>3</td>
<td>3, 5</td>
<td>El-Alawi et al., 2001</td>
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<td>S</td>
<td>am</td>
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<td>15 min</td>
<td>EC50</td>
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<td>S</td>
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<td>4, 5</td>
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<td>S</td>
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<td>15 min</td>
<td>EC50</td>
<td>bioluminescence</td>
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<td>El-Alawi et al., 2001</td>
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<td>N</td>
<td>S</td>
<td>o.a.</td>
<td>17</td>
<td>5 min</td>
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<td>5 min</td>
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<td>Kaiser &amp; Palabrica, 1991</td>
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<td>15 min</td>
<td>EC50</td>
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<td>Kaiser &amp; Palabrica, 1991</td>
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<td>99%</td>
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<td>15</td>
<td>30 min</td>
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<td>bioluminescence</td>
<td>283</td>
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<td>Kaiser &amp; Palabrica, 1991</td>
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<td>Vibrio fischer</td>
<td>Y</td>
<td>S</td>
<td>99%</td>
<td>am</td>
<td>15</td>
<td>20</td>
<td>30 min</td>
<td>EC50</td>
<td>bioluminescence</td>
<td>860</td>
<td>2</td>
<td>115</td>
<td>Loibner et al., 2004</td>
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<td>Vibrio fischer</td>
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<td>S</td>
<td>99%</td>
<td>am</td>
<td>15</td>
<td>20</td>
<td>30 min</td>
<td>EC50</td>
<td>bioluminescence</td>
<td>180</td>
<td>2</td>
<td>115</td>
<td>Loibner et al., 2004</td>
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**Table 110: Chronic toxicity of acenaphthylene (CASnr: 208-96-8) to marine organisms.**

<table>
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<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH [°C]</th>
<th>T [°C]</th>
<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>Vibrio fischer</td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>7.2±0.1</td>
<td>20±1</td>
<td>18 h</td>
<td>EC50</td>
<td>bioluminescence</td>
<td>6570</td>
<td>3</td>
<td>3, 5</td>
<td>El-Alawi et al., 2001</td>
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<td>S</td>
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<td>7.2±0.1</td>
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<td>18 h</td>
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<td>bioluminescence</td>
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<td>El-Alawi et al., 2001</td>
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<td>Test water</td>
<td>pH</td>
<td>T</td>
<td>Salinity</td>
<td>Exp. time</td>
<td>Crit. Endpoint</td>
<td>Value [µg/L]</td>
<td>Ri</td>
<td>Notes</td>
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<td>20±1</td>
<td>8+18 h</td>
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<td>530</td>
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<td>24, 6</td>
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<td>18 h</td>
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<td>growth</td>
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<td>3</td>
<td>3, 5</td>
<td>El-Alawi et al., 2001</td>
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<td>7.2±0.1</td>
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<td>8+18 h</td>
<td>EC50</td>
<td>growth</td>
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<td>El-Alawi et al., 2001</td>
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<td>El-Alawi et al., 2001</td>
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**Table 111: Toxicity ofacenaphthylene (CASnr: 208-96-8) to terrestrial organisms**

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<th>A Purity</th>
<th>Soil type</th>
<th>pH</th>
<th>T</th>
<th>Organic matter</th>
<th>Clay</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value test soil [mg/kgdw]</th>
<th>Value standard soil [mg/kgdw]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tr>
<td>Folsomia fimetaria</td>
<td>23-26 d Y 87</td>
<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>LC50</td>
<td>mortality</td>
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<td>533</td>
<td>3</td>
<td>12, 15, 21, 78</td>
<td>Sverdrup et al., 2002</td>
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<tr>
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<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>LC50</td>
<td>mortality</td>
<td>146</td>
<td>535</td>
<td>3</td>
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<td>21 d</td>
<td>LC10</td>
<td>mortality</td>
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<td>484</td>
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<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>EC10</td>
<td>reproduction</td>
<td>23</td>
<td>85</td>
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<td>Sverdrup et al., 2002</td>
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<td>20±1</td>
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<td>13</td>
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<td>reproduction</td>
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<td>20±1</td>
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<td>21 d</td>
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<td>reproduction</td>
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<td>Sverdrup et al., 2002</td>
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<td>sandy loam</td>
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<td>20±1</td>
<td>2.7</td>
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<td>21 d</td>
<td>LC50</td>
<td>mortality</td>
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<td>sandy loam</td>
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<td>21 d</td>
<td>LC50</td>
<td>mortality</td>
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<td>Sverdrup et al., 2002</td>
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<td>Species</td>
<td>Species properties</td>
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<td>pH</td>
<td>T °C</td>
<td>Organic matter [%]</td>
<td>Clay [%]</td>
<td>Exp. time [d]</td>
<td>Crit.</td>
<td>Endpoint</td>
<td>Value test soil [mg/kgdw]</td>
<td>Value standard soil [mg/kgdw]</td>
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<td>LC10 mortality</td>
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<td>Sverdrup et al., 2002</td>
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<td>EC10 reproduction</td>
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<td>12, 15, 22, 78</td>
<td>Sverdrup et al., 2002</td>
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<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>EC50 reproduction</td>
<td>29</td>
<td>106</td>
<td>2</td>
<td>12, 15, 22, 47, 78</td>
<td>Sverdrup et al., 2002</td>
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<td>23-26 d Y 87 sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
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<td>EC10 reproduction</td>
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<td>97</td>
<td>2</td>
<td>12, 15, 22, 47, 78</td>
<td>Sverdrup et al., 2002</td>
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</table>

**Table 112: Acute toxicity of acenaphthene (CASnr: 83-32-9) to freshwater organisms.**

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<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T °C</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time [h]</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value [µg/L]</th>
<th>RI</th>
<th>Notes</th>
<th>Reference</th>
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<td><strong>Crustacea</strong></td>
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<tr>
<td>Daphnia magna</td>
<td>&lt; 24 h Y S am</td>
<td>7.8±0.2</td>
<td>20±2</td>
<td>250±30</td>
<td>48 h</td>
<td>EC50</td>
<td>immobility</td>
<td>958</td>
<td>2</td>
<td>5</td>
<td>Bisson et al., 2000</td>
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<td>Daphnia magna</td>
<td>&lt; 24 h N Sc ≥80% rw</td>
<td>7.4-9.4</td>
<td>22±1</td>
<td>173</td>
<td>48 h</td>
<td>LC50</td>
<td>mortality</td>
<td>41000</td>
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Table 113: Chronic toxicity of acenaphthene (CASnr: 83-32-9) to freshwater organisms.

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<td>nw</td>
<td>7.4 (7.1-7.6)</td>
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<td>CF</td>
<td>nw</td>
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<td>CF</td>
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<td>7.4 (7.1-7.6)</td>
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<td>35 (24-70)</td>
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Table 114: Acute toxicity of acenaphthene (CASnr: 83-32-9) to marine organisms.

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<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit.</th>
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<td>S</td>
<td>am</td>
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<td>20±1</td>
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<td>EC50</td>
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<td>Salinity [‰]</td>
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<td>Crit.</td>
<td>Endpoint</td>
<td>Value [µg/L]</td>
<td>Ri</td>
<td>Notes</td>
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<td>25-31</td>
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Table 115: Chronic toxicity of acenaphthene (CASnr: 83-32-9) to marine organisms.

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<th>Exp. time</th>
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<th>Ri</th>
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Table 116: Toxicity of acenaphthene (CASnr: 83-32-9) to terrestrial organisms

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<th>Organic matter [%]</th>
<th>Clay [%]</th>
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<th>Crit. Endpoint</th>
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### Table 117: Toxicity of acenaphthene (CASnr: 83-32-9) to benthic organisms

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<th>Crit. Endpoint</th>
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Table 118: Acute toxicity of fluorene (CASnr: 86-73-7) to freshwater organisms.

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<th>Clay [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
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Table 119: Chronic toxicity of fluorene (CASnr: 86-73-7) to freshwater organisms.

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<th>Exp. time</th>
<th>Endpoint</th>
<th>Value [µg/L]</th>
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Table 120: Acute toxicity of fluorene (CASnr: 86-73-7) to marine organisms.

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### Table 121: Chronic toxicity of fluorene (CASnr: 86-73-7) to marine organisms.

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<td>170</td>
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<td>60</td>
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<td>66</td>
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<td>2/3</td>
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Table 123: Acute toxicity of phenanthrene (CASnr: 85-01-8) to freshwater organisms.

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<th>pH</th>
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<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
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<td>N</td>
<td>Sc</td>
<td>≥97%</td>
<td>rw</td>
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<td>48 h</td>
<td>EC₅₀ immobility</td>
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<td>S</td>
<td>am</td>
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<td>20±1</td>
<td>250±25</td>
<td>24 h</td>
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<td>am</td>
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<td>20±1</td>
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<td>EC₅₀ immobility</td>
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<td>S</td>
<td>am</td>
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<td>250±25</td>
<td>48±2 h</td>
<td>EC₅₀ immobility</td>
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<td>S</td>
<td>am</td>
<td>20±2</td>
<td>24 h</td>
<td>EC₅₀ immobility</td>
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<td>90, 65</td>
<td>Verhriest et al., 2001</td>
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<td>pH</td>
<td>T</td>
<td>Hardness CaCO$_3$ [mg/L]</td>
<td>Exp. time</td>
<td>Crit. Endpoint</td>
<td>Value [µg/L]</td>
<td>Ri</td>
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<td>Y</td>
<td>am</td>
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<td>am</td>
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<td>&gt;1024</td>
<td>3</td>
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<td>N</td>
<td>am</td>
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<td>21±1</td>
<td>250</td>
<td>27 h</td>
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<td>N</td>
<td>&gt;96% nw/d w</td>
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<td>240</td>
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<td>immobility</td>
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<td>80</td>
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<td>&gt;96% nw/d w</td>
<td>7.2</td>
<td>20±1</td>
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<td>&gt;96% nw/d w</td>
<td>7.2</td>
<td>20±1</td>
<td>240</td>
<td>48 h</td>
<td>EC10</td>
<td>immobility</td>
<td>391</td>
<td>3</td>
<td>80, 102</td>
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<td>&lt; 24 h</td>
<td>N</td>
<td>≥96% rw</td>
<td>20</td>
<td>160-180</td>
<td>48 h</td>
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<td>immobility</td>
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<td>Smith et al., 1988</td>
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<td><em>Daphnia pulex</em></td>
<td>&lt; 24 h</td>
<td>N</td>
<td>≥96% rw</td>
<td>20</td>
<td>160-180</td>
<td>48 h</td>
<td>EC10</td>
<td>immobility</td>
<td>140</td>
<td>3</td>
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<td>&lt; 24 h</td>
<td>N</td>
<td>≥96% rw</td>
<td>17</td>
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<td>48 h</td>
<td>EC50</td>
<td>immobility</td>
<td>734</td>
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<td>1.9-2.1 mm</td>
<td>Y</td>
<td>Sc</td>
<td>7.5</td>
<td>15±2</td>
<td>96 h</td>
<td>LC50</td>
<td>mortality</td>
<td>100</td>
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<td>36</td>
<td>Trucco et al., 1983</td>
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<td>ACS grade tw</td>
<td>7.2 (6.8-7.5)</td>
<td>20±1</td>
<td>43 (43-48)</td>
<td>48 h</td>
<td>LC50</td>
<td>mortality</td>
<td>&gt;1140</td>
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<td>35, 80</td>
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<td><em>Diporeia spp.</em></td>
<td>1-2 mm, 5-11 m, juvenile</td>
<td>Y</td>
<td>R &gt;98% nw</td>
<td>8.1-8.3</td>
<td>165-250</td>
<td>2 d</td>
<td>EC50</td>
<td>immobility</td>
<td>295</td>
<td>2</td>
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<td>Landrum et al., 2003</td>
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<td><em>Diporeia spp.</em></td>
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<td>R &gt;98% nw</td>
<td>8.1-8.3</td>
<td>165-250</td>
<td>5 d</td>
<td>EC50</td>
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<td>74.3</td>
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<td>Landrum et al., 2003</td>
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<td><em>Gammarus minus</em></td>
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<td>Sc</td>
<td>nw</td>
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<td>mortality</td>
<td>460</td>
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<td>266</td>
<td>Milleman et al., 1984</td>
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</tr>
<tr>
<td><em>Anabaena flos-aqua</em></td>
<td>2*10^5 cells/ml</td>
<td>Y</td>
<td>a.g. am</td>
<td>29</td>
<td>2 h</td>
<td>NOEC</td>
<td>nitrogen fixation</td>
<td>270</td>
<td>2</td>
<td>210</td>
<td>Bastian &amp; Toetz, 1985</td>
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<tr>
<td><em>Anabaena flos-aqua</em></td>
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<td>Y</td>
<td>a.g. am</td>
<td>29</td>
<td>2 h</td>
<td>EC10</td>
<td>nitrogen fixation</td>
<td>520</td>
<td>2</td>
<td>92, 210</td>
<td>Bastian &amp; Toetz, 1985</td>
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<tr>
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<td>2*10^5 cells/ml</td>
<td>Y</td>
<td>a.g. am</td>
<td>29</td>
<td>2 h</td>
<td>EC50</td>
<td>nitrogen fixation</td>
<td>1300</td>
<td>2</td>
<td>92, 210</td>
<td>Bastian &amp; Toetz, 1985</td>
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<tr>
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<td>2*10^5 cells/ml</td>
<td>Y</td>
<td>a.g. am</td>
<td>29</td>
<td>2 h</td>
<td>NOEC</td>
<td>nitrogen fixation</td>
<td>&lt;130</td>
<td>2</td>
<td>210, 211</td>
<td>Bastian &amp; Toetz, 1985</td>
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<td><strong>Insecta</strong></td>
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<td><em>Aedes aegypti</em></td>
<td>&lt; 8 h, first instar</td>
<td>N</td>
<td>tw</td>
<td>&lt;24 h</td>
<td>LC50</td>
<td>mortality</td>
<td>500</td>
<td>3</td>
<td>41</td>
<td>Kagan et al., 1987</td>
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<tr>
<td><em>Chironomus riparius</em></td>
<td>1st instar, &lt;24 h</td>
<td>Y</td>
<td>99.5% DSW</td>
<td>96 h</td>
<td>LC50</td>
<td>mortality</td>
<td>41</td>
<td>2</td>
<td>82</td>
<td>Bleeker et al., 2003</td>
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</table>
### Table 124: Chronic toxicity of phenanthrene (CASnr: 85-01-8) to freshwater organisms.

<table>
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<tr>
<th>Species</th>
<th>Species properties</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO3 [mg/L]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tr>
<td><em>Pseudokirchneriella subcapitata</em></td>
<td></td>
<td>Y S</td>
<td></td>
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<tr>
<td><em>Pseudokirchneriella subcapitata</em></td>
<td>1.3*10^4 cells/ml</td>
<td>N S</td>
<td>&gt;96%</td>
<td>am</td>
<td>8.1-9.0</td>
<td>22±1</td>
<td>3 d EC10 growth rate</td>
<td>803</td>
<td>3</td>
<td>165</td>
<td></td>
<td></td>
<td>Halling-Sørensen et al., 1996</td>
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<tr>
<td><em>Pseudokirchneriella subcapitata</em></td>
<td>1.3*10^4 cells/ml</td>
<td>N S</td>
<td>&gt;96%</td>
<td>am</td>
<td>8.1-8.4</td>
<td>22±1</td>
<td>2 d EC10 growth rate</td>
<td>720</td>
<td>3</td>
<td>165</td>
<td></td>
<td></td>
<td>Halling-Sørensen et al., 1996</td>
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**Note:** The table above provides a detailed overview of the chronic toxicity of phenanthrene (CASnr: 85-01-8) to various freshwater organisms, including their species, properties, test types, purity, test water, pH, temperature, hardness, experimental time, critical endpoints, values, and references.
<table>
<thead>
<tr>
<th>Species</th>
<th>Properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>T [%]</th>
<th>Hardness CaCO3 [mg/L]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Pseudokirchneriella subcapitata</td>
<td>2.1*10^4 cells/ml</td>
<td>Y</td>
<td>S/S</td>
<td>&gt;96% am</td>
<td>8.4-9.0</td>
<td>22±1</td>
<td>2 d EC10 growth rate</td>
<td>110</td>
<td>3</td>
<td>165</td>
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<td>Halling-Sørensen et al., 1996</td>
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<td>Pseudokirchneriella subcapitata</td>
<td>1.2*10^4 cells/ml</td>
<td>Y</td>
<td>Sc</td>
<td>&gt;96% am</td>
<td>7.0-9.0</td>
<td>22±1</td>
<td>2 d EC10 growth rate</td>
<td>139</td>
<td>3</td>
<td>165</td>
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<td>Halling-Sørensen et al., 1996</td>
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<td>1.4*10^4 cells/ml</td>
<td>Y</td>
<td>Sc</td>
<td>&gt;96% am</td>
<td>7.0-7.3</td>
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<td>2 d EC10 growth rate</td>
<td>10</td>
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<td>Y</td>
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<td>&gt;96% am</td>
<td>7.0-8.4</td>
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<td>Y</td>
<td>Sc</td>
<td>&gt;96% am</td>
<td>7.0-7.3</td>
<td>22±1</td>
<td>2 d EC10 growth rate</td>
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<td>165</td>
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<td>Halling-Sørensen et al., 1996</td>
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<td>Y</td>
<td>Sc</td>
<td>&gt;96% am</td>
<td>7.0-8.2</td>
<td>22±1</td>
<td>3 d EC10 growth rate</td>
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<td>Scenedesmus subspicatus</td>
<td>10^4 cells/ml</td>
<td>N</td>
<td>S</td>
<td>&gt;98% am</td>
<td>-</td>
<td>25±1</td>
<td>7 d EC10 growth, area under the curve</td>
<td>4910</td>
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<td>203</td>
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<td>Y</td>
<td>Sc</td>
<td>99% am</td>
<td>6.9±0.2</td>
<td>28±0.5</td>
<td>24 h EC10 cell number</td>
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<td>N</td>
<td>R</td>
<td>am</td>
<td>7.6-7.9</td>
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<td>Crustacea</td>
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<td>Ceriodaphnia dubia</td>
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<td>Y</td>
<td>R</td>
<td>nw</td>
<td>8.1±0.4</td>
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<td>320 3 143 Bastian &amp; Toetz, 1982</td>
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<td>55 3 90 Bleeker et al., 2003</td>
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<td>&gt;98% tw/nw</td>
<td>8.2</td>
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### Table 125: Acute toxicity of phenanthrene (CASnr: 85-01-8) to marine organisms.

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<td>2 to 5 mm, male and non-egg-bearing female</td>
<td>N S</td>
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<td>adult</td>
<td>Y S</td>
<td>&gt;96% nw</td>
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<td>LC50</td>
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<td>139, 266</td>
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<td>15</td>
<td>33</td>
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Table 126: Chronic toxicity of phenanthrene (CASnr: 85-01-8) to marine organisms.

