

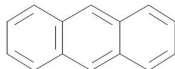
ANTHRACENE

This EQS dossier was prepared by the Sub-Group on Review of the Priority Substances List (under Working Group E of the Common Implementation Strategy for the Water Framework Directive).

The dossier was reviewed by the Scientific Committee on Health and Environmental Risks (SCHER), which commented that it did not agree with the use of an additional assessment factor of 5 for the marine sediment EQS. The additional factor has been removed (see section 7.1.2).

This dossier is a revision of the original EQS fact sheet for anthracene, which was not totally consistent with the revised Technical Guidance for deriving EQS (E.C., 2011) and did not include the latest ecotoxicological and toxicological data contained in the final version of the European Union Risk Assessment Report (E.C., 2008a) made available in the context of assessment of existing chemicals (Regulation 793/93/EEC). The present dossier takes account of that final report and of a report in preparation provided by RIVM (Verbruggen, in prep.) which was made available to the assessor.

1 CHEMICAL IDENTITY

Common name	Anthracene
Chemical name (IUPAC)	Anthracene
Synonym(s)	-
Chemical class (when available/relevant)	Polyaromatic hydrocarbons (PAH)
CAS number	120-12-7
EC number	204-371-1
Molecular formula	C ₁₄ H ₁₀
Molecular structure	
Molecular weight (g.mol ⁻¹)	178.2

2 EXISTING EVALUATIONS AND REGULATORY INFORMATION

Legislation	
Annex III EQS Dir. (2008/105/EC)	No (existing priority substance including in Annex I EQS Dir.)
Existing Substances Reg. (793/93/EC)	Priority List #3. Substance #316. Rapporteur: Greece EU-RAR finalised April 2008
Pesticides(91/414/EEC)	No
Biocides (98/8/EC)	Not notified
PBT substances	Substance ID #022. PBT List #032. Rapporteur: Germany PBT Working Group Summary Fact Sheet ¹ date 10 March 2008 Conclusion : fulfilling PBT & vPvB criteria
Substances of Very High Concern	Included ² because classified PBT (article 57d)

¹ http://ecb.jrc.ec.europa.eu/documents/PBT_EVALUATION/PBT_sum032_CAS_120-12-7.pdf

² http://echa.europa.eu/doc/candidate_list/svhc_supdoc_anthracene_publication.pdf

(1907/2006/EC)	Date of inclusion: 28.10.2008 Decision number ED/67/2008
POPs (Stockholm convention)	No
Other relevant chemical regulation (veterinary products, medicament, ...)	No
Endocrine disrupter (E.C., 2004 and E.C., 2007³)	Not investigated

³ Commission staff working document on implementation of the Community Strategy for Endocrine Disrupters.

3 PROPOSED QUALITY STANDARDS (QS)

3.1 ENVIRONMENTAL QUALITY STANDARD (EQS)

QS_{water, eco} for protection of pelagic organisms is 0.1 µg.l⁻¹ and is deemed the “critical QS” for derivation of an Environmental Quality Standard.

	Value	Comments
Proposed AA-EQS for [freshwater] [µg.l ⁻¹]	0.1	Critical QS is QS _{water, eco}
Proposed AA-EQS for [marine water] [µg.l ⁻¹]	0.1	See section 7
Proposed MAC-EQS for [freshwater] [µg.l ⁻¹]	0.1	See section 7.1
Proposed MAC-EQS for [marine water] [µg.l ⁻¹]	0.1	

3.2 SPECIFIC QUALITY STANDARD (QS)

Protection objective ⁴	Unit	Value	Comments
Pelagic community (freshwater)	[µg.l ⁻¹]	0.1	See section 7.1
Pelagic community (marine water)	[µg.l ⁻¹]	0.1	
Benthic community (freshwater)	[µg.kg ⁻¹ _{dw}]	24	See section 7.1
Benthic community (marine)	[µg.kg ⁻¹ _{dw}]	24	
Predators (secondary poisoning)	[µg.kg ⁻¹ _{biota ww}]	92 222	See section 7.2
	[µg.l ⁻¹]	4.9* – 30.3 (freshwater and marine waters)	
Human health via consumption of fishery products	[µg.kg ⁻¹ _{biota ww}]	2 434.8	See section 7.3
	[µg.l ⁻¹]	0.128* – 0.8 (freshwater and marine waters)	
Human health via consumption of water	[µg.l ⁻¹]	140	

* Worst-case calculation using a value of 19 000 as BCF for molluscs (see section 5.1).