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<td><em>Paralichthys olivaceus</em> 51±4.3 g N R &gt;96% nw 8.03±0.04 20±1 31.8±0.7 4 w NOEC weight gain 89 3 25 Jee et al., 2004</td>
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Table 127: Toxicity of phenanthrene (CASnr: 85-01-8) to terrestrial organisms

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Table 128: Toxicity of phenanthrene (CASnr: 85-01-8) to benthic organisms

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<th>A</th>
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<th>Soil type</th>
<th>pH</th>
<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time [d]</th>
<th>Endpoint</th>
<th>Value test sediment [mg/kg dw]</th>
<th>Value standard sediment [mg/kg dw]</th>
<th>Ri</th>
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<p>| Annelida           |                    |   |            |           |     |        |                   |         |              |          |                            |                                   |    |        |                  |
| <em>Ilyodrilus templetoni</em> | adult            | Y | 98%       | sediment  | 23±1| 4.403  | 10 d              | NOEC    | feeding rate   | 109     | 248                        | 2                  | 51, 59, 72 | Gust &amp; Fleeger, 2006 |
| <em>Ilyodrilus templetoni</em> | adult            | Y | 98%       | sediment  | 23±1| 4.403  | 10 d              | EC50    | feeding rate   | 160     | 363                        | 2                  | 47, 51, 59 | Gust &amp; Fleeger, 2006 |
| <em>Ilyodrilus templetoni</em> | adult            | Y | 98%       | sediment  | 23±1| 4.403  | 10 d              | EC10    | feeding rate   | 93      | 211                        | 2                  | 47, 51, 59 | Gust &amp; Fleeger, 2006 |
| <em>Limnodrilus hoffmeisteri</em> | mature         | Y | 98%       | sediment from drainage system, &lt;125 µm | 25  | 1.2    | 10 d              | LC50    | mortality      | 298     | 2504                      | 2                  | 51, 54, 55, 58 | Lotufo &amp; Fleeger, 1996 |
| <em>Limnodrilus hoffmeisteri</em> | mature         | Y | 98%       | sediment from drainage system, &lt;125 µm | 25  | 1.2    | 10 d              | LC50    | mortality      | 306     | 2573                      | 2                  | 47, 51, 54, 55, 58 | Lotufo &amp; Fleeger, 1996 |
| <em>Limnodrilus hoffmeisteri</em> | mature         | Y | 98%       | sediment from drainage system, &lt;125 µm | 25  | 1.2    | 10 d              | LC10    | mortality      | 150     | 1260                      | 2                  | 47, 51, 54, 55, 58 | Lotufo &amp; Fleeger, 1996 |
| <em>Limnodrilus hoffmeisteri</em> | mature         | Y | 98%       | sediment from drainage system, &lt;125 µm | 25  | 1.2    | 10 d              | NOEC    | mortality      | 143     | 1202                      | 2                  | 51, 54, 55, 58 | Lotufo &amp; Fleeger, 1996 |
| <em>Limnodrilus hoffmeisteri</em> | mature         | Y | 98%       | sediment from drainage system, &lt;125 µm | 25  | 1.2    | 10 d              | EC25    | sediment egestion | 24.5   | 206                        | 2                  | 51, 54, 55, 58 | Lotufo &amp; Fleeger, 1996 |
| <em>Limnodrilus hoffmeisteri</em> | mature         | Y | 98%       | sediment from drainage system, &lt;125 µm | 25  | 1.2    | 10 d              | EC50    | sediment egestion | 48      | 407                        | 2                  | 47, 51, 54, 55, 58 | Lotufo &amp; Fleeger, 1996 |</p>
<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Purity [%]</th>
<th>Sediment type</th>
<th>pH</th>
<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value test sediment [mg/kgdw]</th>
<th>Value standard sediment [mg/kgdw]</th>
<th>Ri</th>
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<td>sediment from drainage system, &lt;125 µm</td>
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<tr>
<td><em>Limnodrilus hoffmeisteri</em></td>
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<td>98%</td>
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<tr>
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<td>47, 51, 54, 55, 58</td>
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<td>14 d</td>
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**Table 129: Acute toxicity of anthracene (CASnr: 120-12-7) to freshwater organisms.**

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<th>Value [µg/L]</th>
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<td>4 h</td>
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<td>&gt;46 (w.s.)</td>
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<td>EC50 growth, area under the curve</td>
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**Amphibia**

- Pleurodeles waltl
  - embryo (stage 53) N R >98% am 20±0.5 6 d LC50 mortality 3 151 Fernandez & L'Haridon, 1992
- Rana pipiens
  - embryo (stage 25) N S sensitizer grade nw 0.5 h LC50 mortality 65 3 84 Kagan et al., 1984
- Rana pipiens
  - embryo (stage 25) N S sensitizer grade nw 5 h LC50 mortality 25 3 84 Kagan et al., 1984
- Rana pipiens
  - embryo (stage 24-28) N S nw tw 24 h LC50 mortality 110 3 86 Kagan et al., 1987

**Crustacea**

- Daphnia magna
  - 4-6 d N Sc ≥97% am 6.0-7.0 23±2 48 h LC50 mortality 36 3 5, 231 Abernethy et al., 1986
- Daphnia magna
  - < 24 h Y S am 7.8±0.2 20±2 250±30 48 h EC50 immobility >25 3 5 Bisson et al., 2000
- Daphnia magna
  - 1.5 mm, 4-6 d N Sc ≥97% am 6.0-7.0 23±2 48 h LC50 mortality 3000 3 231 Bobra et al., 1983
- Daphnia magna
  - <24h N S am 20±2 48h EC50 immobility >900 3 Feldmannová et al. 2006
- Daphnia magna
  - mature N S tw 2 h LC50 mortality 20 3 40 Kagan et al., 1985, 1987
- Daphnia magna
  - < 24 h N S 99% nw/dw 20±2 48 h EC50 immobility 20 3 80, 259 Lampi et al., 2006
- Daphnia magna
  - < 24 h N S 99% nw/dw 20±2 48 h EC50 immobility 11 3 80, 260 Lampi et al., 2006
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<th>Hardness [CaCO₃ mg/L]</th>
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<td>S</td>
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**Macrophyta**

| Lemma gibba             |                  | Y | S         | am         | 24      | 4 h | EC50 | Chl a fluorescense | 6600      |                | 92, 96      |     |       | Huang et al., 1997b             |
| Lemma gibba             |                  | Y | S         | am         | 24      | 4 h | EC10 | Chl a fluorescense | 590       |                | 92, 96, 120 |     |       | Huang et al., 1997b             |
| Lemma gibba             |                  | Y | S         | am         | 24      | 4 h | EC10 | Chl a fluorescense | 110       |                | 92, 96, 120 |     |       | Huang et al., 1997b             |
| Lemma gibba             |                  | Y | S         | high am    | 23      | 6 h | EC50 | Chl a fluorescense | 1800      |                | 88          |     |       | Mallakin et al., 2002           |
| Lemma gibba             |                  | Y | S         | high am    | 23      | 6 h | EC50 | Chl a fluorescense | 1000      |                | 88, 186     |     |       | Mallakin et al., 2002           |
| Lemma gibba             |                  | Y | S         | high am    | 23      | 6 h | EC50 | electron transport | 90        |                | 88          |     |       | Mallakin et al., 2002           |
| Lemma gibba             |                  | Y | S         | high am    | 23      | 6 h | EC50 | electron transport | 50        |                | 88, 186     |     |       | Mallakin et al., 2002           |
| Lemma gibba             |                  | Y | S         | high am    | 23      | 6 h | EC50 | t1/2 photosynthetic activity | 1200      |                | 88          |     |       | Mallakin et al., 2002           |

**Mollusca**

| Utterbackia imbecilis   | glochidia         | Y | R         | 98% rw     | 8.09±0.12 | 22.8±0.5 | 28 h | EC50 | Chl a fluorescense | >16.6      |                | 2           | 67 |       | Weinstein & Polk, 2001          |
| Utterbackia imbecilis   | glochidia         | Y | R         | 98% rw     | 8.09±0.12 | 22.8±0.5 | 4 h+8 h | LC50 | mortality           | 2.84       |                | 2           | 68 |       | Weinstein & Polk, 2001          |
| Utterbackia imbecilis   | glochidia         | Y | R         | 98% rw     | 8.09±0.12 | 22.8±0.5 | 4 h+16 h | LC50 | mortality           | 2.01       |                | 2           | 68 |       | Weinstein & Polk, 2001          |
| Utterbackia imbecilis   | glochidia         | Y | R         | 98% rw     | 8.09±0.12 | 22.8±0.5 | 4 h+24 h | LC50 | mortality           | 1.93       |                | 2           | 68 |       | Weinstein & Polk, 2001          |

**Pisces**

<p>| Lepomis macrochirus     | jv. 0.78±0.05 g, 3.11±0.05 cm | Y | CF Sigma grade III | tw | 7.7 | 20 | 326 | 5 d | LC50 | mortality | 1.27 | 2 | 26 | McCloskey &amp; Oris, 1991 |</p>
<table>
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<th>Species</th>
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<th>Test type</th>
<th>Purity</th>
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<th>pH</th>
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<th>Crit.</th>
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### Table 130: Chronic toxicity of anthracene (CASnr: 120-12-7) to freshwater organisms.

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**Algae**

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<td>≥900</td>
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<td>242, 249 Altenburger et al., 2004</td>
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Table 131: Acute toxicity of anthracene (CASnr: 120-12-7) to marine organisms.

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### Table 132: Chronic toxicity of anthracene (CASnr: 120-12-7) to marine organisms.

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<th>Value [µg/L]</th>
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<th>Notes</th>
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**Table 133: Toxicity of anthracene (CASnr: 120-12-7) to terrestrial organisms**

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**Macrophyta**

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**Microbial processes**

| dehydrogenase          | N >96              | natural sandy soil | 6.8 | 22     | 1.53 | 6.9 | 14 d | EC23       | 5  | 33    | 2  | 69 | Römkbke et al, 1995 |
| dehydrogenase          | N >96              | natural loamy soil | 7.3-7.4 | 22 | 1.98 | 29.5 | 14 d | EC55       | 50 | 253   | 2  | 69 | Römkbke et al, 1995 |
| dehydrogenase          | N >96              | natural sandy soil | 6.8 | 22     | 1.53 | 6.9 | 28 d | EC13       | 5  | 33    | 2  | 69 | Römkbke et al, 1994, 1995 |
| dehydrogenase          | N >96              | natural sandy soil | 6.8 | 22     | 1.53 | 6.9 | 28 d | EC5        | 50 | 327   | 2  | 69 | Römkbke et al, 1994, 1995 |
| dehydrogenase          | N >96              | natural loamy soil | 7.3-7.4 | 22 | 1.98 | 29.5 | 28 d | EC0        | 5  | 25    | 2  | 69 | Römkbke et al, 1994, 1995 |
| dehydrogenase          | N >96              | natural loamy soil | 7.3-7.4 | 22 | 1.98 | 29.5 | 28 d | EC0        | 50 | 253   | 2  | 69 | Römkbke et al, 1994, 1995 |
Table 134: Toxicity of anthracene (CASnr: 120-12-7) to benthic organisms

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<td>3.0</td>
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<td>8, 9, 26, 57, 60</td>
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<td>Y</td>
<td>99</td>
<td>natural sediment, Drontermeer, The Netherlands</td>
<td>6.0-8.5</td>
<td>20±1</td>
<td>12-14</td>
<td>15.5</td>
<td>28d</td>
<td>LC50 mortality</td>
<td>&gt;29</td>
<td>&gt;22</td>
<td>2</td>
<td>8, 9, 10, 11, 12, 57, 58</td>
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<td>99</td>
<td>natural sediment, Drontermeer, The Netherlands</td>
<td>6.0-8.5</td>
<td>20±1</td>
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<td>15.5</td>
<td>28d</td>
<td>LOEC emergence time (males only)</td>
<td>14</td>
<td>11</td>
<td>2</td>
<td>8, 9, 10, 11, 12, 57, 58</td>
<td>Paumen et al. 2008</td>
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<td>99</td>
<td>natural sediment, Drontermeer, The Netherlands</td>
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<td>4.3</td>
<td>2</td>
<td>8, 9, 10, 11, 12, 57, 58</td>
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<td>&gt;99</td>
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<td>8.4</td>
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<td>9.41</td>
<td>-</td>
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<td>20</td>
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<td>Chlamydomonas angulosa</td>
<td>5*10⁴ cells/ml</td>
<td>N</td>
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<td>am</td>
<td>6.5</td>
<td>19</td>
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<td>3 h</td>
<td>EC50 photosynthesis/assimilation</td>
<td>200</td>
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<td>25, 106, 231</td>
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<td>72 h</td>
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<td>500</td>
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<td>Scenedesmus subspicatus</td>
<td>10⁴ cells/ml</td>
<td>N</td>
<td>S &gt;98%</td>
<td>am</td>
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<td>25±1</td>
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<td>growth, area under the curve</td>
<td>18.72</td>
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<td>Scenedesmus vacuolatus</td>
<td>7.5*10⁴ cells/ml</td>
<td>Y</td>
<td>Sc</td>
<td>99%</td>
<td>am</td>
<td>6.9±0.2</td>
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<td>24 h</td>
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<td>Altenburger et al., 2004</td>
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<td>Rana pipiens</td>
<td>embryos (stage 24-28)</td>
<td>N</td>
<td>S</td>
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<td>LC50 mortality</td>
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<td>4-6 d</td>
<td>N</td>
<td>Sc</td>
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<td>am</td>
<td>6.0-7.0</td>
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<td>5, 231</td>
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<td>Y</td>
<td>Sc</td>
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<td>am</td>
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<td>Sc</td>
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<td>am</td>
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<td></td>
<td></td>
<td>2 h</td>
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<td>&lt; 24 h</td>
<td>N</td>
<td>S</td>
<td>95%</td>
<td>mw/d w</td>
<td>20±2</td>
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<td>48 h</td>
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<td>3</td>
<td>80, 259</td>
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<td>S</td>
<td>95%</td>
<td>mw/d w</td>
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<td>S</td>
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<td>am</td>
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<td>20±2</td>
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<td>10</td>
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<td>am</td>
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<td>nw</td>
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<td>48 h</td>
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<td>48 h</td>
<td>EC50</td>
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<td>250 h</td>
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<td>N S 99%</td>
<td>nw</td>
<td>8.0</td>
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### Table 136: Chronic toxicity of pyrene (CASnr: 129-00-0) to freshwater organisms.

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### Note
- **Ri**: Reference number
- **Notes**: Additional notes or comments
- **Reference**: Scientific reference for the data reported.
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Table 137: Acute toxicity of pyrene (CASnr: 129-00-0) to marine organisms.
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Table 138: Chronic toxicity of pyrene (CASnr: 129-00-0) to marine organisms.

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<td>embryo/larval</td>
<td>N</td>
<td>S</td>
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<td>Y</td>
<td>Sc</td>
<td>am 8.29±0.11</td>
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### Table 139: Toxicity of pyrene (CASnr: 129-00-0) to terrestrial organisms

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<th>Crit.</th>
<th>Endpoint</th>
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<td>Sc</td>
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<td>NOEC</td>
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<td>20h</td>
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<td>Bellas et al. 2008</td>
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*Table 139: Toxicity of pyrene (CASnr: 129-00-0) to terrestrial organisms*
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<th>Species</th>
<th>Species properties</th>
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<th>Purity [%]</th>
<th>Soil type</th>
<th>pH</th>
<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time [h]</th>
<th>Crit. Endpoint</th>
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<td>96h</td>
<td>EC50 fluorescence</td>
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**Microbial process**

| nitrification         | Y dessicate       | sandy loam | 6.2 | 20     | 2.7 | 13 | 28 d | EC10 | 130 | 478 | 2 | 10, 21, 78 | Sverdrup et al., 2002d |

Reference:
- Baek et al 2004
- Sverdrup et al, 2002d
### Table 140: Toxicity of pyrene (CASnr: 129-00-0) to benthic organisms

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### Table 141: Acute toxicity of fluoranthene (CASnr: 206-44-0) to freshwater organisms.

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Table 142: Chronic toxicity of fluoranthene (CASnr: 206-44-0) to freshwater organisms.

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### Table 144: Chronic toxicity of fluoranthene (CASnr: 206-44-0) to marine organisms.

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<td>Ri</td>
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<td>74, 90, 94</td>
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<td>93, 90, 94</td>
<td>Boese et al., 1999</td>
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### Echinodermata

<p>| Lytechinus anemesis           | ciliated blastula stage | N | S        | 99% nw 7.8 16 | until late gastrula stage | EC50 | malformation | 820 | 3  | 102 Pillai et al., 2003 |
| Lytechinus anemesis           | ciliated blastula stage | N | S        | 99% nw 7.8 16 | until late gastrula stage | EC10 | malformation | 82  | 3  | Pillai et al., 2003 |
| Lytechinus anemesis           | ciliated blastula stage | N | S        | 99% nw 7.8 16 | until late gastrula stage | NOEC | malformation | 100 | 3  | Pillai et al., 2003 |
| <em>Paracentrotus lividus</em>       | fertilized eggs        | Y | Sc       | 8.29±0.11 18 | 34.20±0.15 48 h EC50 | larval development | &gt;253 | 2  | 5, 273 Bellas et al. 2008 |
| <em>Paracentrotus lividus</em>       | fertilized eggs        | Y | Sc       | 8.29±0.11 18 | 34.20±0.15 48 h EC10 | larval development | 27  | 2  | 5, 273 Bellas et al. 2008 |
| <em>Paracentrotus lividus</em>       | fertilized eggs        | Y | Sc       | 8.29±0.11 18 | 34.20±0.15 48 h LOEC | larval development | 34  | 2  | 5, 273 Bellas et al. 2008 |
| <em>Paracentrotus lividus</em>       | fertilized eggs        | Y | Sc       | 8.29±0.11 18 | 34.20±0.15 48 h EC50 | larval development | 48  | 2  | 272, 273 Bellas et al. 2008 |
| <em>Paracentrotus lividus</em>       | fertilized eggs        | Y | Sc       | 8.29±0.11 18 | 34.20±0.15 48 h EC10 | larval development | 21  | 2  | 272, 273 Bellas et al. 2008 |
| <em>Paracentrotus lividus</em>       | fertilized eggs        | Y | Sc       | 8.29±0.11 18 | 34.20±0.15 48 h LOEC | larval development | 34  | 2  | 272, 273 Bellas et al. 2008 |</p>
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<th>Salinity [‰]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
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<td>nw</td>
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<td>Bellas et al. 2008</td>
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<td>Species</td>
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<td>Purity [%]</td>
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<td>Salinity [%]</td>
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<td>Crit. Endpoint</td>
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**Table 145: Toxicity of fluoranthene (CASnr: 206-44-0) to terrestrial organisms**

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<th>A Purity</th>
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<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
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<th>Crit. Endpoint</th>
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<td>weight</td>
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<td>≥600</td>
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<td>Schaub &amp; Achazi, 1996</td>
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<td>28 d</td>
<td>NOEC cocoon production</td>
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<td>Schaub &amp; Achazi, 1996</td>
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<td>sandy loam</td>
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<td>Sverdrup et al., 2002a</td>
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<td>21 d</td>
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<td>Sverdrup et al., 2002b</td>
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<td>sandy loam</td>
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<td>21 d</td>
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**Microbial process**

| dehydrogenase                | N                  | gleyic luvisol | 6.5 | room temp | 1.4 | 16.4 | 10 d       | NOEC | ≥200                  | ≥1384 | 2            | Eschenbach et al., 1991 |
| heterotrophic flagellates    | Y >99              | sandy loam     | 6.2 | 20         | 2.7 | 13   | 28 d       | ECS  | number 2200          | 8088  | 2            | Sverdrup et al., 2002d |
| nitrification                | Y >99              | sandy loam     | 6.2 | 20         | 2.7 | 13   | 28 d       | EC10 | 13                    | 48    | 2            | Sverdrup et al., 2002d |
| nitrification                | Y >99              | sandy loam     | 6.2 | 20         | 2.7 | 13   | 28 d       | NOEC | 24                    | 88    | 2            | Sverdrup et al., 2002d |
| respiration (CO₂)            | N                  | gleyic luvisol | 6.5 | room temp | 1.4 | 16.4 | 20 h       | NOEC | ≥200                  | ≥1384 | 2            | Eschenbach et al., 1991 |

**Mollusca**

| *Helix aspersa*              | juvenile, 5-7 w, 1.5±0.2 g, 18±2 mm shell | Y >99% | sandy loam | 6.2 | 20 | 2.7 | 13 | 21 d | NOEC | growth | ≥2722 | ≥10008 | 2 | 78, 84 | Sverdrup et al., 2006 |

### Table 146: Toxicity of fluoranthene (CASnr: 206-44-0) to benthic organisms

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Purity</th>
<th>Sediment type</th>
<th>pH</th>
<th>T</th>
<th>Organic matter</th>
<th>Clay</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
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<th>Value standard sediment [mg/kg dw]</th>
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<td>20±2</td>
<td>3.4</td>
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<td>mortality/growth</td>
<td>&lt;3</td>
<td>&lt;8.8</td>
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<td>45, 56, 59</td>
<td>Verrhiest et al., 2001</td>
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<td>10-12 d</td>
<td>Y</td>
<td></td>
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<td>6.5-8.5</td>
<td>20±1</td>
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<td>7.3</td>
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<td>53, 58</td>
<td>Suedel et al., 1993</td>
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<td>10-12 d</td>
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<td>53, 58</td>
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<td>mortality</td>
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<td>Clay [%]</td>
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<td>Crit.</td>
<td>Endpoint</td>
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<td>EC50</td>
<td>defecation rate of faecal pellets</td>
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<td>96-120 h</td>
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<td>96-120 h</td>
<td>EC50</td>
<td>defecation rate of faecal pellets</td>
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<td>Bowmer, 1994</td>
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<td>Mercenaria mercenaria</td>
<td>juvenile, 212-350 µm</td>
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<td>19.8-20.4</td>
<td>7.9-8.1</td>
<td>Y</td>
<td>River sediment from folly River, SC, USA</td>
<td>13</td>
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<td>LC50</td>
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Table 147: Acute toxicity of chrysene (CASnr: 218-01-9) to freshwater organisms.

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<th>A</th>
<th>Test water</th>
<th>Purity [%]</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<td>48 h</td>
<td>EC2</td>
<td>growth</td>
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<td>Jamroz et al., 2003</td>
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<td>N S 95</td>
<td></td>
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<td></td>
<td>48 h</td>
<td>EC1</td>
<td>growth</td>
<td>0.96</td>
<td>3</td>
<td>104</td>
<td>Jamroz et al., 2003</td>
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<td><strong>Crustacea</strong></td>
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<tr>
<td>Daphnia magna</td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>am</td>
<td>7.8±0.2</td>
<td>20±2</td>
<td>250±30</td>
<td>48 h</td>
<td>EC50</td>
<td>immobility</td>
<td>&gt;1.3</td>
<td>2</td>
<td>5</td>
<td>Bisson et al., 2000</td>
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<tr>
<td>Daphnia magna</td>
<td>mature</td>
<td>N</td>
<td>tw</td>
<td>2 h</td>
<td>7.8±0.2</td>
<td>20±2</td>
<td>250±30</td>
<td>48 h</td>
<td>LC50</td>
<td>mortality</td>
<td>1900</td>
<td>3</td>
<td>40</td>
<td>Kagan et al., 1987</td>
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<td>Species</td>
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<td>pH</td>
<td>T °C</td>
<td>Hardness CaCO₃ [mg/L]</td>
<td>Exp. time</td>
<td>Crit. Endpoint</td>
<td>Value [µg/L]</td>
<td>Ri</td>
<td>Notes</td>
<td>Reference</td>
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<tr>
<td>Daphnia magna</td>
<td>&lt; 24 h</td>
<td>N S</td>
<td>98%</td>
<td>nw/dw</td>
<td>20±2</td>
<td>48 h</td>
<td>EC50 immobility</td>
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<td>80, 260</td>
<td>Lampi et al., 2006</td>
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<td>Daphnia magna</td>
<td>neonates &lt;24 h</td>
<td>N S</td>
<td>am</td>
<td>8.0</td>
<td>21±1</td>
<td>24 h</td>
<td>EC50 immobility</td>
<td>&gt;1024</td>
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<td>3.80, 163</td>
<td>3</td>
<td>105, 163</td>
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<td>neonates &lt;24 h</td>
<td>N S</td>
<td>am</td>
<td>8.0</td>
<td>21±1</td>
<td>27 h</td>
<td>EC50 immobility</td>
<td>&gt;1024</td>
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<td>3.80, 163</td>
<td>3</td>
<td>105, 163</td>
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<td>Cyanophyta</td>
<td>Anabaena flos-aqua</td>
<td>2*10^5 cells/ml</td>
<td>Y S</td>
<td>a.g.</td>
<td>am</td>
<td>29</td>
<td>NOEC nitrogen fixation</td>
<td>5.0</td>
<td></td>
<td>3 210</td>
<td>3</td>
<td>92, 210</td>
<td>Bastian &amp; Toetz, 1985</td>
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<tr>
<td>Cyanophyta</td>
<td>Anabaena flos-aqua</td>
<td>2*10^5 cells/ml</td>
<td>Y S</td>
<td>a.g.</td>
<td>am</td>
<td>29</td>
<td>EC10 nitrogen fixation</td>
<td>5.3</td>
<td></td>
<td>3 92, 210</td>
<td>3</td>
<td>92, 210</td>
<td>Bastian &amp; Toetz, 1985</td>
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<tr>
<td>Insecta</td>
<td>Aedes aegypti</td>
<td>&lt; 8 h, first instar</td>
<td>N S</td>
<td>tw</td>
<td>&lt;24 h</td>
<td>LC50 mortality</td>
<td>1700</td>
<td></td>
<td>3 41</td>
<td>3</td>
<td>141</td>
<td>Kagan et al., 1987</td>
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</table>

Table 148: Chronic toxicity of chrysene (CASnr: 218-01-9) to freshwater organisms.

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T °C</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tr>
<td>Algae</td>
<td>Pseudokirchneriella subcapitata</td>
<td>Y S</td>
<td>am</td>
<td>23±2</td>
<td>215</td>
<td>72 h</td>
<td>EC10 growth</td>
<td>&gt;1</td>
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<td>2 167</td>
<td>167</td>
<td>167</td>
<td>Bisson et al., 2000</td>
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<td>Crustacea</td>
<td>Ceriodaphnia dubia</td>
<td>&lt; 24 h</td>
<td>Y R</td>
<td>nw 8.1±0.4</td>
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<td>7 d</td>
<td>EC10 reproduction</td>
<td>&gt;0.09</td>
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<td>2 168</td>
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<td>&lt;24 h</td>
<td>Y IF</td>
<td>99-100%</td>
<td>rw 7.3-8.1</td>
<td>212</td>
<td>21 d</td>
<td>NOEC mortality</td>
<td>≥1.4</td>
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<td>2 45</td>
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<td>45</td>
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<td>Daphnia magna</td>
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<td>Y IF</td>
<td>99-100%</td>
<td>rw 7.3-8.1</td>
<td>212</td>
<td>21 d</td>
<td>NOEC reproduction</td>
<td>≥1.4</td>
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<td>Cyanophyta</td>
<td>Anabaena flos-aqua</td>
<td>10^-4 cells/ml</td>
<td>Y S</td>
<td>p.a.</td>
<td>am</td>
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<td>NOEC standing crop</td>
<td>640</td>
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<tr>
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<td>N S</td>
<td>am</td>
<td>8 d</td>
<td>ECS</td>
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<td>growth rate</td>
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<td>Huang et al., 1997a</td>
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<td>am</td>
<td>8 d</td>
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<td>2000</td>
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<td>3 94, 113</td>
<td>94</td>
<td>113</td>
<td>Huang et al., 1997a</td>
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Table 149: Acute toxicity of chrysene (CASnr: 218-01-9) to marine organisms.

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<th>Species</th>
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<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO3 [mg/L]</th>
<th>Exp. time [µg/L]</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
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<td>Danio rerio</td>
<td>ELS</td>
<td>Y</td>
<td>iF</td>
<td>rw</td>
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<td>NOEC</td>
<td>mortality, hatchability, length, weight</td>
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<td>2</td>
<td>80, 136, 284</td>
<td>Hooftman &amp; Evers-de Ruiter, 1992b</td>
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| Algae                    |                    |    |           |            |            |    |        |                       |                 |               |             |     |       |                          |
| Antithamnion plumula     | spores             | N  | Sc        | rw         | 16         | 22±2 | 96h    | EC50 growth stimulation | 300             |              |             | 3   |       | Boney, 1974              |
| Phaeodactylum tricornutum| 10^4 cells/ml      | N  | S         | rw         | 22±2       | 96h  | EC50   | growth                | 1.0             |              |             | 3   | 282   | Okay and Karacik 2007    |
| Phaeodactylum tricornutum| 10^4 cells/ml      | N  | S         | rw         | 22±2       | 96h  | EC50   | growth                | 0.63            |              |             | 3   | 283   | Okay and Karacik 2007    |

| Annelida                 |                    |    |           |            |            |    |        |                       |                 |               |             |     |       |                          |
| Neanthes arenaceodentata | immature young adult | Y | S        | >98%       | am         | 22±2 | 96 h   | LC50 mortality        | >1000           |              |             | 3   | 50    | Rossi & Neff, 1978       |

<p>| Bacteria                 |                    |    |           |            |            |    |        |                       |                 |               |             |     |       |                          |
| Vibrio fischeri          | N                  | S  | p.a.      | am         | 19         | 15 min | EC50   | bioluminescence       | &gt;100000         |              |             | 3   | 1     | Arfsten et al., 1994     |
| Vibrio fischeri          | N                  | S  | p.a.      | am         | 19         | 30 min | EC50   | bioluminescence       | &gt;100000         |              |             | 3   | 2     | Arfsten et al., 1994     |
| Vibrio fischeri          | N                  | S  | p.a.      | am         | 19         | 15 min | EC50   | bioluminescence       | &gt;100000         |              |             | 3   | 2     | Arfsten et al., 1994     |
| Vibrio fischeri          | N                  | S  | p.a.      | am         | 19         | 30 min | EC50   | bioluminescence       | &gt;100000         |              |             | 3   | 2     | Arfsten et al., 1994     |
| Vibrio fischeri          | N                  | S  | am        | 7.2        | 15 min     | EC50   | bioluminescence       | 1430            |              |             | 3   | 4, 5  | El-Alawi et al., 2002    |
| Vibrio fischeri          | N                  | S  | am        | 7.2        | 15 min     | EC50   | bioluminescence       | 1370            |              |             | 3   | 4, 6  | El-Alawi et al., 2002    |
| Vibrio fischeri          | N                  | S  | p.a.      | am         | 17         | 5 min  | EC50   | bioluminescence       | 920             |              |             | 3   |       | Johnson &amp; Long, 1998     |
| Vibrio fischeri          | N                  | S  | 95        |            | 15 min     | EC7    | bioluminescence       | 0.96            |              |             | 3   |       | Jamroz et al., 2003      |
| Vibrio fischeri          | N                  | S  | 95        |            | 15 min     | EC5    | bioluminescence       | 0.96            |              |             | 3   | 104   | Jamroz et al., 2003      |</p>
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<th>Purity</th>
<th>Test type</th>
<th>pH</th>
<th>T</th>
<th>Salinity</th>
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<th>Crit.</th>
<th>Endpoint</th>
<th>Value</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tbody>
<tr>
<td><em>Vibrio fischeri</em></td>
<td></td>
<td>Y</td>
<td>S</td>
<td>99% am</td>
<td>15</td>
<td>20</td>
<td>30 min</td>
<td>EC10</td>
<td>bioluminescence</td>
<td>&gt;w.s.</td>
<td>2</td>
<td>115</td>
<td>Loibner et al., 2004</td>
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**Crustacea**

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Purity</th>
<th>Test type</th>
<th>pH</th>
<th>T</th>
<th>Salinity</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td><em>Artemia salina</em></td>
<td>&lt; 1 d</td>
<td>N</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 h</td>
<td>LC50</td>
<td>mortality</td>
<td>3000</td>
<td>3</td>
<td>61</td>
<td>Kagan et al., 1987</td>
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</table>

**Mollusca**

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<th>Test type</th>
<th>pH</th>
<th>T</th>
<th>Salinity</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td><em>Mytilus galloprovincialis</em></td>
<td>4-5 cm</td>
<td>N</td>
<td>R</td>
<td>nw</td>
<td>22±2</td>
<td>22</td>
<td>7d</td>
<td>NOEC</td>
<td>filtration rate</td>
<td>≥1.8</td>
<td>3</td>
<td>5</td>
<td>Okay and Karacik 2008</td>
<td></td>
</tr>
<tr>
<td><em>Mytilus galloprovincialis</em></td>
<td>4-5 cm</td>
<td>N</td>
<td>R</td>
<td>nw</td>
<td>22±2</td>
<td>22</td>
<td>7d</td>
<td>EC0</td>
<td>filtration rate</td>
<td>1.8</td>
<td>3</td>
<td>5</td>
<td>Okay and Karacik 2008</td>
<td></td>
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<tr>
<td><em>Mytilus galloprovincialis</em></td>
<td>4-5 cm</td>
<td>N</td>
<td>R</td>
<td>nw</td>
<td>22±2</td>
<td>22</td>
<td>7d</td>
<td>NOEC</td>
<td>filtration rate</td>
<td>≥1.8</td>
<td>3</td>
<td>185</td>
<td>Okay and Karacik 2008</td>
<td></td>
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<tr>
<td><em>Mytilus galloprovincialis</em></td>
<td>4-5 cm</td>
<td>N</td>
<td>R</td>
<td>nw</td>
<td>22±2</td>
<td>22</td>
<td>7d</td>
<td>EC0</td>
<td>filtration rate</td>
<td>1.8</td>
<td>3</td>
<td>185</td>
<td>Okay and Karacik 2008</td>
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**Table 150: Chronic toxicity of chrysene (CASnr: 218-01-9) to marine organisms.**

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<th>T</th>
<th>Salinity</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tbody>
<tr>
<td><em>Phaeodactylum tricornutum</em></td>
<td>10^4 cells/ml</td>
<td>N</td>
<td>S</td>
<td>nw</td>
<td>22±2</td>
<td>22</td>
<td>96h</td>
<td>EC10</td>
<td>growth</td>
<td>&gt;1.8</td>
<td>3</td>
<td>279</td>
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<td>Okay and Karacik 2007</td>
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**Bacteria**

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<th>Species</th>
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<th>Test type</th>
<th>pH</th>
<th>T</th>
<th>Salinity</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value</th>
<th>Ri</th>
<th>Notes</th>
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<tr>
<td><em>Vibrio fischeri</em></td>
<td></td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>7.2</td>
<td>20</td>
<td>8+18 h</td>
<td>EC50</td>
<td>bioluminescence</td>
<td>89980</td>
<td>3</td>
<td>24, 5</td>
<td>El-Alawi et al., 2002</td>
<td></td>
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<tr>
<td><em>Vibrio fischeri</em></td>
<td></td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>7.2</td>
<td>20</td>
<td>8+18 h</td>
<td>EC50</td>
<td>bioluminescence</td>
<td>84750</td>
<td>3</td>
<td>24, 6</td>
<td>El-Alawi et al., 2002</td>
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<td>N</td>
<td>S</td>
<td>am</td>
<td>7.2</td>
<td>20</td>
<td>8+18 h</td>
<td>EC50</td>
<td>growth</td>
<td>89680</td>
<td>3</td>
<td>24, 5</td>
<td>El-Alawi et al., 2002</td>
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<td><em>Vibrio fischeri</em></td>
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<td>N</td>
<td>S</td>
<td>am</td>
<td>7.2</td>
<td>20</td>
<td>8+18 h</td>
<td>EC50</td>
<td>growth</td>
<td>84940</td>
<td>3</td>
<td>24, 6</td>
<td>El-Alawi et al., 2002</td>
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### Table 151: Toxicity of chrysene (CASnr: 218-01-9) to terrestrial organisms

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<th>Species</th>
<th>Species properties</th>
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<th>Purity [%]</th>
<th>Soil type</th>
<th>pH</th>
<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time [d]</th>
<th>Crit. Endpoint</th>
<th>Value test soil [mg/kgdw]</th>
<th>Value standard soil [mg/kgdw]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<td>Annelida</td>
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<tr>
<td>Eisenia fetida</td>
<td></td>
<td>Y</td>
<td>artificial soil</td>
<td>room temp</td>
<td>10</td>
<td>20</td>
<td>14 d</td>
<td>NOEC mortality</td>
<td>≥1000</td>
<td>≥1000</td>
<td>2</td>
<td>11, 45, 59, 70</td>
<td>Bowmer et al., 1993</td>
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<td>Insecta</td>
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<tr>
<td>Folsomia candida</td>
<td>10-12 d</td>
<td>Y</td>
<td>artificial soil</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>28 d</td>
<td>NOEC reproduction (number of cocoons)</td>
<td>≥180</td>
<td>≥180</td>
<td>3</td>
<td>30, 31, 59</td>
<td>Bowmer et al., 1993</td>
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<tr>
<td>Folsomia fimetaria</td>
<td>23-26 d</td>
<td>Y</td>
<td>&gt;95 sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>LC50 mortality</td>
<td>&gt;1030</td>
<td>&gt;3787</td>
<td>2</td>
<td>12, 21, 78</td>
<td>Sverdrup et al., 2002</td>
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<td>Table 152: Acute toxicity of benz[a]anthracene (CASnr: 56-55-3) to freshwater organisms.</td>
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<td>Species</td>
<td>Species properties</td>
<td>A</td>
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<td>Purity [%]</td>
<td>Test water</td>
<td>pH</td>
<td>T [°C]</td>
<td>Hardness CaCO₃ [mg/L]</td>
<td>Exp. time [h]</td>
<td>Crit. Endpoint</td>
<td>Value [µg/L]</td>
<td>Ri</td>
<td>Notes</td>
<td>Reference</td>
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<tr>
<td>Algae</td>
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<tr>
<td>Pseudokirchneriella subcapitata</td>
<td></td>
<td>N</td>
<td>S</td>
<td>≥99% am</td>
<td>23</td>
<td>96 h</td>
<td>EC50 growth rate</td>
<td>&gt;40000</td>
<td>3</td>
<td>47</td>
<td>Cody et al., 1984</td>
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</tr>
<tr>
<td>Scenedesmus vacuolatus</td>
<td>7.5*10^4 cells/ml</td>
<td>Y</td>
<td>Sc</td>
<td>99% am</td>
<td>6.9±0.2</td>
<td>28±0.5</td>
<td>24 h</td>
<td>EC50 cell number</td>
<td>14</td>
<td>2</td>
<td>242, 249</td>
<td>Altenburger et al., 2004</td>
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<td>Amphibia</td>
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<tr>
<td>Pleurodeles waltl</td>
<td>larvae (stage 53)</td>
<td>N</td>
<td>R</td>
<td>~95% am</td>
<td>20±0.5</td>
<td>6 d</td>
<td>LC50 mortality</td>
<td>3.125&lt;&gt;6.25</td>
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<td>151</td>
<td>Fernandez &amp; L’Haridon, 1992</td>
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<tr>
<td>Crustacea</td>
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<tr>
<td>Daphnia magna</td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>S</td>
<td>am</td>
<td>7.8±0.2</td>
<td>20±2</td>
<td>250±30</td>
<td>48 h</td>
<td>EC50 immobility</td>
<td>&gt;9.1</td>
<td>2</td>
<td>5</td>
<td>Bisson et al., 2000</td>
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</tbody>
</table>
### Table 153: Chronic toxicity of benz[a]anthracene (CASnr: 56-55-3) to freshwater organisms.

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tbody>
<tr>
<td><strong>Algae</strong></td>
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</tr>
<tr>
<td>Pseudokirchneriella subcapitata</td>
<td></td>
<td>Y</td>
<td>am</td>
<td>≥99%</td>
<td>nw</td>
<td>7.5</td>
<td>15±2</td>
<td></td>
<td>96 h</td>
<td>LC50 mortality</td>
<td>10</td>
<td>2</td>
<td>36</td>
<td>Trucco et al., 1983</td>
</tr>
<tr>
<td>Scenedesmus vacuolatus</td>
<td>7.5*10⁴ cells/ml</td>
<td>Y</td>
<td>am</td>
<td>99%</td>
<td>nw</td>
<td>6.9±0.2</td>
<td>28±0.5</td>
<td></td>
<td>24 h</td>
<td>EC10 cell number</td>
<td>8.0</td>
<td>2</td>
<td>242, 249</td>
<td>Altenburger et al., 2004</td>
</tr>
<tr>
<td><strong>Cyanobacteria</strong></td>
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</tr>
<tr>
<td>Anabaena flos-aquae</td>
<td>2*10⁵ cells/ml</td>
<td>Y</td>
<td>a.g.</td>
<td>am</td>
<td>29</td>
<td>21±1</td>
<td>28±0.5</td>
<td></td>
<td>2 h</td>
<td>NOEC nitrogen fixation</td>
<td>19</td>
<td>3</td>
<td>210</td>
<td>Bastian &amp; Toetz, 1985</td>
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<tr>
<td>Anabaena flos-aquae</td>
<td>2*10⁵ cells/ml</td>
<td>Y</td>
<td>a.g.</td>
<td>am</td>
<td>29</td>
<td>21±1</td>
<td>250</td>
<td></td>
<td>24 h</td>
<td>EC50 immobility</td>
<td>≥1024</td>
<td>3</td>
<td>80, 163</td>
<td>Wernersson 2003</td>
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<td>Scenedesmus vacuolatus</td>
<td>7.5*10⁴ cells/ml</td>
<td>Y</td>
<td>am</td>
<td>≥99%</td>
<td>nw</td>
<td>6.9±0.2</td>
<td>72±1</td>
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<td>72 h</td>
<td>EC10 growth rate</td>
<td>18</td>
<td>3</td>
<td>47, 102</td>
<td>Cody et al., 1984</td>
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<tr>
<td>Scenedesmus vacuolatus</td>
<td>7.5*10⁴ cells/ml</td>
<td>Y</td>
<td>am</td>
<td>99%</td>
<td>nw</td>
<td>6.9±0.2</td>
<td>28±0.5</td>
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<td>24 h</td>
<td>EC10 cell number</td>
<td>8.0</td>
<td>2</td>
<td>242, 249</td>
<td>Altenburger et al., 2004</td>
</tr>
</tbody>
</table>

**Notes:**
- A: Algae
- Y: Yellow
- Sc: Silver
- T: Test temperature
- Purity: [%, ±]
- Test water: nw/dw
- pH: [±]
- Hardness: CaCO₃ [mg/L]
- Exp. time: [h]
- Crit. Endpoint: Value [µg/L]
- Notes: Reference
Table 154: Acute toxicity of benz[a]anthracene (CASnr: 56-55-3) to marine organisms.