⁴ Please note that as recommended in the Technical Guidance for deriving EQS (E.C., 2011), “EQSs [...] are not reported for ‘transitional and marine waters’, but either for freshwater or marine waters”. If justified by substance properties or data available, QS for the different protection objectives are given independently for transitional waters or coastal and territorial waters.

4 MAJOR USES AND ENVIRONMENTAL EMISSIONS

4.1 USES AND QUANTITIES

All data hereunder are extracted from Anthracene EU-RAR (E.C., 2008a)

4.1.1 Production

Anthracene EU-RAR (E.C., 2008a) states that “anthracene is present in coal tar, from where it can be recovered efficiently. Hence, recovery from coal tar and, in particular, from anthracene oil (one of coal tar’s distillate fractions), constitutes the basis for the industrial production of anthracene.

Anthracene is produced in a single plant in the EU, starting from light anthracene oil, a fraction of coal tar distillation containing about 6% anthracene, by the combined application of crystallisation and vacuum distillation, and the product is further refined by recrystallisation.

At the time of the risk assessment the EU consisted of 15 Member States, therefore this report considers only the production and use of anthracene in these 15 Member States.

Additional releases of and exposure to anthracene can occur during the production and use of products (e.g. coal tar or creosote and related products) which contain anthracene as part of complex mixtures and not through the addition of isolated, commercial anthracene. Also additional releases occur through processes of incomplete combustion, in occupational and other settings, which result in the release of complex mixtures containing anthracene. While contributing to background environmental concentrations of anthracene, anthracene-related risks associated with such products or processes are not within the scope of the present Report.”

4.1.2 Uses

Anthracene EU-RAR (E.C., 2008a) states that “use of anthracene in the EU is restricted to the manufacture of pyrotechnics and in scientific research laboratories. In accordance with Council Directive 79/831, the latter type of use does not come under the terms of the present Report.”

4.2 ESTIMATED ENVIRONMENTAL EMISSIONS

EU-RAR (E.C., 2008a) states that anthracene occurs in fossil fuels and is released into the environment as a product of incomplete combustion of organic matter (IARC, 1983). It has been identified in the mainstream smoke of cigarettes, cigar and pipe smoke, mainstream smoke of marijuana cigarettes, exhaust emissions from gasoline engines, samples of charcoal-broiled steaks, edible oils, surface water, tap water, waste water, and dried sediment of lakes (IARC, 1983). In addition, anthracene has been identified in emissions from open burning of scrap rubber tires, in high octane gasoline, in coke oven emissions, and in emissions from asphalt processes (Verschueren, 1996). Anthracene is emitted from the open burning of scrap rubber tires at an average concentration of 53 mg/kg of tire (De Marini et. al., 1995 as cited in E.C., 2008a).

The following emissions to the environment were considered in evaluating the risks, under the scope of the Council Regulation 793/93/EEC, associated with the life cycle of production and use of anthracene and anthracene-containing products:

- 1) Anthracene production : Preparation of crude anthracene from anthracene oil, purification of crude anthracene and anthracene packaging.
- 2) Uses of anthracene or anthracene-containing products: Manufacture of pyrotechnics (formulation and processing).

5 ENVIRONMENTAL BEHAVIOUR

5.1 ENVIRONMENTAL DISTRIBUTION

		Master reference
Water solubility (mg.l ⁻¹)	0.047	Mackay <i>et al.</i> , 1992 <i>in</i> E.C., 2008a
Volatilisation	Anthracene is not likely to volatilise from surface water.	
Vapour pressure (Pa)	9.4 10 ⁻⁴	Mackay <i>et al.</i> , 1992 <i>in</i> E.C., 2008a
Henry's Law constant (Pa.m ³ .mol ⁻¹)	4.3	Mackay <i>et al.</i> , 1992 <i>in</i> E.C., 2008a
Adsorption	The value 29 512 is used for derivation of QS	
Organic carbon – water partition coefficient (K _{OC})	log K _{OC} = 4.47 (<i>calculated from K_{OW}</i>) K _{OC} = 29 512	Karickhoff <i>et al.</i> , 1979
Sediment – water partition coefficient (K _{sed-water})	739 (<i>calculated from K_{OC}</i>)	E.C., 2011
Bioaccumulation	The BCF values of 3 042 (fish) and 19 000 (molluscs) are used for derivation of QS_{biota sec. pois.} and BMF₁ = BMF₂ = 1 given the absence of biomagnification (Bleeker, 2009).	
Octanol-water partition coefficient (Log K _{ow})	4.68	Mackay <i>et al.</i> , 1992 <i>in</i> E.C., 2008a
BCF	4.34	<i>Calculated from K_{ow}</i>
	<p>Values per taxa based on data reported in the BCF dedicated table hereafter:</p> <ul style="list-style-type: none"> - BCF plants = 28 - BCF annelids = 2 671 (geo. mean) - BCF molluscs = 19 000⁵ - BCF crustaceans = 2 536 (geo. mean) - BCF fish = 3 042 (geo. mean) <p>BCF is set to the highest geometric mean of values reported for fish, that is to say 3 042.</p> <p>Moreover, these data demonstrate an absence of biomagnification given that higher trophic levels (fish and amphibians) present lower BCF values than lower trophic levels such as molluscs. Therefore, trophic dilution seems more likely than biomagnification and BMF values should be set to 1 by default.</p>	Bleeker, 2009

⁵ During the review process, CONCAWE stated that they considered the use of this value “questionable, as the paper from which this value originates is selected describes an experiment that is not designed to measure a BCF. The test animals were exposed mainly to non dissolved anthracene, which makes the concluded BCF value uncertain and doubtful.”

Table summarising BCF values for anthracene in several aquatic species (Bleeker, 2009)

Taxa	Species	Test system (a)	Chem. Analysis (b)	BCF (l.kg ⁻¹)	Type (c)	Reliability (d)	References
Pisces	Cyprinus carpio	FT	GCMS	1 890, 2 225 ¹ 2 545, 1 960 ²	Equi. Kin.	2	RIITI, 1977
	<i>Pimephales promelas</i> (eggs)	FT	HPLC	563 – 966 ⁶	Equi.	2	Hall and Oris, 1991
	<i>Pimephales promelas</i> (male)			1 126, 2 476 ⁶			
	<i>Pimephales promelas</i> (female)			3 581, 4 973 ⁶			
Mollusca	<i>Perna viridis</i>	SR	GC	19 000 ³	Equi.	2	Richardson <i>et al.</i> , 2005
Crustacea	<i>Daphnia magna</i>	SR	HPLC	970	Equi.	2	Newsted and Giesy, 1987
	<i>Daphnia pulex</i>	S	Flu.Spec.	917	Equi.	2	Southworth <i>et al.</i> , 1978
	<i>Hyalella azteca</i>	FT	¹⁴ C	1 800	Equi.	2	Landrum and Scavia, 1983
	<i>Pontoporeia hoyi</i>	FT	¹⁴ C	16 800 39 727	Kin. Kin.	2 1	Landrum, 1982 Landrum, 1988
Oligochaeta	<i>Lumbriculus variegatus</i>	SR	HPLC	1 370	Equi.	2	Ankley <i>et al.</i> , 1997
	<i>Stylodrilus heringianus</i>	FT	¹⁴ C	5 206	Kin.	2	Frank <i>et al.</i> , 1986
Magnoliophyta	<i>Lemna gibba</i>	S	¹⁴ C	4 – 28 ⁶	Kin.	2	Duxbury <i>et al.</i> , 1997

¹ Values represent (a range of) BCF values from (a range of) different exposure concentrations.

² Kinetic model with estimated uptake rate constant based on fish size applied to the data, high and low concentration, respectively.

³ In this study BCF values are based on lipid weight, values given in this table are normalized to 5% lipid content. It is to be noted that this value can not be considered as a BCF as such. In fact, the test was conducted with a majority of anthracene (ca. 95%) being present as non dissolved. Given the feeding mode of molluscs (filtration), the internal value compared to the concentration in the media can therefore be considered as BAF, more than a BCF, i.e. a value taking into account concentration *via* water but also *via* trophic pathway. In this regard, CONCAWE stated during the review process that "this statement is incorrect as a BAF is considered the amount taken up via food (test material) that is present in the food that is supplied to the test animals during the test. As the mollusca are exposed to pure undissolved anthracene nor conclusion on BCF neither BAF can be drawn from this paper."

a) FT: flow-through system; S: static; SR: static renewal. b) ¹⁴C: radioactive carbon in the parent compound; GC: Gas chromatography; GCMS: Gas chromatography with mass spectrometry; Flu.Spec.: fluorescence spectrometry; ³H: radioactive hydrogen in the parent compound; HPLC: high pressure liquid chromatography. c) Kin.: Kinetic BCF, i.e. k_1/k_2 ; Equi.: BCF at (assumed) equilibrium, i.e. $C_{organism}/C_{water}$. d) Reliability; 1: valid without restrictions; 2: valid with restrictions.