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tr>
<td>Ceriodaphnia dubia</td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>R</td>
<td>nw</td>
<td>8.1±0.4</td>
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<td>240±40</td>
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<td>reproduction</td>
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<td>Bisson et al., 2000</td>
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<tr>
<td>Anabaena flos-aqua</td>
<td>10^4 cells/ml</td>
<td>Y</td>
<td>S p.a.</td>
<td>am</td>
<td>29</td>
<td>2 w</td>
<td>NOEC</td>
<td>standing crop</td>
<td>8.3</td>
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<td>3</td>
<td>143</td>
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<td>Bastian &amp; Toetz, 1982</td>
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<tr>
<td>Lemma gibba</td>
<td>N S</td>
<td>am</td>
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<td>8 d</td>
<td>EC70</td>
<td>growth rate</td>
<td>2000</td>
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<td>3</td>
<td>94</td>
<td>113</td>
<td>Huang et al., 1997a</td>
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<td>Lemma gibba</td>
<td>N S</td>
<td>am</td>
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<td>EC100</td>
<td>growth rate</td>
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<td>Oryzias latipes</td>
<td>ELS</td>
<td>N</td>
<td>Rc</td>
<td>am</td>
<td>24±1</td>
<td>~300</td>
<td>18 d</td>
<td>NOEC</td>
<td>≥200</td>
<td>hatchling, time to hatch</td>
<td>3</td>
<td>258</td>
<td></td>
<td>Rhodes et al. 2005</td>
</tr>
<tr>
<td>Oryzias latipes</td>
<td>ELS</td>
<td>N</td>
<td>Rc</td>
<td>am</td>
<td>24±1</td>
<td>~300</td>
<td>18 d</td>
<td>NOEC</td>
<td>≥200</td>
<td>malformations, hatch length</td>
<td>3</td>
<td>102</td>
<td>258</td>
<td>Rhodes et al. 2005</td>
</tr>
<tr>
<td>Oryzias latipes</td>
<td>ELS</td>
<td>N</td>
<td>Rc</td>
<td>am</td>
<td>24±1</td>
<td>~300</td>
<td>18 d</td>
<td>EC10</td>
<td>79</td>
<td>malformations</td>
<td>3</td>
<td>102</td>
<td>258</td>
<td>Rhodes et al. 2005</td>
</tr>
<tr>
<td><strong>Protozoa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrahymena pyriformis</td>
<td>2*10^4 cells/ml</td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>28</td>
<td>6 h</td>
<td>NOEC</td>
<td>cell viability</td>
<td>&gt;8400</td>
<td></td>
<td>3</td>
<td>251</td>
<td></td>
<td>Bamdad et al., 1997</td>
</tr>
</tbody>
</table>

Table 154: Acute toxicity of benz[a]anthracene (CASnr: 56-55-3) to marine organisms.
Table 155: Chronic toxicity of benz[a]anthracene (CASnr: 56-55-3) to marine organisms.

<table>
<thead>
<tr>
<th>Species</th>
<th>Test type</th>
<th>Purity</th>
<th>Test water</th>
<th>pH</th>
<th>T</th>
<th>Salinity</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibrio fischeri</td>
<td>Y</td>
<td>S 99%</td>
<td>am</td>
<td>15</td>
<td>20</td>
<td>30 min</td>
<td>EC10</td>
<td>bioluminescence</td>
<td>&gt;w.s.</td>
<td>2</td>
<td>115</td>
<td>Loibner et al., 2004</td>
</tr>
</tbody>
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Table 156: Toxicity of benz[a]anthracene (CASnr: 56-55-3) to terrestrial organisms

<table>
<thead>
<tr>
<th>Species</th>
<th>Test type</th>
<th>Purity</th>
<th>Soil type</th>
<th>pH</th>
<th>T</th>
<th>Organic matter</th>
<th>Clay</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value test soil [mg/kg dw]</th>
<th>Value standard soil [mg/kg dw]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enchytraeus crypticus</td>
<td>adult</td>
<td>0.4-0.6 cm</td>
<td>Y 99</td>
<td>sandy loam</td>
<td>5.6±0.4</td>
<td>20</td>
<td>3.9</td>
<td>8.1</td>
<td>28 d</td>
<td>LC50 mortality</td>
<td>&gt;930</td>
<td>&gt;2379</td>
<td>2</td>
<td>21, 57, 67, 85</td>
</tr>
<tr>
<td>Enchytraeus crypticus</td>
<td>adult</td>
<td>0.4-0.6 cm</td>
<td>Y 99</td>
<td>sandy loam</td>
<td>5.6±0.4</td>
<td>20</td>
<td>3.9</td>
<td>8.1</td>
<td>28 d</td>
<td>EC50 reproduction</td>
<td>&gt;930</td>
<td>&gt;2379</td>
<td>2</td>
<td>21, 57, 67, 85</td>
</tr>
<tr>
<td>Species</td>
<td>Species properties</td>
<td>A purity</td>
<td>Soil type</td>
<td>pH</td>
<td>T [°C]</td>
<td>Organic matter [%]</td>
<td>Clay [%]</td>
<td>Exp. time [d]</td>
<td>Crit.</td>
<td>Endpoint</td>
<td>Value test soil [mg/kg dw]</td>
<td>Value standard soil [mg/kg dw]</td>
<td>RI</td>
<td>Notes</td>
</tr>
<tr>
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</tr>
<tr>
<td>Enchytraeus crypticus</td>
<td>adult 0.4-0.6 cm</td>
<td>Y 99</td>
<td>sandy loam</td>
<td>5.6±0.4</td>
<td>20</td>
<td>3.9</td>
<td>8.1</td>
<td>28</td>
<td>NOEC</td>
<td>reproduction</td>
<td>≥930</td>
<td>≥2379</td>
<td>2</td>
<td>21, 57, 67, 85</td>
</tr>
<tr>
<td><strong>Crustacea</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Oniscus asellus</td>
<td>6-10 mg</td>
<td>Y 99</td>
<td>90% leaves with 10 dogfood</td>
<td>20±1</td>
<td>&gt;90%</td>
<td>0</td>
<td>47 w</td>
<td>NOEC</td>
<td>growth females</td>
<td>9.0</td>
<td>1.0</td>
<td>≥285</td>
<td>≥32</td>
<td>2</td>
</tr>
<tr>
<td>Oniscus asellus</td>
<td>6-10 mg</td>
<td>Y 99</td>
<td>90% leaves with 10 dogfood</td>
<td>20±1</td>
<td>&gt;90%</td>
<td>0</td>
<td>47 w</td>
<td>EC10</td>
<td>growth females</td>
<td>21</td>
<td>2.3</td>
<td>≥285</td>
<td>≥32</td>
<td>2</td>
</tr>
<tr>
<td>Oniscus asellus</td>
<td>6-10 mg</td>
<td>Y 99</td>
<td>90% leaves with 10 dogfood</td>
<td>20±1</td>
<td>&gt;90%</td>
<td>0</td>
<td>47 w</td>
<td>NOEC</td>
<td>protein, reproduction, survival, growth males</td>
<td>≥285</td>
<td>≥32</td>
<td>≥285</td>
<td>≥32</td>
<td>2</td>
</tr>
<tr>
<td>Oniscus asellus</td>
<td>6-10 mg</td>
<td>Y 99</td>
<td>90% leaves with 10 dogfood</td>
<td>20±1</td>
<td>&gt;90%</td>
<td>0</td>
<td>47 w</td>
<td>NOEC</td>
<td>growth females</td>
<td>7.4</td>
<td>0.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oniscus asellus</td>
<td>6-10 mg</td>
<td>Y 99</td>
<td>90% leaves with 10 dogfood</td>
<td>20±1</td>
<td>&gt;90%</td>
<td>0</td>
<td>47 w</td>
<td>EC10</td>
<td>growth females</td>
<td>17</td>
<td>1.9</td>
<td>≤233</td>
<td>≤26</td>
<td>2</td>
</tr>
<tr>
<td>Porcellio scaber</td>
<td>7-11 mg</td>
<td>Y 99</td>
<td>90% leaves with 10 dogfood</td>
<td>20±1</td>
<td>&gt;90%</td>
<td>0</td>
<td>16 w</td>
<td>NOEC</td>
<td>growth, protein</td>
<td>≥285</td>
<td>≥32</td>
<td>≥285</td>
<td>≥32</td>
<td>2</td>
</tr>
<tr>
<td>Porcellio scaber</td>
<td>7-11 mg</td>
<td>Y 99</td>
<td>90% leaves with 10 dogfood</td>
<td>20±1</td>
<td>&gt;90%</td>
<td>0</td>
<td>16 w</td>
<td>NOEC</td>
<td>growth, protein</td>
<td>≥233</td>
<td>≥26</td>
<td>≥233</td>
<td>≥26</td>
<td>2</td>
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<td></td>
</tr>
<tr>
<td>Folsomia candida</td>
<td>11-13 d</td>
<td>Y 99</td>
<td>sandy loam</td>
<td>5.6±0.4</td>
<td>20</td>
<td>3.9</td>
<td>8.1</td>
<td>28</td>
<td>LC50</td>
<td>mortality</td>
<td>&gt;990</td>
<td>&gt;2532</td>
<td>2</td>
<td>21, 57, 67, 85</td>
</tr>
</tbody>
</table>
### Table 157: Toxicity of benz[a]anthracene (CASnr: 56-55-3) to benthic organisms

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Purity [%]</th>
<th>Soil type</th>
<th>pH</th>
<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value test soil [mg/kgdw]</th>
<th>Value standard soil [mg/kgdw]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhepoxynius abronius</td>
<td></td>
<td>Y</td>
<td>mudy sand marine sediment, McKinney Slough, OR, USA</td>
<td>15</td>
<td>4.4</td>
<td>10 d</td>
<td>LC50 mortality</td>
<td>&gt;28</td>
<td>&gt;64</td>
<td>&gt;28</td>
<td>&gt;64</td>
<td>2</td>
<td>22, 24, 46, 52, 59</td>
<td>Boese et al., 1998</td>
<td></td>
</tr>
<tr>
<td>Rhepoxynius abronius</td>
<td></td>
<td>Y</td>
<td>mudy sand marine sediment, McKinney Slough, OR, USA</td>
<td>15</td>
<td>4.4</td>
<td>10 d</td>
<td>EC50 reburial</td>
<td>&gt;28</td>
<td>&gt;64</td>
<td>&gt;28</td>
<td>&gt;64</td>
<td>2</td>
<td>22, 24, 46, 52, 59</td>
<td>Boese et al., 1998</td>
<td></td>
</tr>
<tr>
<td>Rhepoxynius abronius</td>
<td></td>
<td>Y</td>
<td>mudy sand marine sediment, McKinney Slough, OR, USA</td>
<td>15</td>
<td>4.4</td>
<td>10 d</td>
<td>LC50 mortality</td>
<td>&gt;28</td>
<td>&gt;64</td>
<td>&gt;28</td>
<td>&gt;64</td>
<td>2</td>
<td>23, 24, 46, 52, 59</td>
<td>Boese et al., 1998</td>
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<tr>
<td>Rhepoxynius abronius</td>
<td></td>
<td>Y</td>
<td>mudy sand marine sediment, McKinney Slough, OR, USA</td>
<td>15</td>
<td>4.4</td>
<td>10 d</td>
<td>EC50 reburial</td>
<td>&gt;28</td>
<td>&gt;64</td>
<td>&gt;28</td>
<td>&gt;64</td>
<td>2</td>
<td>23, 24, 46, 52, 59</td>
<td>Boese et al., 1998</td>
<td></td>
</tr>
</tbody>
</table>
Table 158: Acute toxicity of benzo[k]fluoranthene (CASnr: 207-08-9) to freshwater organisms.

<table>
<thead>
<tr>
<th>Species properties</th>
<th>A Test type</th>
<th>Purity [%]</th>
<th>Test water pH</th>
<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time [h]</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Notes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustacea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daphnia magna</td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>S</td>
<td>am</td>
<td>7.8±0.2</td>
<td>20±2</td>
<td>250±30</td>
<td>EC50 immobility</td>
<td>&gt;1.1</td>
<td>2</td>
</tr>
<tr>
<td>Daphnia magna</td>
<td>&lt;24 h</td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>7.8</td>
<td>20±1</td>
<td>250±25</td>
<td>EC50 immobility</td>
<td>&gt;1</td>
<td>3</td>
</tr>
<tr>
<td>Daphnia magna</td>
<td>&lt;24 h</td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>7.8</td>
<td>20±1</td>
<td>250±25</td>
<td>EC50 immobility</td>
<td>&gt;1</td>
<td>3</td>
</tr>
<tr>
<td>Daphnia magna</td>
<td>&lt;24 h</td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>7.8</td>
<td>20±1</td>
<td>250±25</td>
<td>EC90 immobility</td>
<td>&gt;1</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 159: Chronic toxicity of benzo[k]fluoranthene (CASnr: 207-08-9) to freshwater organisms.

<table>
<thead>
<tr>
<th>Species properties</th>
<th>A Test type</th>
<th>Purity [%]</th>
<th>Test water pH</th>
<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time [d]</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Notes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td></td>
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</tr>
<tr>
<td>Pseudokirchneriella subcapitata</td>
<td>Y</td>
<td>S</td>
<td>am</td>
<td>23±2</td>
<td>215</td>
<td>72 h</td>
<td>EC10 growth</td>
<td>&gt;1</td>
<td>2</td>
<td>167</td>
</tr>
<tr>
<td>Crustacea</td>
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</tr>
<tr>
<td>Ceriodaphnia dubia</td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>R</td>
<td>nw</td>
<td>8.1±0.4</td>
<td>25±2</td>
<td>240±40</td>
<td>EC10 reproduction</td>
<td>&gt;1.08</td>
<td>2</td>
</tr>
<tr>
<td>Daphnia magna</td>
<td>&lt;24 h</td>
<td>Y</td>
<td>R</td>
<td>am</td>
<td>20</td>
<td>21 d</td>
<td>NOEC</td>
<td>≥2.2</td>
<td>2</td>
<td>80, 287</td>
</tr>
<tr>
<td>Daphnia magna</td>
<td>&lt;24 h</td>
<td>Y</td>
<td>R</td>
<td>am</td>
<td>20</td>
<td>21 d</td>
<td>EC10</td>
<td>&gt;2.2</td>
<td>2</td>
<td>80, 287</td>
</tr>
<tr>
<td>Pisces</td>
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<td></td>
</tr>
<tr>
<td>Danio rerio</td>
<td>ELS</td>
<td>Y</td>
<td>IF</td>
<td>nw</td>
<td>7.8-8.2</td>
<td>25±1</td>
<td>204</td>
<td>LC52 length, weight</td>
<td>&lt;0.58</td>
<td>2</td>
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</tbody>
</table>
### Table 160: Acute toxicity of benzo[k]fluoranthene (CASnr: 207-08-9) to marine organisms.

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danio rerio</td>
<td>ELS</td>
<td>Y</td>
<td>IF</td>
<td>100%</td>
<td>rw</td>
<td>7.9-8.2</td>
<td>24.6-25.0</td>
<td>206</td>
<td>42 d</td>
<td>NOEC</td>
<td>mortality</td>
<td>0.35</td>
<td>2</td>
<td>23, 80, 284</td>
<td>Hooftman &amp; Evers-de Ruiter, 1992c</td>
</tr>
<tr>
<td>Danio rerio</td>
<td>ELS</td>
<td>Y</td>
<td>IF</td>
<td>100%</td>
<td>rw</td>
<td>7.9-8.2</td>
<td>24.6-25.1</td>
<td>206</td>
<td>42 d</td>
<td>LC50</td>
<td>mortality</td>
<td>0.65</td>
<td>2</td>
<td>23, 80, 92, 284</td>
<td>Hooftman &amp; Evers-de Ruiter, 1992c</td>
</tr>
<tr>
<td>Danio rerio</td>
<td>ELS</td>
<td>Y</td>
<td>IF</td>
<td>100%</td>
<td>rw</td>
<td>7.9-8.2</td>
<td>24.6-25.2</td>
<td>206</td>
<td>42 d</td>
<td>NOEC</td>
<td>length</td>
<td>&lt;0.19</td>
<td>2</td>
<td>23, 80, 284</td>
<td>Hooftman &amp; Evers-de Ruiter, 1992c</td>
</tr>
<tr>
<td>Danio rerio</td>
<td>ELS</td>
<td>Y</td>
<td>IF</td>
<td>100%</td>
<td>rw</td>
<td>7.9-8.2</td>
<td>24.6-25.3</td>
<td>206</td>
<td>42 d</td>
<td>EC50</td>
<td>length</td>
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<td>2</td>
<td>23, 80, 284</td>
<td>Hooftman &amp; Evers-de Ruiter, 1992c</td>
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<td>ELS</td>
<td>Y</td>
<td>IF</td>
<td>100%</td>
<td>rw</td>
<td>7.9-8.2</td>
<td>24.6-25.4</td>
<td>206</td>
<td>42 d</td>
<td>EC10</td>
<td>length</td>
<td>0.17</td>
<td>2</td>
<td>23, 80, 284</td>
<td>Hooftman &amp; Evers-de Ruiter, 1992c</td>
</tr>
<tr>
<td>Danio rerio</td>
<td>ELS</td>
<td>Y</td>
<td>IF</td>
<td>100%</td>
<td>rw</td>
<td>7.9-8.2</td>
<td>24.6-25.5</td>
<td>206</td>
<td>42 d</td>
<td>NOEC</td>
<td>weight</td>
<td>0.35</td>
<td>2</td>
<td>23, 80, 284</td>
<td>Hooftman &amp; Evers-de Ruiter, 1992c</td>
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<td>Danio rerio</td>
<td>ELS</td>
<td>Y</td>
<td>IF</td>
<td>100%</td>
<td>rw</td>
<td>7.9-8.2</td>
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<td>Hooftman &amp; Evers-de Ruiter, 1992c</td>
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<td>IF</td>
<td>100%</td>
<td>rw</td>
<td>7.9-8.2</td>
<td>24.6-25.7</td>
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<td>42 d</td>
<td>EC10</td>
<td>weight</td>
<td>0.31</td>
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<td>23, 80, 284</td>
<td>Hooftman &amp; Evers-de Ruiter, 1992c</td>
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**Bacteria**

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<th>Species</th>
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<th>pH</th>
<th>T [°C]</th>
<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<td>Y</td>
<td>S</td>
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<td>bioluminescence</td>
<td>&gt;w.s.</td>
<td>2</td>
<td>115</td>
<td>Loibner et al., 2004</td>
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### Table 161: Chronic toxicity of benzo[k]fluoranthene (CASnr: 207-08-9) to marine organisms.