5.2 ABIOTIC AND BIOTIC DEGRADATIONS

		Master reference
Hydrolysis	Hydrolysis of anthracene is not expected. Studies showed no hydrolysis in Mabey <i>et al.</i> , 1982 and Howard <i>et al.</i> , 1991.	E.C., 2008a
Photolysis	Anthracene is photoreactive. Anthracene concentration may be reduced remarkably by UV radiation. (Trapido and Veressinina, 1994). The half-life for photolysis in water lies in the range 20 minutes and 124.8 hours depending on the experimental conditions used. The highest value in this range corresponds to photolysis in winter solar conditions. The lower photolysis rate constant for a 3 x 10 ⁻⁷ M aqueous solution of anthracene was measured to be 5.16 x 10 ⁻⁴ /sec (Zingg and Sigman, 1993)	E.C., 2008a
Biodegradation	The results from standard test for biodegradation in water show that PAH with up to four aromatic rings are biodegradable (EHC, 1998). Although some evidence for anaerobic transformation of PAHs has been obtained (Coates <i>et al.</i> , 1997; Thierrin <i>et al.</i> , 1993), PAHs are usually considered to be persistent under anaerobic conditions (Neff, 1979; Volkering and Breure, 2003). Because marine sediments are often anaerobic, degradation of PAHs in this compartment is expected to be very slow.	E.C., 2008a; E.C., 2008b

6 AQUATIC ENVIRONMENTAL CONCENTRATIONS

6.1 ESTIMATED CONCENTRATIONS

Compartment		Predicted environmental concentration (PEC) regional	Master reference
Freshwater ($\mu\text{g.l}^{-1}$)	Calculated PEC _{local} – production of anthracene	$1.23 \cdot 10^{-5}$	E.C., 2008a
	Calculated PEC _{local} – production of pyrotechnics (formulation)	$3.62 \cdot 10^{-2}$	
	Site-specific PEC _{local}	$1.1 \cdot 10^{-7}$	
	PEC _{regional}	$1.22 \cdot 10^{-5}$	
	PEC _{continental}	$1.05 \cdot 10^{-6}$	
Freshwater sediment ($\mu\text{g.kg}^{-1}$ dw)	Calculated PEC _{local} – production of anthracene	$3.62 \cdot 10^{-2}$	E.C., 2008a
	Calculated PEC _{local} – production of pyrotechnics (formulation)	107	
	Site-specific PEC _{local}	$3.3 \cdot 10^{-4}$	
	PEC _{regional}	$7.06 \cdot 10^{-2}$	
	PEC _{continental}	$6.05 \cdot 10^{-3}$	
Biota (freshwater) ($\mu\text{g.kg}^{-1}$ ww)	Calculated PEC _{oral} – production of anthracene	0.112	E.C., 2008a
	Calculated PEC _{oral} – production of pyrotechnics (formulation)	135	
Biota (marine)		No data available	
Biota (marine predators)		No data available	

6.2 MEASURED CONCENTRATIONS

Compartment		Measured environmental concentration (MEC)	Master reference
Freshwater ($\mu\text{g.l}^{-1}$)		PEC 1: 0.027 PEC 2: 0.007	James <i>et al.</i> , 2009 ⁽¹⁾
Marine waters (coastal and/or transitional) ($\mu\text{g.l}^{-1}$)		No data available	
WWTP effluent ($\mu\text{g.l}^{-1}$)		No data available	
Sediment ($\mu\text{g.kg}^{-1}$ dw)	Sed < 2 mm	PEC 1: 183 PEC 2: 59.5	James <i>et al.</i> , 2009 ⁽¹⁾
	Sed 20 μm	PEC 1: 459.6 PEC 2: 384.7	
	Sed 63 μm	PEC 1: 27 PEC 2: 13.5	
Biota ($\mu\text{g.kg}^{-1}$ ww)	Invertebrates	PEC 1: 4.11 PEC 2: 1.46	James <i>et al.</i> , 2009 ⁽¹⁾
	Fish	No data available	

	Marine predators	No data available
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⁽¹⁾ data originated from EU monitoring data collection