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<th>pH</th>
<th>T [°C]</th>
<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tr>
<td>Psammechinus miliaris</td>
<td>fertilized eggs, 2-8 cells, &lt;4 h</td>
<td>Y</td>
<td>S</td>
<td>nw</td>
<td>20</td>
<td>32</td>
<td>48 h</td>
<td>NOEC larval development</td>
<td>≥ 2.6</td>
<td>2</td>
<td>80, 288</td>
<td>AquaSense 2004</td>
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<tr>
<td>Psammechinus miliaris</td>
<td>fertilized eggs, 2-8 cells, &lt;4 h</td>
<td>Y</td>
<td>S</td>
<td>nw</td>
<td>20</td>
<td>32</td>
<td>48 h</td>
<td>EC10 larval development</td>
<td>&gt; 2.6</td>
<td>2</td>
<td>80, 288</td>
<td>AquaSense 2004</td>
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<td>Mollusca</td>
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<tr>
<td>Crassostrea gigas</td>
<td>fertilized eggs, 2-8 cells, &lt;4 h</td>
<td>Y</td>
<td>S</td>
<td>nw</td>
<td>20</td>
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<td>48 h</td>
<td>NOEC larval development</td>
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<td>80, 286</td>
<td>AquaSense 2004</td>
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<tr>
<td>Crassostrea gigas</td>
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<td>Y</td>
<td>S</td>
<td>nw</td>
<td>20</td>
<td>32</td>
<td>48 h</td>
<td>EC10 larval development</td>
<td>&gt; 2.6</td>
<td>2</td>
<td>80, 286</td>
<td>AquaSense 2004</td>
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### Table 162: Toxicity of benzo[k]fluoranthene (CASnr: 207-08-9) to terrestrial organisms

<table>
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<th>Species properties</th>
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<th>Soil type</th>
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<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value test soil [mg/kg dw]</th>
<th>Value standard soil [mg/kg dw]</th>
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<tr>
<td>Folsomia candida</td>
<td>10-12 d</td>
<td>Y</td>
<td>artificial soil</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>28 d</td>
<td>NOEC reproduction (number of cocoons)</td>
<td>≥ 180</td>
<td>2</td>
<td>10, 45, 50, 59</td>
<td>Bowmer et al., 1993</td>
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<td>Folsomia fimetaria</td>
<td>23-26 d</td>
<td>Y</td>
<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>LC50 mortality</td>
<td>&gt; 560</td>
<td>&gt; 2059</td>
<td>2</td>
<td>12, 21, 78</td>
<td>Sverdrup et al., 2002</td>
<td></td>
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<tr>
<td>Folsomia fimetaria</td>
<td>23-26 d</td>
<td>Y</td>
<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>EC10 reproduction</td>
<td>&gt; 560</td>
<td>&gt; 2059</td>
<td>2</td>
<td>12, 21, 78</td>
<td>Sverdrup et al., 2002</td>
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Table 163: Toxicity of benzo[k]fluoranthene (CASnr: 207-08-9) to benthic organisms

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Purity [%]</th>
<th>Sediment type</th>
<th>pH</th>
<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value test sediment [mg/kg dw]</th>
<th>Value standard sediment [mg/kg dw]</th>
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</tr>
<tr>
<td>Daphnia magna</td>
<td>&lt;24 h</td>
<td>Y</td>
<td>artificial sediment</td>
<td>20±2</td>
<td>3.4</td>
<td>30</td>
<td>24 h</td>
<td>EC5 immunity</td>
<td>300</td>
<td>882</td>
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<td>45, 56, 59</td>
<td>Verrhiest et al., 2001</td>
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<td>Daphnia magna</td>
<td>&lt;24 h</td>
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<td>artificial sediment</td>
<td>20±2</td>
<td>3.4</td>
<td>30</td>
<td>48 h</td>
<td>EC45 immunity</td>
<td>300</td>
<td>882</td>
<td>3</td>
<td>45, 56, 59</td>
<td>Verrhiest et al., 2001</td>
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<td>Hyalella azteca</td>
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<td>3.4</td>
<td>30</td>
<td>14 d</td>
<td>NOEC mortality/growth</td>
<td>≥300</td>
<td>≥882</td>
<td>2</td>
<td>45, 56, 59</td>
<td>Verrhiest et al., 2001</td>
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Table 164: Acute toxicity of benzo[b]fluoranthene (CASnr: 205-99-2) to freshwater organisms.

<table>
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<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tr>
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</tr>
<tr>
<td>Daphnia magna</td>
<td>&lt;24 h</td>
<td>Y</td>
<td>S</td>
<td>am</td>
<td>7.8±0.2</td>
<td>20±2</td>
<td>250±30</td>
<td>48 h</td>
<td>EC50 immunity</td>
<td>&gt;1.1</td>
<td>2</td>
<td>5</td>
<td>Bisson et al., 2000</td>
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<tr>
<td>Daphnia magna</td>
<td>4 d</td>
<td>N</td>
<td>99%</td>
<td>nw</td>
<td>8.0</td>
<td>20</td>
<td>250</td>
<td>24 h</td>
<td>EC50 immunity</td>
<td>&gt;1024</td>
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<td>80</td>
<td>Wernersson &amp; Dave, 1997</td>
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<tr>
<td>Daphnia magna</td>
<td>4 d</td>
<td>N</td>
<td>99%</td>
<td>nw</td>
<td>8.0</td>
<td>20</td>
<td>250</td>
<td>28 h</td>
<td>EC50 immunity</td>
<td>4.2</td>
<td>3</td>
<td>81</td>
<td>Wernersson &amp; Dave, 1997</td>
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Table 165: Chronic toxicity of benzo[b]fluoranthene (CASnr: 205-99-2) to freshwater organisms.

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<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
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<tr>
<td>Pseudokirchneriella subcapitata</td>
<td>Y</td>
<td>S</td>
<td>am</td>
<td>23±2</td>
<td>215</td>
<td>72 h</td>
<td>EC10 growth</td>
<td>&gt;1</td>
<td>2</td>
<td>167</td>
<td>Bisson et al., 2000</td>
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<tr>
<td>Ceriodaphnia dubia</td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>R</td>
<td>nw</td>
<td>8.1±0.4</td>
<td>25±2</td>
<td>240±40</td>
<td>7 d</td>
<td>EC10 reproduction</td>
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<td>168</td>
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Table 166: Acute toxicity of benzo[b]fluoranthene (CASnr: 205-99-2) to marine organisms.

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<th>pH</th>
<th>T °C</th>
<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
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<th>Notes</th>
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<td></td>
<td>Loibner et al., 2004</td>
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<tr>
<td><em>Vibrio fischeri</em></td>
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<td>Y</td>
<td>S</td>
<td>99%</td>
<td>am</td>
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<td>20</td>
<td>30 min</td>
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<td>bioluminescence</td>
<td>&gt;w.s.</td>
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Table 167: Toxicity of benzo[b]fluoranthene (CASnr: 205-99-2) to terrestrial organisms

<table>
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<th>Species properties</th>
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<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value test soil [mg/kgdw]</th>
<th>Value standard soil [mg/kgdw]</th>
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<td>Sverdrup et al., 2002</td>
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<tr>
<td><em>Folsomia fimetaria</em></td>
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<td>23-26 d</td>
<td>Y</td>
<td>&gt;98</td>
<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>LC50</td>
<td>mortality</td>
<td>&gt;360</td>
<td>&gt;1324</td>
<td>2</td>
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<td>Y</td>
<td>&gt;98</td>
<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
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<td>21 d</td>
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<td>reproduction</td>
<td>&gt;360</td>
<td>&gt;1324</td>
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Table 168: Toxicity of benzo[b]fluoranthene (CASnr: 205-99-2) to benthic organisms

<table>
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<tr>
<th>Species</th>
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<th>pH</th>
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<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value test sediment [mg/kgdw]</th>
<th>Value standard sediment [mg/kgdw]</th>
<th>Ri</th>
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<th>Reference</th>
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<td>Boese et al., 1998</td>
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<tr>
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<td>15</td>
<td>4.4</td>
<td>10 d</td>
<td>LC50</td>
<td>mortality</td>
<td>&gt;46</td>
<td>&gt;105</td>
<td>2</td>
<td>22, 24, 46, 52, 59</td>
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<td></td>
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<td>muddy sand marine sediment, McKinney Slough, OR, USA</td>
<td>15</td>
<td>4.4</td>
<td>10 d</td>
<td>EC50</td>
<td>reburial</td>
<td>&gt;46</td>
<td>&gt;105</td>
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<td>Crit.</td>
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<td>4.4</td>
<td>10 d</td>
<td>LC50</td>
<td>mortality</td>
<td>&gt;46</td>
<td>&gt;105</td>
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<td>Boese et al., 1998</td>
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<td><em>Rhepoxynius abronius</em></td>
<td>Y</td>
<td>muddy sand marine sediment, McKinney Slough, OR, USA</td>
<td>15</td>
<td>4.4</td>
<td>10 d</td>
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<td>reburial</td>
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<td>&gt;105</td>
<td>2</td>
<td>23, 24, 46, 52, 59</td>
<td>Boese et al., 1998</td>
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**Table 169: Acute toxicity of benzo[a]pyrene (CASnr: 50-32-8) to freshwater organisms.**

<table>
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<tr>
<th>Species</th>
<th>Purity</th>
<th>Test water</th>
<th>pH</th>
<th>T</th>
<th>EC50</th>
<th>Growth</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<td><em>Ankistrodesmus braunii</em></td>
<td>N</td>
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<td>23</td>
<td>72 h</td>
<td>EC50</td>
<td>growth</td>
<td>1300</td>
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<td>37</td>
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<td>72 h</td>
<td>EC50</td>
<td>growth</td>
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<td>37</td>
<td>Schoeny et al., 1988</td>
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<td>EC50</td>
<td>growth</td>
<td>&gt;4000</td>
<td>3</td>
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<td>EC50</td>
<td>growth</td>
<td>&gt;4000</td>
<td>3</td>
<td>37</td>
<td>Schoeny et al., 1988</td>
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<td>23</td>
<td>96 h</td>
<td>EC50</td>
<td>growth</td>
<td>&gt;13000</td>
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<td>growth</td>
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<td>Cody et al., 1984</td>
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<td>EC50</td>
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<td>growth</td>
<td>15</td>
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<td>Schoeny et al., 1988</td>
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<td>growth, area under the curve</td>
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<tr>
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<td>R</td>
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<td>20±0.5</td>
<td>48 h</td>
<td>LC50</td>
<td>mortality</td>
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<td>3</td>
<td>92, 200</td>
<td>Fernandez &amp; L'Haridon, 1994</td>
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<td>Crit. Endpoint</td>
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<td>tw</td>
<td>20±0.5</td>
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<td>200 Fernandez &amp; L’Haridon, 1994</td>
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<td>LC50 mortality</td>
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<td>92, 200 Fernandez &amp; L’Haridon, 1994</td>
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<td>am</td>
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<td></td>
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<td>am</td>
<td>20±1</td>
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<td>LC50 mortality</td>
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<td>S</td>
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<td></td>
<td>am</td>
<td>7.8±0.2</td>
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<td>250±30</td>
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<td>EC50 immobility</td>
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<td>nw/d w</td>
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<td>nw/d w</td>
<td>20±2</td>
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<td>S</td>
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<td>nw/d w</td>
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<td>S</td>
<td>pract</td>
<td>rw</td>
<td>8.0</td>
<td>20</td>
<td>250</td>
<td>EC50 immobility</td>
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<td>3</td>
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<tr>
<td>Daphnia magna 4 d</td>
<td>N</td>
<td>S</td>
<td>pract</td>
<td>rw</td>
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<td>20</td>
<td>250</td>
<td>EC50 immobility</td>
<td>8.6</td>
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<td>Test water</td>
<td>pH</td>
<td>T [°C]</td>
<td>Hardness CaCO₃ [mg/L]</td>
<td>Exp. time</td>
<td>Crit. Endpoint</td>
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<tr>
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<td>1.9-2.1 mm</td>
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<td>96 h</td>
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<tr>
<td>Anabaena flos-aquae</td>
<td>5*10⁵ cells/ml</td>
<td>N</td>
<td>S</td>
<td>≥99%</td>
<td>am</td>
<td>23</td>
<td>72 h</td>
<td>EC50 growth</td>
<td>&gt;4000</td>
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<td>Aedes aegypti</td>
<td>&lt; 8 h, first instar</td>
<td>N</td>
<td>S</td>
<td>p.a.</td>
<td>tw</td>
<td>&lt;24 h</td>
<td>LC50 mortality</td>
<td>1.8</td>
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<td>Pisces</td>
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<td>Pimephales promelas</td>
<td>larvae</td>
<td>Y</td>
<td>R</td>
<td>high</td>
<td>tw</td>
<td>24</td>
<td>120 h</td>
<td>LC50 mortality</td>
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<td>24 h</td>
<td>LC50 mortality</td>
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Table 170: Chronic toxicity of benzo[a]pyrene (CASnr: 50-32-8) to freshwater organisms.

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<th>Species</th>
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<th>Purity [%]</th>
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<th>pH</th>
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<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
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<td>S</td>
<td>am</td>
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<td>215</td>
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<td>167</td>
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<td>am</td>
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<td>96 h</td>
<td>EC10 growth</td>
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<td>38, 102</td>
<td>Cody et al., 1984</td>
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<td>am</td>
<td>23</td>
<td>96 h</td>
<td>EC10 growth</td>
<td>10</td>
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<td>47, 102</td>
<td>Cody et al., 1984</td>
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<td>S</td>
<td>≥99%</td>
<td>am</td>
<td>23</td>
<td>96 h</td>
<td>EC10 growth</td>
<td>0.96</td>
<td>3</td>
<td>46, 102</td>
<td>Cody et al., 1984</td>
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<tr>
<td>Scenedesmus subspicatus</td>
<td>10⁴ cells/ml</td>
<td>N</td>
<td>S</td>
<td>&gt;98%</td>
<td>am</td>
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<td>27.2</td>
<td>7 d</td>
<td>EC10 growth, area under the curve</td>
<td>0.03</td>
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<td>203</td>
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<td>&gt;98%</td>
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<td>25±1</td>
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<td>72 h</td>
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<td>Xenopus leavis</td>
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<td>R</td>
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<td>23±1</td>
<td>96 h</td>
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<td>Test water</td>
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<td>T [°C]</td>
<td>Hardness CaCO₃ [mg/L]</td>
<td>Exp. time</td>
<td>Crit. Endpoint</td>
<td>Value [µg/L]</td>
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<td>Notes</td>
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<td>240±40</td>
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Table 171: Acute toxicity of benzo[a]pyrene (CASnr: 50-32-8) to marine organisms.

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Table 172: Chronic toxicity of benzo[a]pyrene (CASnr: 50-32-8) to marine organisms.
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<th>pH</th>
<th>T [°C]</th>
<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
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<td>S</td>
<td>nw</td>
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<td>32</td>
<td>48 h</td>
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<td>larval development</td>
<td>≥1.6</td>
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<td>S</td>
<td>nw</td>
<td>20</td>
<td>32</td>
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<td>Oniscus asellus</td>
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<td>98</td>
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<td>98</td>
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### Table 174: Acute toxicity of benzo[ghi]perylene (CASnr: 191-21-2) to freshwater organisms.

<table>
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<th>Species</th>
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<th>Purity [%]</th>
<th>Soil type</th>
<th>pH</th>
<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value test soil [mg/kg dw]</th>
<th>Value standard soil [mg/kg dw]</th>
<th>Ri</th>
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<td>S</td>
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<td>7.8±0.2</td>
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<td>250±30</td>
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<td>EC50</td>
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<td>&gt;0.2</td>
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<td>S, 5</td>
<td>Bisson et al., 2000</td>
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### Table 175: Chronic toxicity of benzo[ghi]perylene (CASnr: 191-21-2) to freshwater organisms.

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<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time [h]</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
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### Table 176: Acute toxicity of benzo[ghi]perylene (CASnr: 191-21-2) to marine organisms.

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<th>Salinity [%]</th>
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### Table 177: Chronic toxicity of benzo[ghi]perylene (CASnr: 191-21-2) to marine organisms.

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<td>3</td>
<td>24, 5</td>
<td>El-Alawi et al., 2002</td>
</tr>
<tr>
<td>Vibrio fischeri</td>
<td></td>
<td>N</td>
<td>S</td>
<td>am</td>
<td>7.2</td>
<td>20</td>
<td>8+18 h</td>
<td>EC50</td>
<td>growth</td>
<td>17750</td>
<td>3</td>
<td>24, 6</td>
<td>El-Alawi et al., 2002</td>
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</table>

### Table 178: Toxicity of benzo[ghi]perylene (CASnr: 191-21-2) to terrestrial organisms

<table>
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<tr>
<th>Species</th>
<th>Species properties</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Soil type</th>
<th>pH</th>
<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time</th>
<th>Endpoint</th>
<th>Value test soil [mg/kg dw]</th>
<th>Value standard soil [mg/kg dw]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tr>
<td><strong>Insecta</strong></td>
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<tr>
<td>Folsomia candida</td>
<td></td>
<td>10-12 d</td>
<td>Y</td>
<td>artificial soil</td>
<td>20</td>
<td>10</td>
<td>20 28 d</td>
<td>NOEC reproduction (number of cocoons)</td>
<td>≥180</td>
<td>≥180</td>
<td>2</td>
<td>10, 45, 51, 59</td>
<td>Bowmer et al., 1993</td>
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</table>

### Table 179: Acute toxicity of dibenz[a,h]anthracene (CASnr: 53-70-3) to freshwater organisms.

<table>
<thead>
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<th>Species</th>
<th>Species properties</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO3 [mg/L]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<td><strong>Amphibia</strong></td>
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</tr>
<tr>
<td>Pleurodeles walti</td>
<td>larvae (stage 53)</td>
<td>N</td>
<td>R</td>
<td>97%</td>
<td>am</td>
<td>20±0.5</td>
<td>6 d</td>
<td>LC50</td>
<td>mortality</td>
<td>&gt;200</td>
<td>3</td>
<td>151</td>
<td>Fernandez &amp; L'Haridon, 1992</td>
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<tr>
<td><strong>Crustacea</strong></td>
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</tr>
<tr>
<td>Daphnia magna</td>
<td></td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>S</td>
<td>am</td>
<td>7.8±0.2</td>
<td>20+2</td>
<td>48 h</td>
<td>EC50 immobility</td>
<td>&gt;0.35</td>
<td>2</td>
<td>5</td>
<td>Bisson et al., 2000</td>
</tr>
<tr>
<td>Species</td>
<td>Species properties</td>
<td>A</td>
<td>Test type</td>
<td>Purity [%]</td>
<td>Test water</td>
<td>pH</td>
<td>T [°C]</td>
<td>Hardness CaCO₃ [mg/L]</td>
<td>Exp. time</td>
<td>Crit. Endpoint</td>
<td>Value [µg/L]</td>
<td>Ri</td>
<td>Notes</td>
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<tr>
<td><em>Daphnia magna</em></td>
<td>&lt; 24 h</td>
<td>N</td>
<td>S</td>
<td>97%</td>
<td>nw/d 20±2</td>
<td>20</td>
<td>48</td>
<td>1.56</td>
<td></td>
<td>EC50 immobility</td>
<td>1.56</td>
<td>3</td>
<td>80, 259</td>
</tr>
<tr>
<td><em>Daphnia magna</em></td>
<td>&lt; 24 h</td>
<td>N</td>
<td>S</td>
<td>97%</td>
<td>nw/d 20±2</td>
<td>20</td>
<td>48</td>
<td>0.55</td>
<td></td>
<td>EC50 immobility</td>
<td>0.55</td>
<td>3</td>
<td>80, 260</td>
</tr>
<tr>
<td><em>Daphnia magna</em></td>
<td>4 d</td>
<td>N</td>
<td>S</td>
<td>97%</td>
<td>rw 8.0</td>
<td>20</td>
<td>250</td>
<td>496</td>
<td></td>
<td>EC50 immobility</td>
<td>496</td>
<td>3</td>
<td>80, 163</td>
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<tr>
<td><em>Daphnia magna</em></td>
<td>4 d</td>
<td>N</td>
<td>S</td>
<td>97%</td>
<td>rw 8.0</td>
<td>20</td>
<td>28</td>
<td>4.6</td>
<td></td>
<td>EC50 immobility</td>
<td>4.6</td>
<td>3</td>
<td>81, 163</td>
</tr>
<tr>
<td><em>Daphnia magna</em></td>
<td>neonates &lt;24 h</td>
<td>N</td>
<td>S</td>
<td>am 8.0</td>
<td>21±1 250</td>
<td>24</td>
<td>4.6</td>
<td>&gt;1024</td>
<td></td>
<td>EC50 immobility</td>
<td>&gt;1024</td>
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<td>80, 163</td>
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<tr>
<td><em>Daphnia magna</em></td>
<td>neonates &lt;24 h</td>
<td>N</td>
<td>S</td>
<td>am 8.0</td>
<td>21±1 250</td>
<td>27</td>
<td>4.6</td>
<td>1.76</td>
<td></td>
<td>EC50 immobility</td>
<td>1.76</td>
<td>3</td>
<td>105, 163</td>
</tr>
<tr>
<td><em>Pimephales promelas</em></td>
<td>larvae</td>
<td>Y</td>
<td>R</td>
<td>high tw 24</td>
<td>120±1 250</td>
<td>24</td>
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<td>NOEC mortality</td>
<td></td>
<td></td>
<td>≥0.15</td>
<td>2</td>
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</tbody>
</table>

**Table 180: Chronic toxicity of dibenz[a,h]anthracene (CASnr: 53-70-3) to freshwater organisms.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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</thead>
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<tr>
<td><strong>Algae</strong></td>
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<tr>
<td><em>Pseudokirchneriella subcapitata</em></td>
<td></td>
<td>Y</td>
<td>S</td>
<td>am</td>
<td></td>
<td>23±2</td>
<td>72</td>
<td>EC10 growth</td>
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<td></td>
<td>0.14</td>
<td>2</td>
<td>167</td>
<td>Bisson et al., 2000</td>
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<td><strong>Crustacea</strong></td>
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</tr>
<tr>
<td><em>Ceriodaphnia dubia</em></td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>R</td>
<td>nw 8.1±0.4</td>
<td>240±40 240±40</td>
<td>7</td>
<td>d EC10 reproduction</td>
<td>&gt;0.032</td>
<td></td>
<td></td>
<td>2.168</td>
<td>2</td>
<td>168</td>
<td>Bisson et al., 2000</td>
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<td><strong>Macrophyta</strong></td>
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<tr>
<td><em>Lemna gibba</em></td>
<td>N</td>
<td>S</td>
<td>am</td>
<td></td>
<td></td>
<td>25±2</td>
<td>8 d EC11 growth rate</td>
<td>2000</td>
<td></td>
<td></td>
<td>3</td>
<td>94, 113</td>
<td>Huang et al., 1997a</td>
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<tr>
<td><em>Lemna gibba</em></td>
<td>N</td>
<td>S</td>
<td>am</td>
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<td>25±2</td>
<td>8 d EC18 growth rate</td>
<td>2000</td>
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<td>94, 113</td>
<td>Huang et al., 1997a</td>
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</table>
Table 181: Acute toxicity of dibenz[a,h]anthracene (CASnr: 53-70-3) to marine organisms.

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tbody>
<tr>
<td><strong>Annelida</strong></td>
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<tr>
<td>Neanthes arenaceodentata immature young adult</td>
<td>Y S &gt;98% am 22±2 32 96 h</td>
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<td></td>
<td></td>
<td>LC50 mortality</td>
<td>&gt;1000</td>
<td>3 50</td>
<td></td>
<td>Rossi &amp; Neff, 1978</td>
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<tr>
<td><strong>Bacteria</strong></td>
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<td></td>
</tr>
<tr>
<td>Vibrio fischeri</td>
<td></td>
<td>N</td>
<td>S am 7.2</td>
<td>room temp</td>
<td>15 min</td>
<td>EC50</td>
<td>bioluminescence</td>
<td>97180</td>
<td>3 4 5</td>
<td>El-Alawi et al., 2002</td>
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<tr>
<td>Vibrio fischeri</td>
<td></td>
<td>N</td>
<td>S am 7.2</td>
<td>room temp</td>
<td>15 min</td>
<td>EC50</td>
<td>bioluminescence</td>
<td>96550</td>
<td>3 4 6</td>
<td>El-Alawi et al., 2002</td>
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<tr>
<td>Vibrio fischeri</td>
<td></td>
<td>Y</td>
<td>S 99% am</td>
<td></td>
<td>15 20 30 min</td>
<td>EC10</td>
<td>bioluminescence</td>
<td>&gt;w.s. 2115</td>
<td>2 115</td>
<td>Loibner et al., 2004</td>
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</table>

Table 182: Chronic toxicity of dibenz[a,h]anthracene (CASnr: 53-70-3) to marine organisms.

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<tr>
<th>Species</th>
<th>Species properties</th>
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<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tr>
<td><strong>Algae</strong></td>
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<tr>
<td>Antithamnion plumula spores</td>
<td>N Sc rw 16 =19 7 d</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NOEC growth stimulation</td>
<td>&lt;10</td>
<td>3 214</td>
<td></td>
<td>Boney &amp; Corner, 1962</td>
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<td><strong>Bacteria</strong></td>
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<tr>
<td>Vibrio fischeri</td>
<td></td>
<td>N</td>
<td>S am 7.2</td>
<td></td>
<td>8+18 h EC50</td>
<td>bioluminescence</td>
<td>94850</td>
<td>3 24 5</td>
<td>El-Alawi et al., 2002</td>
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<tr>
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<td>S am 7.2</td>
<td></td>
<td>8+18 h EC50</td>
<td>bioluminescence</td>
<td>1350</td>
<td>3 24 6</td>
<td>El-Alawi et al., 2002</td>
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<tr>
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<td>N</td>
<td>S am 7.2</td>
<td></td>
<td>8+18 h EC50</td>
<td>growth</td>
<td>93990</td>
<td>3 24 5</td>
<td>El-Alawi et al., 2002</td>
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<tr>
<td>Vibrio fischeri</td>
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<td>N</td>
<td>S am 7.2</td>
<td></td>
<td>8+18 h EC50</td>
<td>growth</td>
<td>1340</td>
<td>3 24 6</td>
<td>El-Alawi et al., 2002</td>
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</table>
**Table 183: Toxicity of dibenz[a,h]anthracene (CASnr: 53-70-3) to terrestrial organisms**

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Purity [%]</th>
<th>Soil type</th>
<th>pH</th>
<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time [d]</th>
<th>Endpoint</th>
<th>Value test soil [mg/kgdw]</th>
<th>Value standard soil [mg/kgdw]</th>
<th>RI</th>
<th>Notes</th>
<th>Reference</th>
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<tbody>
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<td>Folsomia fimetaria</td>
<td>23-26 d</td>
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<td>97</td>
<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>LC50 mortality</td>
<td>&gt;780</td>
<td>&gt;2868</td>
<td>2</td>
<td>12, 21, 78</td>
<td>Sverdrup et al., 2002</td>
</tr>
<tr>
<td>Folsomia fimetaria</td>
<td>23-26 d</td>
<td>Y</td>
<td>97</td>
<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>EC10 reproduction</td>
<td>&gt;780</td>
<td>&gt;2868</td>
<td>2</td>
<td>12, 21, 78</td>
<td>Sverdrup et al., 2002</td>
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</table>

**Table 184: Acute toxicity of indeno[1,2,3-cd]pyrene (CASnr: 193-39-5) to freshwater organisms.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value [µg/L]</th>
<th>RI</th>
<th>Notes</th>
<th>Reference</th>
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<tr>
<td><strong>Crustacea</strong></td>
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<td></td>
</tr>
<tr>
<td>Daphnia magna</td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>S</td>
<td>am</td>
<td>7.8±0.2</td>
<td>20±2</td>
<td>250±30</td>
<td>48 h</td>
<td>EC50 immobility</td>
<td>&gt;357</td>
<td>3</td>
<td>5</td>
<td>Bisson et al., 2000</td>
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</table>

**Table 185: Chronic toxicity of indeno[1,2,3-cd]pyrene (CASnr: 193-39-5) to freshwater organisms.**

<table>
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<tr>
<th>Species</th>
<th>Species properties</th>
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<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Hardness CaCO₃ [mg/L]</th>
<th>Exp. time</th>
<th>Crit.</th>
<th>Endpoint</th>
<th>Value [µg/L]</th>
<th>RI</th>
<th>Notes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Algae</strong></td>
<td></td>
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<tr>
<td>Pseudokirchneriella subcapitata</td>
<td></td>
<td>Y</td>
<td>S</td>
<td>am</td>
<td>23±2</td>
<td>215</td>
<td>72 h</td>
<td>EC10 growth</td>
<td>1.5</td>
<td>2</td>
<td>167</td>
<td>Bisson et al., 2000</td>
<td></td>
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<tr>
<td><strong>Crustacea</strong></td>
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<tr>
<td>Ceriodaphnia dubia</td>
<td>&lt; 24 h</td>
<td>Y</td>
<td>R</td>
<td>nw</td>
<td>8.1±0.4</td>
<td>25±2</td>
<td>240±40</td>
<td>7 d</td>
<td>EC10 reproduction</td>
<td>0.27</td>
<td>2</td>
<td>168</td>
<td>Bisson et al., 2000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 186: Acute toxicity of indeno[1,2,3-cd]pyrene (CASnr: 193-39-5) to marine organisms.

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Test type</th>
<th>Purity [%]</th>
<th>Test water</th>
<th>pH</th>
<th>T [°C]</th>
<th>Salinity [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value [µg/L]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Bacteria</td>
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<tr>
<td><em>Vibrio fischeri</em></td>
<td></td>
<td></td>
<td></td>
<td>Y S</td>
<td>99% am</td>
<td>15</td>
<td>20</td>
<td>30 min</td>
<td>EC10</td>
<td>bioluminescence</td>
<td>&gt;w.s.</td>
<td>2</td>
<td>115</td>
<td>Loibner et al., 2004</td>
</tr>
</tbody>
</table>

### Table 187: Toxicity of indeno[1,2,3-cd]pyrene (CASnr: 193-39-5) to terrestrial organisms

<table>
<thead>
<tr>
<th>Species</th>
<th>Species properties</th>
<th>A</th>
<th>Purity [%]</th>
<th>Soil type</th>
<th>pH</th>
<th>T [°C]</th>
<th>Organic matter [%]</th>
<th>Clay [%]</th>
<th>Exp. time</th>
<th>Crit. Endpoint</th>
<th>Value test soil [mg/kgdw]</th>
<th>Value standard soil [mg/kgdw]</th>
<th>Ri</th>
<th>Notes</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>Insecta</td>
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<tr>
<td><em>Folsomia fimetaria</em></td>
<td></td>
<td>Y</td>
<td></td>
<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>LC50 mortality</td>
<td>&gt;910</td>
<td>&gt;3346</td>
<td>2</td>
<td>12, 21, 78</td>
<td>Sverdrup et al., 2002</td>
</tr>
<tr>
<td><em>Folsomia fimetaria</em></td>
<td></td>
<td>Y</td>
<td></td>
<td>sandy loam</td>
<td>6.2</td>
<td>20±1</td>
<td>2.7</td>
<td>13</td>
<td>21 d</td>
<td>EC10 reproduction</td>
<td>&gt;910</td>
<td>&gt;3346</td>
<td>2</td>
<td>12, 21, 78</td>
<td>Sverdrup et al., 2002</td>
</tr>
</tbody>
</table>
Notes

Notes to aquatic toxicity studies:
1: Solvent 2% ethanol, caused no significant effects; light regime: 30 min. dark
2: Solvent: see 1; light regime 30 min. light from source with UV-A+B, total irradiation 400-800 mW/cm² for 30 min.
3: Complex medium with yeast extract, peptone and bactopeptamin
4: Minimal medium (without carbon sources)
5: Exposure in the dark
6: Exposure in simulated solar radiation (SSR), visible light:UV-A:UV-B = 100:10:1 with an intensity of 40 µmol/m²/s
7: Unclear dose response curve, 14% effect at 450 µg/l
8: Solvent is methanol (<0.4 mg/l); lowest oxygen conc. In test 4.9 mg/l
9: *Sarotherodon mossambicus* is the same species as *Oreochromis mossambicus*
10: SSR; light regime: two cool white fluorescent one 350-nm and one 300-nm photoreactor lamps producing UV-A+UV-B; ratio visible:UV-A:UV-B =100:10:1 based on the number of photons, total intensity 40 µmol m⁻² s⁻¹, this is comparable with natural sunlight (spectrum+intensity)
11: Actual concentration 70% of nominal at 0 h and 50% after the renewal period of 8 h; the results are presented as the calculated average between t=0 and t=8 h after renewal according to a first order kinetics loss model; first renewal after 12 h of incubation
12: Light regime: 12 h incubation in the dark, then constant light with "white fluorescent bulbs" used with a filter to eliminate UV-A+B (<390 nm); UV-A produced by blacklights, the intensity of the UV-A in the test was 765 µW/cm²; UV-B radiation was filtered from the blacklight spectrum.
13: No UV-radiation; visible light by "white fluorescent lamps"; light regime:16 h light and 8 h dark
14: UV-radiation at 31 µW/cm²; ratio UV-A:UV-B=8:1; visible light by "white fluorescent lamps"; light regime: 16 h light and 8 h dark
15: UV-radiation at 60 µW/cm²; ratio UV-A:UV-B=8:1; visible light by "white fluorescent lamps"; light regime: 16 h light and 8 h dark
16: UV-radiation at 117 µW/cm²; ratio UV-A:UV-B=8:1; visible light by "white fluorescent lamps"; light regime: 16 h light and 8 h dark
17: Reproduction measured as total number of neonates after 6 broods
18: 23% effect at 1.9 µg/l
19: Reproduction as number of broods per animal and number of live young per brood per animal and as total number of young
20: Exposure time is total life-time; light regime: 16 h light and 8 h dark by "cool white fluorescent bulbs" 1100 lx
21: Growth measured as length of the first brood animals
22: Actual conc. 27-76%, average 48%; highest concentration (180 µg/l) is tested in separate test
23: Actual concentrations were 36-109% of initial concentrations (average 72%)
24: 8 hours exposure in minimal medium (without carbon sources), after which 18 hours exposure in complex medium with yeast extract, peptone and bactopeptamin followed
25: Photoperiod 12:12 light:dark
26: Constant illumination: UV-A+B and visible light, spectrum 91% equal to natural sunlight; UV-A and UV-B intensities are 108 and 6.7 µW/cm²; total
intensity approximately equal to 0.5 and 1 m depth in an eutrophic lake;
24 h pre-exposure to anthracene in dark; oxygen concentration 6.9 mg/l
27: As 26, except oxygen concentration is 8.1 mg/L
28: As 26 except oxygen concentration is 5.0 mg/L
29: Based on mean actual concentrations, which were 72-95% of nominal (on
average 84%); all test concentration remained constant within 10% over
48 h, while in the lowest test concentration the concentration at the end
was almost three times the initial concentration; low concentrations of
other PAHs detected at t=0
30: 48 h pre-exposure to anthracene in the dark, followed by 96 h
anthracene+UV exposure, light regime: 24 h light during 96 h exposure;
simulated sunlight produced by white and ultraviolet fluorescent bulbs;
UV-B intensity is 14.8 µW/cm²; UV-A (365±36nm):UV-B
(310±34nm)=1.42
31: As 30 except UV-B intensity is 170 µW/cm²
32: As 30 except UV-B intensity is 70 µW/cm²
33: 24 h pre-exposure to anthracene in the dark, followed by 24 h
anthracene+UV exposure, light regime: 24 h light during 24 h exposure;
simulated sunlight: UV-B intensity is 150 µW/cm²
34: Oxygen concentration minimal 2 mg/l; photoperiod 14:10 h light:dark with
approximately 1000 lux
35: Concentrations were prepared fr om water accommodated fraction stock
solutions, which were measured and reported as ranges
36: Light regime: 12 h light and 12 h dark with mixed fluorescent and natural
light
37: Light regime: 16 h light and 8 h dark, illumination with "white light"
38: Light regime: 16 h light and 8 h dark, illumination with "gold light" with an
energy output of 7.5·10⁻⁵ W/m² at 670, 1.4·10⁻³ W/m² at 550 nm and
1.0·10⁻⁶ W/m² at 380 nm
39: Light regime: 16 h light and 8 h dark, at 1086 lux; results expressed as
57% of the water soluble fraction, solubility in test water is 34000 µg/l
40: Exposure 1 h in the dark followed by 1 h irradiation with 13 W/m² of UV
light (320-400 nm; maximum 350 nm)
41: Exposure ca. 12 h in the dark followed by 1 h irradiation with 13 W/m² of
UV light (320-400 nm; maximum 350 nm); mortality recorded
immediately after irradiation period
42: Exposure ca. 0.5 h in the dark followed by 0.5 h irradiation with 7.5 W/m²
of UV light (320-400 nm; maximum 350 nm), mortality recorded the next
day
43: 4 m old sexually mature fish were exposed for two weeks to 6 and 12 µg/L
with a 16:8 light:dark photoperiod. Then, one male and two females per
aquarium were exposed to the same concentration and photoperiod for a
spawning period of 6 w and to 12 and 20 µg/L for an additional period of
3 w. Eggs were collected and percent hatching and survival were recorded
in water without anthracene during 96 h.
44: LT50 study, only 1 concentration tested; actual concentration is 67% of
initial concentration; light regime: 24 h light; 24 h pre-exposure with
chrysene without UV radiation; light intensity during test period: UV-A
120 µW/cm², UV-B= 25 µW/cm²; UV-A: UV-B ratio= 4.12:1
45: Actual concentration 41-81% of initial concentration, average 58%
46: Light regime: 16 h light and 8 h dark, illumination with "black light" with an
energy output of 3.2·10⁻⁷ W/m² at 670 nm, 1.9·10⁻⁵ W/m² at 550 nm
and 5.7·10⁻⁷ W/m² at 380 nm
47: Light regime: 16 h light and 8 h dark, illumination with "cool white fluorescent light" with an energy output of $7.0 \times 10^{-5}$ W/m² at 670 nm, $2.3 \times 10^{-3}$ W/m² at 550 nm and $1.3 \times 10^{-4}$ W/m² at 380 nm.

48: LT50 study, at the end of the 96-h test period no mortality effect was found for phenanthrene and dibenz[a,h]anthracene and less than 20% for benzo[ghi]perylene; simulated UV-A at 95 µW/m² and UV-B at 20 µW/m²; 24 h preincubation with toxicant without light; only 1 concentration tested.

49: Light regime 13:11 h light:dark

50: Effect concentration is expressed on basis of the initial measured concentration.

51: Constant artificial illumination.

52: Concentration based on actual concentrations; strong decrease in test concentration: 2% recovered after 96 h; initial concentration is 85% of nominal concentration; time weighted average concentration calculated.

53: Constant illumination by incandescent light at 340 ft candles; effect concentrations are based on the geometric mean between the nominal and the 24 h measured concentrations.

54: Actual concentration on average over 4 days 65% of initial concentration; based on actual concentrations.

55: Tidal schedule with 0% exposure to air; animals from field population acclimated for 1 month.

56: Actual concentration 54% of initial concentration, in static renewal test somewhat lower.

57: 11% mortality at 10 µg/L and 16% at 50 µg/L.

58: Photoperiod 14:10 h light:dark; LC50 estimated with Spearman & Karber.

59: Method similar to the method of Korn et al., 1979.

60: Concentration based on actual concentrations; strong decrease in test concentration: 32% recovered after 96 h; initial concentration is 103% of nominal concentration; time weighted average concentration calculated.

61: Exposure 2 h in the dark followed by 1 h irradiation with 13 W/m² of UV light (320-400 nm; maximum 350 nm); mortality recorded immediately after irradiation period.

62: Photoperiod 16:8 h light:dark with an intensity of 75-80 µE·m⁻²·s⁻¹ produced by "cool white fluorescent" light; renewal on days 7 and 11; test performed in screw-capped erlenmeyers with about 1/5 headspace.

63: Derived from the figures with mean, standard deviation and number of replicates.

64: 48 h exposure in the dark followed by 2 h exposure under UV-A (365 nm, 247 µW/cm²).

65: Exposure under white light (2500 lux, 74-92 µW/cm²), 16 h light/8 h dark.

66: 48 h exposure in white light (see 65) followed by 2 h exposure under UV-A (365 nm, 247 µW/cm²).

67: Exposure under ambient laboratory lighting (UV-A < 2 µW/cm²); renewal every 8 h.

68: Exposure with UV-A (320-400 nm), intensity 70.0±0.5 µW/cm² for anthracene and 69.0±1.0 µW/cm² for fluoranthene; renewal every 8 h; 4 h pre-exposed under ambient laboratory lighting.