7 EFFECTS AND QUALITY STANDARDS

Final CTPht EU-RAR (E.C., 2008b) states that "PAHs can be toxic via different mode of actions, such as non-polar narcosis and phototoxicity. The last is caused by the ability of PAHs to absorb ultraviolet A (UVA) radiation (320–400 nm), ultraviolet B (UVB) radiation (290–320 nm), and in some instances, visible light (400–700 nm). This toxicity may occur through two mechanisms: photosensitization, and photomodification. Photosensitization generally leads to the production of singlet oxygen, a reactive oxygen species that is highly damaging to biological material. Photo-modification of PAHs, usually via oxidation, results in the formation of new compounds and can occur under environmentally relevant levels of actinic radiation (Lampi et al., 2005). The photo[induced] toxic effects can be observed after a short period of exposure, which explains why for PAHs like anthracene, fluoranthene and pyrene, where photo[induced] toxicity is most evident, the acute toxicity values are even lower than the chronic toxicity values. According to Weinstein and Oris (1999) there is a growing body of evidence which suggests that photo[induced] toxic PAHs may be degrading aquatic habitats, particularly those in highly contaminated areas with shallow or clear water. For example, the photoinduced chronic effects of anthracene have been reported at those UV intensities occurring at depths of 10 to 12 m in Lake Michigan (Holst & Giesy, 1989). In addition to direct uptake of PAHs from the water column, another potential route of exposure for aquatic organisms is their accumulation from sediments (see e.g. Clemens et al., 1994; Kukkonen & Landrum, 1994), followed by subsequent solar ultraviolet radiation exposures closer to the surface. Ankley et al. (2004) also concluded in their peer review that PAHs are present at concentrations in aquatic systems such that animals can achieve tissue concentrations sufficient to cause photoactivated toxicity. Although UV penetration can vary dramatically among PAH-contaminated sites, in their view it is likely that at least some portion of the aquatic community will be exposed to UV radiation at levels sufficient to initiate photoactivated toxicity. They do recognize that at present time, the ability to conduct PAH photoactivated risk assessment of acceptable uncertainty is limited by comprehensive information on species exposure to PAH and UV radiation during all life stages. PAH exposure and uptake, as well as UV exposure, are likely to vary considerably among species and life stages as they migrate into and out of contaminated locations and areas of high and low UV penetration. For all but sessile species, these patterns of movements are the greatest determinant of the risk for photoactivated toxicity.

Despite these uncertainties, it is thought that the photo[induced] toxic effects cannot be ignored in the present effects assessment. Therefore these effects are also considered in deriving the QS for aquatic species. It should be noted that the UV exposure levels of the selected studies did not exceed the UV levels under natural sun light conditions."

7.1 ACUTE AND CHRONIC AQUATIC ECOTOXICITY

Ecotoxicity data reported in the tables hereunder were extracted exclusively from the finalised version of CTPHT EU-RAR (E.C., 2008a) and an RIVM report in preparation (Verbruggen, in prep.) which was made available to the assessor.

Many ecotoxicity data are available to assess anthracene effects. When for a single study, several effects or no effects data were available for the same species, same exposure duration and the same endpoint,; geometric means were calculated.

Information on the absence/presence of light as well as the type was reported in the tables as much as possible.

Whenever it was possible, for each species, endpoints were reported for tests for which results were based on measured concentrations (reported as (m) in the tables hereunder) rather than nominal concentrations (reported as (n) in the tables hereunder). Also, when available, information was given on the types of exposure lead, that can be: static (s), static closed (sc), renewal (r) or continuous flow (cf).

In the table below, all data reported were considered valid for effects assessment purpose, i.e. could be given a reliability index (Klimisch code) of 1 or 2, or were considered useful as supporting information for effects assessment purpose, i.e. could be given a reliability index (Klimisch code) of 2/3. Information on reliability were retrieved from finalised version of CTPHT EU-RAR (E.C., 2008a) and an RIVM report in preparation (Verbruggen, in prep.).