69: Laboratory fluorescent light with 581±140 lux and a photoperiod of 12:12 h light:dark.

70: Laboratory ultraviolet light with 359-587 µW/cm² UV-A and 63-80 µW/cm² UV-B and a photoperiod of 12:12 h light:dark.

71: Laboratory ultraviolet light with 783-850 µW/cm² UV-A and 104 µW/cm² UV-B and a photoperiod of 12:12 h light:dark.

72: Outdoor natural UV irradiation: midday intensities UV-A 1273-2660 µW/cm² and UV-B 76-182 µW/cm² (only measured for mysid, grass...
shrimp and inland silverside); tests performed in period with generally sunny weather between June and September

73: 12 h day/night photoperiod at 100 µE/m²/s

74: Exposure without UV light

75: After 96 h exposure and 1 h reburial, animals were transferred to uncontaminated seawater and irradiated for 1 h with UV (UV-A 167 µW/cm² and UV-B 58 µW/cm²)

76: After exposure in water only, transfer to sediment with overlying water to measure reburial EC50 after 1 h

77: Reburial in sediment was measured for 1 h after the 1 h UV irradiation

78: After 48 h exposure to fluoranthene 48 h exposure to UV light (UV-A: 782-829 µW/cm² and UV-B: 130-153 µW/cm²)

79: After 48 h exposure to fluoranthene 48 h exposure to UV light (UV-A: 417-475 µW/cm² and UV-B: 61-72 µW/cm²)

80: Light regime 16:8 light:dark

81: After exposure for 24 h at 16:8 light:dark, 2 h exposure under UV irradiation (295-365 nm; peak 340 nm; intensity 370±20 µW/cm²) and a recovery period of 2 h; temperature during UV-radiation and recovery 23 °C

82: Mercury light source 330-800 nm, including some UV-A

83: Test with UV filter which blocked most radiation (75±14%) below 400 nm

84: Exposure in sunlight

85: Exposure ca. 0.5 h in the dark followed by 0.5 h irradiation with sunlight, mortality recorded the next day

86: Exposure 1 h in the dark, followed by 30 min sunlight, back to dark and mortality recording after 24 h

87: Visible light:UV-A:UV-B=100:10:1; UV-A intensity 62-68 µW/cm² and UV-B intensity 2-5 µW/cm², except in second experiment with X. Laevis with UV-B from 0.5 to 1.5 µW/cm²

88: Simulated solar radiation; visible light (PAR):UV-A:V-B=100:10:1 and a total fluence rate of 100 µmol/m²/s

89: UV irradiation: UV-A: 456.2±55 µW/cm²; UV-B: 6.3±0.1 µW/cm²; photoperiod of 12:12 h light:dark

90: Sediment test

91: Determined from presented data and LC50 with log-logistic dose-response relationship

92: Determined from presented data with log-logistic dose-response relationship

93: Exposed to UV light for 1 h at the end of the 10-d test (UV-A: 97 µW/cm² and UV-B: 2225 µW/cm²)

94: Single concentration, no dose-response curve; SSR at 100 µmol·m⁻²·s⁻¹ based on integration of 290-700 nm

95: Cool fluorescent white light (100 µmol·m⁻²·s⁻¹)

96: Simulated solar radiation (100 µmol·m⁻²·s⁻¹)

97: After pretreatment with SSR for photomodification

98: Gold light (0.17 µW/cm² UV-B, 0.09 µW/cm² UV-A, 167.72 µW/cm² visible); 16:8 h light:dark

99: Fluorescent light (1.32 µW/cm² UV-B, 13.65 µW/cm² UV-A, 424.69 µW/cm² visible); 16:8 h light:dark

100: UV enhanced light (7.54 µW/cm² UV-B, 102.08 µW/cm² UV-A, 289.24 µW/cm² visible); 16:8 h light:dark

101: Dim yellow light >500 nm

102: Determined from data from figures and log-logistic dose-response relationship

103: Test performed in triplicate, average value
104: Under UV: 254 nm; 2.49·10^{18} quanta/L·s
105: After exposure for 24 h at 16:8 light:dark, 2 h exposure under UV irradiation (295-365 nm; peak 340 nm; intensity 370±20 µW/cm²) and 1 h of recovery in test medium; temperature increased by less than 2 °C during UV-radiation
106: Light intensity 400 foot candles
107: UV irradiation: UV-B (peak 313 nm; range: 294-400 nm): 2.3 kJ/m²/h for 2 times 2 h per day
108: After photomodification UV-B (290-320 nm): 40 µmol·m⁻²·s⁻¹ for 24 h (anthracene), 48 h (phenanthrene) or 96 h (benzo(a)pyrene) 25 µmol·m⁻²·s⁻¹ for 5 d (fluoranthene, naphthalene) or 7 d (pyrene)
109: Visible light; light regime: two cool white fluorescent lamps
110: SSR: ratio visible:UV-A:UV-B=100:10:1 based on the number of photons, total intensity varying from 20 to 60 µmol·m⁻²·s⁻¹
111: SSR: total intensity 40 µmol·m⁻²·s⁻¹; UV-B varying from 1 to 4% of visible light
112: Visible light, total intensity varying from 60 to 150 µmol·m⁻²·s⁻¹
113: After photomodification UV:B 6 µmol·m⁻²·s⁻¹) until less than 10% of the parent compound remained
114: After photomodification UV:B (290-320 nm; 25 µmol·m⁻²·s⁻¹) for various time periods
115: Lumistox test
116: Microtox test with 'minimal salts medium'
117: Single concentration, no dose-response curve; natural sunlight for 16 h per day visible:UV-A:UV-B 200:10:1, 1700 µmol·m⁻²·s⁻¹
118: After photomodification for 7 d in natural sunlight for 16 h per day visible:UV-A:UV-B 200:10:1, 1700 µmol·m⁻²·s⁻¹
119: After photomodification for 16 d in natural sunlight for 16 h per day visible:UV-A:UV-B 200:10:1, 1700 µmol·m⁻²·s⁻¹
120: After photomodification UV:B (290-320 nm; 20 µmol·m⁻²·s⁻¹)
121: In the third experiment no effect was observed at the highest tested concentration of 7.2 µg/L, this value is considered in the geometric mean as NOEC because it is higher than the two NOECs from the other experiments
122: Light regime: 12 h incubation in the dark, then constant light with "white fluorescent bulbs" used with a filter to eliminate UV-A+B (<390 nm); UV-A produced by blacklights, the intensity of the UV-A in the test was 410 µW/cm²; UV-B radiation was filtered from the blacklight spectrum.
123: Light regime: 12 h incubation in the dark, then constant light with "white fluorescent bulbs" used with a filter to eliminate UV-A+B (<390 nm); UV-A produced by blacklights, the intensity of the UV-A in the test was 406 µW/cm²; UV-B radiation was filtered from the blacklight spectrum.
124: Light regime: 12 h incubation in the dark, then constant light with "white fluorescent bulbs" used with a filter to eliminate UV-A+B (<390 nm); UV-A produced by blacklights, the intensity of the UV-A in the test was 218 µW/cm²; UV-B radiation was filtered from the blacklight spectrum.
125: Light regime: 12 h incubation in the dark, then constant light with "white fluorescent bulbs" used with a filter to eliminate UV-A+B (<390 nm); UV-A produced by blacklights, the intensity of the UV-A in the test was 125 µW/cm²; UV-B radiation was filtered from the blacklight spectrum.
126: Data from two separate tests combined
127: Geometric mean of three tests
128: Tidal schedule with 33% exposure to air; animals from field population acclimated for 1 month
129: Tidal schedule with 66% exposure to air; animals from field population acclimated for 1 month

130: Light regime during hatching: 16:8 light:8 fluorescent light with UV-A (67.94±9.02 µW/cm² at 365±36 nm) and UV-B (6.71±0.81 µW/cm² at 310±34 nm)

131: Light regime during hatching: 16:8 light:dark gold fluorescent light >500 nm

132: Concentrations based on actual concentrations; actual concentrations ranged from an average value of 87% after preparation of the solution to just above or below the detection limit before renewal; concentrations calculated as half the initial concentration (average recovery times the nominal concentration)

133: Concentrations based on nominal concentrations; actual concentrations ranged from 78 to 142% with an average value of 118%; lowest NOEC is the same on basis of nominal and actual concentrations

134: Concentrations based on actual concentrations; actual concentrations ranged from an average value of 83% after preparation of the solution to just above or below the detection limit before renewal; concentrations calculated as half the initial concentration (half of the average recovery times the nominal concentration)

135: Exposure ca. 12 h in the dark followed by 30 min irradiation with 13.5 W/m² UVA (>320, <400nm, peak 350 nm); mortality recorded immediately after irradiation period

136: Only one concentration tested

137: Concentrations based on actual concentrations; strong decrease in test concentration: 7% recovered after 96 h; initial concentration is 102% of nominal concentration; time weighted average concentration calculated

138: Strong decrease in test concentration: 22% recovered after 96 h; initial concentration is 95% of nominal concentration

139: Renewal every 12 h; constant light from 1.5 meter distance

140: Photoperiod 14:10 h light:dark at 200 µE/m²/s

141: Precipitate formed

142: 875 to 1000 ft-c from cool-white fluorescent bulbs; growth rate from 1 to 4 d seems not to be affected (possibly due to loss of compound)

143: Light regime: continuous light at 9.514-19.028 W·m⁻²·s⁻¹ (200-400 foot candles). Concentrations declined significantly in 14 d. Acenaphthene, fluorene, naphthalene, and pyrene almost completely dissappeared, benz[a]anthracene, phenanthrene, chrysene, and fluoranthene by 85, 77, 62, and 49%, respectively

144: Light regime 6:18 sunlight:dark

145: Light regime 16:8 h light:dark (10-20 µE/m²/s; 50-100 ft-c)

146: Light regime 16:8 h light:dark (1000 lux)

147: Concentration declined to undetectable levels after 96 h; probably based on measured initial concentrations

148: Concentration declined to undetectable levels after 72 h; probably based on measured initial concentrations

149: Concentration declined to undetectable levels after 48 h; probably based on measured initial concentrations

150: Especially higher concentrations declined in 48 h, lower concentration were 0.5 µg/L; solvent control was significantly different from seawater and no information on the amount of ethanol is given

151: Irradiated throughout the experiment with UV-A light: (320-400 nm; maximum at 365 nm) at 2.5 W/m²

152: Concentrations based on actual concentrations; renewal was every 3 days; after 2 and 3 days phenanthrene was not detected anymore;
concentrations calculated as half the initial concentration (average recovery times the nominal concentration)

153: Average concentrations over 4 days estimated to be 26% of initial concentrations, based on measured time-weighted average concentrations

154: Pre-exposure of 24 h followed by 30 min irradiation with natural sunlight on a clear day: UV intensity 4245 µW/cm²; UV-B intensity 484 µW/cm²

155: Pre-exposure of 24 h followed by 60 min irradiation with natural sunlight on a partly cloudy day: UV intensity 2441 µW/cm²; UV-B intensity 278 µW/cm²

156: Pre-exposure of 24 h followed by 60 min irradiation with natural sunlight on a complete cloudy day: UV intensity 1657 µW/cm²; UV-B intensity 189 µW/cm²

157: Pre-exposure of 24 h followed by 45 min irradiation with natural sunlight on a clear day covered with a filter for UV-B (70-75% reduction in 285-315 nm)

158: Pre-exposure of 24 h followed by 45 min irradiation with natural sunlight on a clear day covered with a filter for UV-A and UV-B (70-75% reduction in 285-380 nm)

159: Pre-exposure of 24 h followed by 45 min irradiation with natural sunlight on a clear day covered with a filter to reduce the total spectrum (>285 nm): UV intensity 1314 µW/cm²

160: Artificial light with low UV emission used

161: Artificial light simulated sunlight with 30-65 µW/cm² UV-A (310-420 nm; peak at 350 nm) and 0.5-5 µW/cm² UV-B (250-400 nm; peak at 290 nm); Test result based on nominal concentrations, measured concentrations were > 80% of nominal

162: Exposure without UV light; determined from data from two ECx data and log-logistic dose-response relationship; Test result based on nominal concentrations, measured concentrations were > 80% of nominal

163: Substance dissolved in acetone, added to the bottom of the beaker and acetone was evaporated. To prepare the highest test solution, dilution water was added and series of test concentrations were prepared from this highest test concentration. For the volatile substances this may have caused substantial loss, while the nominal concentration of 1024 µg/L substantially exceeded the solubility of several substances.

164: Light regime 16:8 light:dark; mercury lamps with 150 µE·m⁻²·s⁻¹

165: Fluorescent light at 4-8 klux; to some of the air-tight flasks enrichment with HCO₃⁻ was added in different quantities to control pH

166: From a population pre-exposed to 7.9±0.8 µg/L during breeding and 6.2±0.8 µg/L during hatching and rearing

167: 6000-8000 lux on the level of the solutions

168: Photoperiod 16:8 h light:dark at less than 500 lux

169: Constant illumination at 4000 lux; continuously aerated in open system

170: Values based on nominal concentrations; actual concentrations were decreased by 20 to 30% initially and by 32 to 52% at the end of the 96 h toxicity studies. Average values were decreased by 76% in the chronic daphnid study, 51% in the chronic chironomid study, and 66% in the bluegill sunfish study

171: Based on actual concentrations by correcting nominal concentrations for average recovery

172: In the dark for 2 h, then irradiated with fluorescent UV-lamps at 975-1000 µW/cm² with maximum at 312 nm for 8 h

173: In the dark for 2 h, then irradiated in sunlight at 407-1428 µW/cm² >290 nm for 8 h
174: In the dark for 2 h, then irradiated with fluorescent UV-lamps at 975-1000 µW/cm² with maximum at 375 nm for 8 h
175: Light regime: 16:8 h light:dark by fluorescent bulbs at 1100 lx; measured concentrations were 68-90% (acute) and 110-168% (chronic) of nominal; values are expressed as mean measured concentrations
176: Different from solvent control (acetone), not different from seawater control, i.e. acetone had a positive effect
177: Concentrations based on actual concentrations; actual concentrations were 45-90% of nominal by GC-FID and 55-90% by GC-MS; concentrations calculated as 70% of the nominal concentration
178: Photoperiod of 16:8 h light:dark under cool white fluorescent lamps at an intensity of 28 lx
179: Laboratory fluorescent light with UV radiation very similar to sunlight
180: Fluorescent light with 9.70±0.66 µW/cm² UV-A (365±36 nm) and 3.37±0.22 µW/cm² UV-B (310±34 nm) with a photoperiod of 16:8 h light:dark
181: Ultraviolet light with 397±35.1 µW/cm² UV-A (365±36 nm) and 134±22.8 µW/cm² UV-B (310±34 nm) with a photoperiod of 16:8 h light:dark
182: UV lacking fluorescent laboratory lighting with a photoperiod of 12:12 h light:dark
183: Continuous visible light with a total visible fluence rate of 100 µmol/m²/s
184: Continuous simulated solar radiation with a total visible fluence rate of 100 µmol/m²/s
185: 2 hour a day under UV exposure with UV-A at 172-180 µW/cm² and UV-B at 4.2-6.3 µW/cm²; statistical analysis unclear
186: After photomodification with 20 µmol/m²/s UV-B (comparable to sunlight) for 7 d
187: Laboratory ultraviolet light with 283 µW/cm² UV-A and 47 µW/cm² UV-B and a photoperiod of 12:12 h light:dark
188: Laboratory ultraviolet light with 612 µW/cm² UV-A and 82 µW/cm² UV-B and a photoperiod of 12:12 h light:dark
189: Laboratory fluorescent light and a photoperiod of 16:8 h light:dark
190: Laboratory ultraviolet light with 465-724 µW/cm² UV-A and 68-109 µW/cm² UV-B and a photoperiod of 16:8 h light:dark
191: Laboratory ultraviolet light with 7 µW/cm² UV-A and a photoperiod of 16:8 h light:dark
192: Laboratory ultraviolet light with 64 µW/cm² UV-A and a photoperiod of 16:8 h light:dark
193: Laboratory ultraviolet light with 360 µW/cm² UV-A and a photoperiod of 16:8 h light:dark
194: Laboratory ultraviolet light with 676 µW/cm² UV-A and a photoperiod of 16:8 h light:dark
195: Laboratory ultraviolet light with 1788 µW/cm² UV-A and a photoperiod of 16:8 h light:dark
196: Fluorescent light with a photoperiod of 16:8 h light:dark and intensity of 270 lux
197: Derived from the figures with mean, standard error and number of replicates
198: Test performed outdoors in sunlight with 200-1650 µW/cm² UV-A and 45-320 µW/cm² UV-B
199: FETAX test
200: Test performed with 250 µW/cm² UV-A 320-400 nm (6.5 lx); peak at 365 nm
201: Test performed with continuously irradiation with 2100 µW/cm² visible light 400-750 nm (1220 lx)
202: Exposure under normal illumination
203: Photoperiod 15:9 h light:dark by white fluorescent lamps with an intensity of 40 µE/m²/s; based on nonexponential growth after 7 d; tested concentrations above aqueous solubility except for pyrene and the two lowest concentrations of naphthalene
204: Exposure with UV-A (320-400 nm), intensity 64.7±1.0 µW/cm²; renewal every 8 h; 72 h pre-exposed under ambient laboratory lighting
205: 16:8 light:dark photoperiod with fluorescent light; at the end of the exposure period clams were transferred to beakers with fresh sediment
206: Exposure with UV-A (320-400 nm), intensity 64.7±1.0 µW/cm²; renewal every 8 h; 72 h pre-exposed under ambient laboratory lighting
207: Calculated without the highest treatment of 500 µg/L
208: Exposure ca. 12 h in the dark followed by 30 min irradiation with 13.5 W/m² UV-A (>320, <400nm, peak 350 nm); mortality recorded after a recovery period of 24 h in water with food in the dark; data after 11 days for adult emergence are not suitable because control mortality is not well-defined
209: Time weighted concentrations from exponentially decreasing trend presented in figure used for calculations; concentrations above aqueous solubility; maximum concentration added with 0.04% acetone
210: Light regime: continuous light at 9.514-19.028 W·m⁻²·s⁻¹ (200-400 foot candles)
211: Results from second test
212: One duplicate significantly reduced, the other not
213: Photoperiod 12:12 h light:dark at 6000 lux; substance applied in 50 ppb Tween 20 acetone solution, acetone evaporated, culture medium added and autoclaved for 20 min; growth rate recalculated from generation time; condition of exponential growth phase was probably met
214: Solution contains 21 mg EDTA/L; fluorescent light used
215: Results from third test
216: Stock solution measured; results based on nominal concentration
217: Radiolabelled compound; aqueous concentrations measured; results based on nominal concentration; loss up to 50% by the end of the experiment
218: Based on measured concentrations; average measured concentrations exceeded nominal concentrations; therefore, it is estimated that reported measured concentrations may be overestimated by 25%.
219: Based on measured concentrations; before renewal average measured concentrations declined by an average of 25.4% per day
220: Based on measured concentrations; before renewal average measured concentrations declined by an average of 18.1% per day
221: Based on measured concentrations; before renewal average measured concentrations declined by an average of 17.6% per day
222: First 12 h dark, then continuous visible light at ~100 µE·m⁻²·s⁻¹
223: First 12 h dark, then combination of visible and UV-A (~785 µW·cm⁻²) light continuously
224: First 12 h dark, then continuous visible light at ~75 µE·m⁻²·s⁻¹
225: First 12 h dark, then combination of visible and UV-A (~805 µW·cm⁻²) light continuously
226: UV-A (320-400 nm) ranging from 50.5 (bottom) to 82.5 µW·cm⁻² (top); UV-B (285-320 nm) ranging from 3.6 to 8.65 µW·cm⁻²
Benthic species tested in water-only exposure

96 h exposure to fluoranthene subsequently followed by exposure to ultraviolet light in fresh Lake Superior water at an UV-A (310-390 nm) intensity of 16.6 µW/cm²

96 h exposure to fluoranthene subsequently followed by exposure to ultraviolet light in fresh Lake Superior water at an UV-A (310-390 nm) intensity of 33.5 µW/cm²

96 h exposure to fluoranthene subsequently followed by exposure to ultraviolet light in fresh Lake Superior water at an UV-A (310-390 nm) intensity of 75.2 µW/cm²

Test solutions prepared from saturated solutions in medium, which were not measured but compared with aqueous solubility data and calculated from the aqueous solubility

Weak dose-response relationship

In the presence of sand

Transferred to clean natural water afterwards either without treatment or followed by irradiation for 15 min by 370 kJ/m² UV light

Determined 5 to 6 months after hatching; spacing between concentrations is a factor of 10

Exposure to sunlight with mean fluence of $1.2 \times 10^{-5}$ mW/mm² UVA (320-400 nm) and $1 \times 10^{-4}$ mW/mm² UVB (290-320 nm)

Test was set up as bioconcentration experiment with fish eggs and larvae

*Tanytarsus dissimilis* is the same species as *Paratanytarsus parthenogeneticus*

Experiments are in duplicate

Exact values read from figure are more precise than the rounded off values in the table

Photoperiod 16:8 light:dark by fluorescent lamps with an intensity of 28 lm at the water surface

Fluorescent light with an intensity of 13-18 W/m² (22-33 kLux) equivalent to 350 µE·m⁻²·s⁻¹ at the surface of the test vessels

Algal species is from the Baltic Sea but tested at 30 °C and 0.2 psu

Continuous fluorescent light (PAR 380-690 nm) at 12 W·m⁻²

Continuous fluorescent light (PAR 380-690 nm) at 33 W·m⁻²

Continuous fluorescent light (PAR 380-690 nm) at 48 W·m⁻²

Continuous fluorescent light (PAR 380-690 nm) at 64 W·m⁻²

Aerated with 0.1% CO₂; pH increased to 9.5±0.4; concentrations dropped with half lifes of 2 h for anthracene and 7 h for phenanthrene at PAR of 64 W·m⁻² although it was determined in a separate unaerated experiment that this did not influence the percentage inhibition much; TWA values are only 11% and 35% for anthracene and phenanthrene respectively

Results based on initial concentrations, nominal if measured concentrations were more than 80%, otherwise actual concentrations; loss in 24 h was more than 20% for anthracene, benz[a]anthracene and pyrene

Gold light (0.17 µW/cm² UV-B, 0.09 µW/cm² UV-A, 167.72 µW/cm² visible); 16:8 h light:dark

Test performed in proteose-peptone-yeast salts (PPYS) complex medium

Read from figure

After exposure for 1 h, transferred to filtered sea water with exposure to UV (UVA (320-400 nm) 2.095 mW/cm² and UVB (280-320 nm) 0.325 mW/cm²) for 4 h and recovery in filtered sea water for 24 h in the dark

After exposure for 1 h, transferred to filtered sea water with exposure to sunlight (UVA (320-400 nm) 4.914 mW/cm² and UVB (280-320 nm)
0.581 mW/cm²) for 4 h and recovery in filtered sea water for 24 h in the dark
255: After exposure for 1 h, transferred to filtered sea water with exposure to UV (UVA (320-400 nm) 2.098 mW/cm² and UVB (280-320 nm) 0.313 mW/cm²) for 4 h and recovery in filtered sea water for 24 h in the dark
256: After exposure for 1 h, transferred to filtered sea water with exposure to UV (UVA (320-400 nm) 1.979 mW/cm² and UVB (280-320 nm) 0.276 mW/cm²) for 4 h and recovery in filtered sea water for 24 h in the dark
257: After exposure for 1 h, transferred to filtered sea water with exposure to UV (UVA (320-400 nm) 1.455 mW/cm² and UVB (280-320 nm) 0.196 mW/cm²) for 4 h and recovery in filtered sea water for 24 h in the dark
258: Photoperiod 16:8 h light:dark with cool-white fluorescent light (~36 µmol/m²/s; ~400-700 nm); performed in glass bottles with Teflon lined caps
259: Visible light+UVA (320-400 nm) at 56 and 4.6 µmol/m²/s
260: Visible light+UVA (320-400 nm)+UVB (290-320 nm) at 61, 4.4, and 0.45 µmol/m²/s
261: Effect concentration is expressed on basis of the initial actual concentration
262: At the lowest biomass tested (50 eggs/mL). Higher biomasses lead to reduced concentration and less toxicity. Concentration decreased by 68.4% in 1 h.
263: At the second lowest biomass tested (100 eggs/mL). Higher biomasses lead to reduced concentration and less toxicity. Concentration decreased by 68.4% in 1 h.
264: At the two lowest biomasses tested (50 and 100 eggs/mL). Higher biomasses lead to reduced concentration and less toxicity. Concentrations decreased by 68.4 and 75.6% in 1 h.
265: At the all biomasses tested (0, 50, 100, 200 and 400 embryos/mL). Concentration decreased by 78.1 in control (water only) and 85.3, 89.7, 90.1, and 92.2% in the tests with embryos.
266: Based on measured concentrations
267: Value extrapolated outside the test range (40-290 µg/L)
268: 0.024 ly·min⁻¹ photosynthetically active radiation (PAR)
269: Concentrations based on initial concentrations; all concentrations declined by about 25-50% in 24 h before renewal
270: Uncertainty about reported concentration (8-12 ppb; 10⁻⁹ mg/ml is also reported); no control with water has been incorporated, only a control containing BSA
271: Exposure period followed by a recovery period of 24 h in clean seawater
272: Photoperiod 14:10 h light:dark by cool daylight lamps (380-780 nm, PAR) with an intensity of 70 µE/m²/s
273: Average of measured concentrations <80% of nominal, unclear if results are based on measured or nominal concentration therefore not recalculated
274: Constant light by fluorescent light with an intensity of 350 lux; renewal every 12 h
275: Based on nominal concentrations
276: Initial concentrations on average 60% of nominal, concentrations after 48 h were below detection limit; cross-contamination with other PAHs not excluded
Based on average measured concentration in the highest test concentration; initial concentrations varied from 72 to 81%.

Initial concentrations on average 50 to 60% of nominal, concentrations after 48 h were below detection limit; cross-contamination with other PAHs not excluded.

Under fluorescent light at an intensity of 3500-4000 lux, no UV light; growth curves are presented but axis is inconclusive.

Under fluorescent light at an intensity of 3500-4000 lux and 1 hour a day under UV exposure with UV-A at 172-180 µW/cm² and UV-B at 4.2-6.3 µW/cm²

Under fluorescent light at an intensity of 3500-4000 lux and 2 hour a day under UV exposure with UV-A at 172-180 µW/cm² and UV-B at 4.2-6.3 µW/cm²

Under fluorescent light at an intensity of 3500-4000 lux and 3 hour a day under UV exposure with UV-A at 172-180 µW/cm² and UV-B at 4.2-6.3 µW/cm²

Under fluorescent light at an intensity of 3500-4000 lux and 4 hour a day under UV exposure with UV-A at 172-180 µW/cm² and UV-B at 4.2-6.3 µW/cm²

Yellow light

Under fluorescent light at an intensity of 3500-4000 lux and 1 hour a day under UV exposure with UV-A at 172-180 µW/cm² and UV-B at 4.2-6.3 µW/cm²

Notes to terrestrial toxicity studies:

1: Route of exposure is through food (mixture of poplar-, maple-, end birch-leaves at a ratio of 3:2:1) added with 10% DOKO dogfood at a ratio of 9:1; food was renewed every week; added in acetone and acetone left to evaporate

2: LOEC, significant effect; not clear if other concentrations were tested as well; 60% of maximum water carrying capacity; spiked with acetone to quartz sand and sand added to the soil at a maximum percentage of 10% (dry weight); soil with benzo[a]pyrene aged for 1 month

3: Light regime: 16 h light and 8 h dark at an intensity of 400 lux; 75% moisture; 40% of maximum water carrying capacity; soil with benzo[a]pyrene aged for 1 week; benzo[a]pyrene with similar purity from a different supplier was slightly less toxic (no details) on both weight gain and cocoon production

4: Light regime: 12 h light and 12 h dark

5: Exposure through food (poplar leaves); food was renewed every week; added in acetone and acetone left to evaporate

6: Growth as post emergence of seedlings (OECD 208)

7: Photoperiod 16:8 h light:dark at an intensity of 6500 lux produced by fluorescent bulbs
8: Estimated half-lives were 1.6 and 1.3 days for the low (0.5 mg/kg) and high (25 mg/kg) concentration, concentrations were below detection limit of 0.02 mg/kg after 20 d; no significant effect during the whole 80 day test period; CO₂ was measured on d 1.5, 3, 5, 7, 11, 17, 25, 32, 40, 52, 60, 66, 74, 80 and inorganic nitrogen on d 7, 14, 21, 28, 35, and 56.

9: Recovery only 2.4-14% of nominal after the 21 d period

10: Test performed in the dark

11: Recovery 48-89% after 14 d; average actual concentration after 14 days at the highest tested concentration of 1000 mg/kg was 885 mg/kg

12: Photoperiod 12:12 h light:dark under lighting of about 400-800 lux

13: Continuous outside illumination of about 400-800 lux

14: Light regime: 16 h light and 8 h dark; illumination with 400 W lamp emitting light with wavelength spectrum 310-780 nm with <1% UV; photo flux density 300 μE·m⁻²·s⁻¹

15: Average recovery of two to three concentrations after 21 days was 6% for napthalene, 32% for acenaphtene, 33% for acenaphthylene and 85% for anthracene, relative to the initial measured concentrations

16: Soil was aged for 10 days before toxicity testing

17: Soil was aged for 40 days before toxicity testing

18: Soil was aged for 120 days before toxicity testing

19: Spiked by mixing with a known quantity of dried soil and mixed with soil to obtain the final concentration

20: Based on time weighted average concentrations; initial recovery and loss over 28 days were 84% and 4% for pyrene, 103% and 11% for fluoranthene, 99% and 96% for phenanthrene, and 80% and 84% fluorene, respectively

21: Based on initial measured concentrations

22: Values are recalculated to time weighted average concentrations

23: Average recovery of one low and high concentration after 21 days was 33% for fluorene, 72% for phenanthrene, 83% for fluoranthene and 79% for pyrene, relative to the initial measured concentrations; 10 d measured as well

24: Test result based on nominal concentrations, initial measured concentrations were on average 99% and ranged from 93% to 112% of nominal values

25: Photoperiod 16:8 light:dark at an intensity of 47.3 μmol/m²/s

26: Exposure for 21 d in soil, 2 d counting/extraction, 6 d in drought chamber at 98.2% RH and 2 d at 100% RH

27: Solvent control performed, test performed at approximately 100% of the water holding capacity

28: Freshwater species tested in soil

29: 50 soils were tested, the one with the lowest LC50 is reported here; dichloromethane was used as carrier, evaporated for 24h; soil analysed before addition of phenanthrene; PAH contaminated soil, EC50 not corrected for background

30: 28% reduction but not significant compared with control; at 100 mg/kg no reduction was observed after 21 days exposure

31: Test result based on nominal concentrations

32: Spiked with 20 ml toluene per kg dry soil and left to volatilize for 3 h

33: According to ISO guideline 11268-2

34: According to ISO guideline 11267

35: According to ISO guideline 11269-2

36: According to ISO guideline 17155

37: According to ISO/DIS guideline 15685
38: Test result based on nominal concentrations, measured concentrations were > 75% of nominal
39: 16 h/d 130 µmol/s/m² PAR; at 100 mg/kg 22 to 41 % reduction
40: Spiked with chlorinated hydrocarbon (unclear which solvent and in what amount) and left to volatilize for only 2 h under a hood
41: Determined from means and standard deviation from figures and number of replicates (n=5)
42: Constant light intensity
43: Value determined with the trimmed Spearman-Karber method is considered unreliable as it clearly lies below the 50% effect level
44: Method to determine NOEC was not mentioned; EC10 value might be substantially lower but could not be determined, because weight loss occurred at higher concentrations; EC10 for absolute weight is in the order of 9 mg/kg
45: Test result based on nominal concentrations, measured concentrations were > 80% of nominal
46: Time weighted average concentrations over one week were 57% for fluorene, 29% for phenanthrene, 63% for fluoranthene, 82% for benzo[a]anthracene and 101% for benzo[a]pyrene
47: Determined from data from figures and/or tables and log-logistic dose-response relationship
48: Determined from two ECx data and log-logistic dose-response relationship
49: Soil was renewed every week; average recovery of samples at the beginning and end of the week in this test system was 75% (64-84%); concentrations corrected for average recovery
50: Soil was renewed every week; average 82-93% of nominal concentration; 37% reduction but not significant compared with control
51: Soil was renewed every week; average 83-84% of nominal concentration; 36% reduction but not significant compared with control
52: Test result based on nominal concentrations, initial recovery less than 50%
53: Stimulation of growth at lower concentration up to 0.05 mg/kg, substance added in acetone, left to evaporate for 24 h
54: EC20 divided by a factor of three
55: Light regime 12:12 h light:dark at 400 lux
56: 16:8 h photoperiod (light:dark); substance added in acetone, evaporated in a fume hood for 7 d; rehydrated to 60% of water holding capacity
57: Light regime 16:8 h light:dark
58: Soil stored at 4 ºC for one month
59: Spiked with acetone to the total amount of quartz sand and acetone left to evaporate
60: Spiked with small amount of acetone or chloroform to the dry soil, and solvent left to evaporate
61: Spiked with acetone to the dry soil, acetone left to evaporate and water added
62: Soil was renewed every week; average recovery of samples at the beginning and end of the week in this test system was 94% (84-115%)
63: Carrier acetone, evaporated for at least 24h at 28-30 ºC before start experiment; natural sunlight 12h/day; unclear if OM or OC is reported; results not clear enough (no statistics performed) to label the NOEC as reliable values
64: 12:12 h light:dark
65: Experiment performed in a system containing 30 g dry sand brought to 20±2% moisture. The test substrate was added in acetone to horse manure with a moisture content of 75% on top of the sand. It is unclear
whether the concentration indeed relate to the horse manure only and whether the concentrations are expressed on dry weight.

66: Soil contains 38% sand and 60% clay and silt
67: Substance added in acetone, evaporated overnight
68: Exposure for 21 d in soil, 2 d counting/extraction, 7 d in drought chamber at 97.8% RH and 2 d at 100% RH
69: Spiked to quartz sand before application
70: Test according to OECD 207
71: Two days of seed germination and seedling emergence followed by 14 d exposure, photoperiod 16:8 h light:dark at least 7000 lux
72: Continuous light at 250-500 lux
73: EC10 calculated from data presented in figures; calculated EC10 is in accordance with the estimated NOEC of 192 mg/kg presented by the authors
74: Light regime 16:8 h light:dark at ca. 600 lux; 1% cow dung added
75: Cocoons observed for 35 d after test
76: Cocoons observed in control is significantly higher than in the tests with fluoranthene and combined exposure
77: Cocoons observed in next concentration of 100 mg/kg almost stopped, while equal at 1 and 10 mg/kg
78: Substance added in acetone, evaporated under a fume head for 24 h
79: Exposure for 21 d in soil, 2 d counting/extraction, 7 d in drought chamber at 98.2% RH and 2 d at 100% RH
80: Light regime: 12 h light and 12 h dark at an intensity of 400-800 lux
81: According to draft OECD guideline
82: Per replicate 100 live adult springtails (Folsomia fimetaria) were added as food items
83: Similar to the ISO (1997) guideline
84: Based on draft ISO guideline; highest nominal concentration tested was 2800 mg/kg; results expressed as average of measured concentration at start and end of the exposure period; photoperiod 16:8 h light:dark
85: Concentrations at the end of the experiment were at least 70% of the actual initial concentrations for anthracene, benzo[a]anthracene, pyrene and benzo[a]pyrene, but only 1-10% for naphthalene and 5 to 35% for phenanthrene
86: Value is geomean of reported range
87: Results from second experiment
88: Results from third experiment

Notes to benthic toxicity studies:
1: Sediment was aged for one-and-a-half months in the dark at 4 ºC before use
2: Dark and UV-A (108.4±1.3 µW/cm²)
3: Stored for 5 w after spiking
4: Stored for 60 d after spiking
5: Stored for 18 m after spiking
6: Stored for 3 w after spiking
7: Average loss over 10 days was 23%
8: Values are based on average measured concentrations
9: Light intensity 50 µmol quanta/m²/s by mercuy lamps; UV filters used to minimise photodegradation
10: Stored for 7 d after spiking
11: Test according to OECD 218
12: Read from figure
13: Only initial sediment concentrations were measured, which were 71-100% of nominal.
14: 12:12 h light:dark
15: Determined under normoxic conditions (DO of 5.91 mg/L, 82.1% saturation); salinity 27.2‰; placed under fluorescent lights
16: Determined under moderately hypoxic conditions (DO of 3.62 mg/L, 50.3% saturation); salinity 25.5‰; placed under fluorescent lights
17: Determined under normoxic conditions (DO of 6.86 mg/L, 95.4% saturation); salinity 29.2‰; placed under fluorescent lights
18: Determined under moderately hypoxic conditions (DO of 3.96 mg/L, 56.0% saturation); salinity 28.6‰; placed under fluorescent lights
19: Large difference between percentages organic carbon and organic matter: 0.38% oc and 2.4% om
20: Light regime 16 h light/8 h dark; mercury light source mimicking natural light; spiked with 0.3% v/v acetone
21: Effect is most pronounced with females; effect is absent (anthracene) or almost absent (phenanthrene) with males
22: Sediment (muddy sand) with overlying seawater (28 o/oo) exposure for 10 days; 1 h reburial in control sediment
23: 1 h UV radiation after 10 days exposure and 1 h reburial: UV-A (321-400 nm) 315±36 µW/cm2 and UV-B (280-320 nm) 128±12 µW/cm2 and visible light (401-700 nm) 3400±278 µW/cm2; after irradiation again 1 h reburial
24: L(E)C50 values given as µmol/g OC (2.58%) is converted to mg/kg sediment
25: 24 h exposure in sediment was followed by 3 h exposure in sediment in the presence of food (algae)
26: Sediment was aged for 10 days before toxicity testing
27: Gold light (0.17 µW/cm2 UV-B, 0.09 µW/cm2 UV-A, 167.72 µW/cm2 visible); 16:8 h light;dark
28: Fluorescent light (1.32 µW/cm2 UV-B, 13.65 µW/cm2 UV-A, 424.69 µW/cm2 visible); 16:8 h light;dark
29: UV enhanced light (7.54 µW/cm2 UV-B, 102.08 µW/cm2 UV-A, 289.24 µW/cm2 visible); 16:8 h light;dark
30: Two experiments, no clear dose response curves; high control mortality for Diporeia sp. and low growth rate constant for Hyalella in experiment 1; yellow light >500 nm
31: Stored for 13 d after spiking
32: Stored for 27 d after spiking
33: Stored for 41 d after spiking
34: Stored for 55 d after spiking
35: Stored for 69 d after spiking
36: Stored for 83 d after spiking
37: Stored for 121 d after spiking
38: Stored for 170 d after spiking
39: Actual concentrations were always above 65% of nominal
40: Base sediment amended with organic carbon from Zostera (macrophyta)
41: Base sediment amended with organic carbon from suspended solids
42: Base sediment amended with organic carbon from mud
43: Base sediment amended with organic carbon from oyster feces
44: Base sediment amended with organic carbon from shrimp feces
45: Based on nominal concentrations
46: Based on measured concentrations
47: Determined from data from figures and/or tables and log-logistic dose-response relationship
Determined from two ECx data and log-logistic dose-response relationship

Determined from means and standard deviation from figures and number of replicates (10)

No clear dose-response relationship, because highest concentration deviates

Test performed in the dark

Test performed under continuous light

Light regime 16:8 h light:dark (10-20 µE/m²/s; 50-100 ft-c)

Average loss over 10 days was 5.8% for pyrene and 54.2% for phenanthrene

Values are based on initial measured concentrations

Exposure under white light (2500 lux, 74-92 µW/cm²), 16 h light/8 h dark

Light regime 16:8 h light:dark

Wet sediment spiked with substance in acetone

Walls of glass bottles coated with substance and mixed with sediment by rolling

Portion dry sediment spiked with substance in acetone and left to evaporate and mixed with rest of sediment afterwards

Water sediment system spiked in water with fluoranthene in acetone

Determined from raw data and log-logistic dose-response relationship with LC50
Environmental risk limits for polycyclic aromatic hydrocarbons (PAHs)
For direct aquatic, benthic, and terrestrial toxicity

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