7.1.1 Organisms living in the water column

ACUTE EFFECTS			Klimisch code	Master reference
Algae & aquatic plants (mg.l ⁻¹)	Freshwater Algae	<i>Pseudokirchneriella subcapitata</i> / 22h / dark EC ₅₀ – growth = 0.0066 (m, r)	2 acc ^{ing} to RIVM and EU-RAR	Gala and Giesy, 1992
		<i>Pseudokirchneriella subcapitata</i> / 22h / UV EC ₅₀ – growth = 0.0039 (m, r)	2 acc ^{ing} to RIVM and EU-RAR	Gala and Giesy, 1992
		<i>Chlorella pyrenoidosa</i> / 96h EC ₅₀ = 1.47	2 acc ^{ing} to EU-RAR	Yan <i>et al.</i> , 1999
		<i>Chlorella vulgaris</i> / 96h EC ₅₀ = 1.27		
		<i>Chlorella protothecoides</i> / 24h-96h EC ₅₀ – 24h = 2.53 EC ₅₀ – 96h = 0.85		
	Marine Algae	<i>Nitzschia closterium</i> / 72h EC ₅₀ = 0.06	2 acc ^{ing} to EU-RAR	Huang <i>et al.</i> , 2000
		<i>Isochrysis galbana</i> / 72h EC ₅₀ = 0.065	2 acc ^{ing} to EU-RAR	Huang <i>et al.</i> , 2000
		<i>Platymonas subcordiformis</i> / 72h EC ₅₀ = 0.094	2 acc ^{ing} to EU-RAR	Huang <i>et al.</i> , 2000
	Freshwater Plants	<i>Lemna gibba</i> / unknown duration EC ₅₀ – growth = 1.5	2 acc ^{ing} to EU-RAR 3 acc ^{ing} to RIVM	Huang <i>et al.</i> , 1997a; Huang <i>et al.</i> , 1997b; Huang <i>et al.</i> , 1997c
		<i>Lemna gibba</i> / unknown duration EC ₅₀ – growth = 1.5		Huang <i>et al.</i> , 1997a; Huang <i>et al.</i> , 1997b; Huang <i>et al.</i> , 1997c
<i>Lemna gibba</i> / 20d IC ₅₀ – growth = 0.2		Huang <i>et al.</i> , 1995; Huang <i>et al.</i> , 1997a; Huang <i>et al.</i> , 1997b; Huang <i>et al.</i> , 1997c		
Invertebrates (mg.l ⁻¹)	Freshwater Molluscs	No information available		
	Marine Molluscs	<i>Mulinia lateralis</i> / 48h - expo UV LC ₅₀ = 0.00647 (m, s) - expo fluo. light: LC ₅₀ = 4.260 (m, s) <i>Mulinia lateralis</i> / 96h - expo UV LC ₅₀ = 0.0689 (m, s) - expo fluo. light: LC ₅₀ = 13.3 (m, s)	2 acc ^{ing} to RIVM and EU-RAR	Pelletier <i>et al.</i> , 1997a
		<i>Utterbackia imbecilis</i> / 28h / lab lighting LC ₅₀ > 0.0166 (m, r) <i>Utterbackia imbecilis</i> / 28h / UV LC ₅₀ = 1.93 10 ⁻³ (m, r)	2 acc ^{ing} to RIVM	Weinstein and Polk, 2001
		Freshwater Crustaceans	<i>Daphnia pulex</i> / 24h dark + 30mn sunlight EC ₅₀ – immobilisation = 0.001 (m, s)	2 acc ^{ing} to RIVM and EU-RAR

ACUTE EFFECTS			Klimisch code	Master reference
		<i>Daphnia magna</i> / 48h / dark EC ₅₀ – immobilisation > 0.025 (m, s)	2 acc ^{ing} to RIVM	Bisson <i>et al.</i> , 2000
		<i>Daphnia magna</i> / 14mn / UV EC ₅₀ – immobilisation = 0.0012 <i>Daphnia magna</i> / 24 – 25h / sunlight & dark EC ₅₀ – immobilisation = 0.0012	2 acc ^{ing} to EU-RAR	Oris <i>et al.</i> , 1984
		<i>Daphnia magna</i> / 24h EC ₅₀ = 0.211 (n, sc) <i>Daphnia magna</i> / 48h EC ₅₀ = 0.0095 (n, sc)	2 acc ^{ing} to EU-RAR 3 acc ^{ing} to RIVM	Munoz and Tarazona, 1993
		<i>Daphnia magna</i> / 48h EC ₅₀ = 0.754	2 acc ^{ing} to EU-RAR	Smith <i>et al.</i> , 1988
		<i>Daphnia magna</i> / 23±1h EC ₅₀ = 0.022 mmol.l ⁻¹	2 acc ^{ing} to EU-RAR	Huovinen <i>et al.</i> , 2001
		<i>Daphnia magna</i> / 24h LTC ₅₀ = 0.015	2 acc ^{ing} to EU-RAR	Newsted and Giesy, 1987
		Marine Crustaceans	<i>Artemia salina</i> / 1h / UV EC ₅₀ = 0.02	2 acc ^{ing} to EU-RAR
	<i>Artemia salina</i> / 48h LC ₅₀ > 0.05 (n, sc)		2 acc ^{ing} to EU-RAR 3 acc ^{ing} to RIVM	Abernethy <i>et al.</i> , 1986
	<i>Mysidopsis bahia</i> / 48h / UV - expo UV LC ₅₀ = 0.0036 (m, s) - expo fluo. light: LC ₅₀ = 0.535 (m, s)		2 acc ^{ing} to RIVM and EU-RAR	Pelletier <i>et al.</i> , 1997b
	Freshwater Insects	<i>Aedes aegypti</i> / 48h / dark & UV LC ₅₀ = 0.0268	2 acc ^{ing} to RIVM	Oris <i>et al.</i> , 1984
		<i>Aedes aegypti</i> / 24h / sunlight & dark LC ₅₀ < 0.001 (n, s)	2 acc ^{ing} to EU-RAR 3 acc ^{ing} to RIVM	Kagan <i>et al.</i> , 1985
		<i>Culicid mosquito larvae</i> / 24h LC ₅₀ = 0.0268	2 acc ^{ing} to EU-RAR	Oris <i>et al.</i> , 1984
		<i>Chironomus riparius</i> / 96h / mercury light LC ₅₀ = 0.0025 (m, s) <i>Chironomus riparius</i> / 96h / UV LC ₅₀ = 0.110 (m, s)	2 acc ^{ing} to RIVM	Bleeker <i>et al.</i> , 2003
	Sediment	No information available		
	Fish (mg.l ⁻¹)	Freshwater	<i>Lepomis macrochirus</i> / 96h LC ₅₀ = 0.003 – 0.026	1 acc ^{ing} to EU-RAR

ACUTE EFFECTS		Klimisch code	Master reference
		<i>Lepomis macrochirus</i> / 96h LC ₅₀ = 0.0119 – 0.02647	1 acc ^{ing} to EU-RAR 2 acc ^{ing} to RIVM Oris <i>et al.</i> , 1984
		<i>Lepomis macrochirus</i> / 120h / UV LC ₅₀ = 0.00127 (m, cf)	2 acc ^{ing} to RIVM McCloskey and Oris, 1991
		<i>Pimephales promelas</i> / 24h LC ₅₀ = 0.36	2 acc ^{ing} to EU-RAR Oris and Giesy, 1987
		<i>Pimephales promelas</i> / 120h LC ₅₀ < 0.0054 (m, r)	2 acc ^{ing} to RIVM Oris and Giesy, 1987
		<i>Pimephales promelas</i> / 24h LC ₅₀ = 0.36 (n, s)	2 acc ^{ing} to EU-RAR 3 acc ^{ing} to RIVM Kagan <i>et al.</i> , 1987
		<i>Oryzias latipes</i> / 24h LC ₅₀ = 0.21	2 acc ^{ing} to EU-RAR Reutgerswerke AG, 1991
	Marine	No information available	
Sediment	No information available		
Amphibien (mg.l⁻¹)	Freshwater	<i>Rana pipiens</i> / acute test LC _{50-30mn} = 0.065 (n, s) LC _{50-5h} = 0.025 (n, s) LC _{50-24h} = 0.11 (n, s)	2 acc ^{ing} to EU-RAR 3 acc ^{ing} to RIVM Kagan <i>et al.</i> , 1984

CHRONIC EFFECTS			Valid according to	Master reference
Algae & aquatic plants (mg.l ⁻¹)	Freshwater Algae	<i>Pseudokirchneriella subcapitata</i> / 22h - no UV: NOEC _{growth} < 0.003 - expo UV: NOEC _{growth} = 0.0015 (m, r)	2 acc ^{ing} to RIVM and EU-RAR	Gala and Giesy, 1992
		<i>Selenastrum capricornutum</i> / unknown duration NOEC _{growth} = 0.04	2 acc ^{ing} to EU-RAR	Cody <i>et al.</i> , 1984
		<i>Scenedesmus vacuolatus</i> / 24h EC ₁₀ – cell number = 0.016 (m, sc)	2 acc ^{ing} to RIVM	Altenburger <i>et al.</i> , 2004
		<i>Chlorella pyrenoidosa</i> / 24h NOEC = 0.03	2 acc ^{ing} to EU-RAR	Oris <i>et al.</i> , 1984
	Marine Algae	No information available		
Freshwater Plants	<i>Lemna gibba</i> / 8d LOEC _{growth} = 0.01 – 0.06	2 acc ^{ing} to EU-RAR 3 acc ^{ing} to RIVM	Huang <i>et al.</i> , 1995; Huang <i>et al.</i> , 1997a; Huang <i>et al.</i> , 1997b; Huang <i>et al.</i> , 1997c	
Invertebrates (mg.l ⁻¹)	Freshwater Molluscs	No information available		
	Marine Molluscs	<i>Crassostrea gigas</i> / 48h / light :dark=16h:8h EC ₁₀ – larval development > 0.0028 (m, s)	2 acc ^{ing} to RIVM	AquaSense, 2004
		<i>Mulinia lateralis</i> (embryo-larval) / 48h / UV - L(E)C ₅₀ = 0.00647 (m, s)	2 acc ^{ing} to RIVM	Pelletier <i>et al.</i> , 1997b
	Freshwater Crustaceans	<i>Daphnia magna</i> / 21d - no UV: NOEC _{repro} = 0.0022 (m, r) - expo UV: NOEC _{repro} = 0.0015 (m, r)	2 acc ^{ing} to RIVM and EU-RAR	Foran <i>et al.</i> , 1991
		<i>Daphnia magna</i> / 21d - no UV: NOEC _{repro} < 0.0021 (m, r) - expo UV: NOEC _{repro} < 0.0019 (m, r)	2 acc ^{ing} to RIVM	Holst and Giesy, 1989
		<i>Ceriodaphnia dubia</i> / 7d EC ₁₀ – reproduction > 0.0034 (m, r)	2 acc ^{ing} to RIVM	Bisson <i>et al.</i> , 2000
	Marine Crustaceans	No information available		
	(Marine) Echinoderms	<i>Psammechinus miliaris</i> / 48h / light :dark=16h:8h NOEC _{larval development} ≥ 0.0028 (m, s)	2 acc ^{ing} to RIVM	AquaSense, 2004
Sediment	<i>Chironomus tentans</i> / 10d / UV LC ₅₀ = 0.006 (m, r)	2 acc ^{ing} to RIVM and EU-RAR	Hatch and Burton Jr., 1999	
Fish (mg.l ⁻¹)	Freshwater	<i>Lepomis macrochirus</i> / 200h / UV NOEC _{survival} = 0.0012 – 0.0135	2 acc ^{ing} to EU-RAR	Oris and Giesy, 1986
		<i>Pimephales promelas</i> / 63d / sunlight NOEC _{deformities} < 0.0067 (m, cf)	2 acc ^{ing} to RIVM and EU-RAR	Hall and Oris, 1991

		<i>Pimephales promelas</i> / 63d / sunlight NOEC _{hatching} = 0.012 (m, cf)	2 acc ^{ing} to EU-RAR	Hall and Oris, 1991
	Marine	No information available		
	Sediment	No information available		

As regards water, anthracene EU-RAR (E.C., 2008a) states that “anthracene is very phototoxic and [acute] toxic effects (LC_{50} values) are observed at concentrations lower or equal to the lowest chronic effect concentrations. 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 (e.g. Allred and Giesy, 1985). In the study by Allred & Giesy (1985), 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 only one exposure concentration does not result in 100% effects. As the photo[induced] toxic effects can be observed after a short period of exposure, the long-term NOEC will be nearly identical to the short term NOEC or effect concentrations. This acute study with *Daphnia pulex* (Allred and Giesy, 1985) should be considered to be a worst-case situation for light intensity, because of the steepness of the dose-response relationship. The LC_{50} is estimated to be $1.0 \mu\text{g.l}^{-1}$. Therefore, an assessment factor of 10 to this LC_{50} is considered to be appropriate” to derive AA-QS_{water, eco} and the resulting standard is $0.1 \mu\text{g.l}^{-1}$.”

Anthracene EU-RAR (E.C., 2008a) also reports from the dataset available that “marine crustaceans seem to be subject to photo[induced] toxicity as well as fresh water species” and that “from the limited data the sensitivity of marine species is comparable with that of fresh water species.” Therefore, the AA-QS_{freshwater, eco} is also suitable for marine aquatic species and AA-QS_{marine water, eco} is equal to $0.1 \mu\text{g.l}^{-1}$.

Finally, given the high acute toxicity of the substance in sunlight conditions, it seems reasonable to set the MAC values equal to AA-QS values.

Tentative QS _{water} Assessment factor method	Relevant study for derivation of QS	AF	Tentative QS
MAC _{freshwater, eco}	<i>Daphnia pulex</i> / 24h dark + 30mn sunlight $LC_{50} = 0.001 \text{ mg.l}^{-1}$	10	$0.1 \mu\text{g.l}^{-1}$
MAC _{marine water, eco}		10	$0.1 \mu\text{g.l}^{-1}$
AA-QS _{freshwater, eco}		10	$0.1 \mu\text{g.l}^{-1}$
AA-QS _{marine water, eco}		10	$0.1 \mu\text{g.l}^{-1}$

7.1.2 Sediment-dwelling organisms

CHRONIC EFFECTS			Valid according to	Master reference
Invertebrates (mg.l ⁻¹)	Sediment Annelids	<i>Lumbriculus variegatus</i> / 28d / normalized 5% organic carbon NOEC _{reproduction} = 1.2 mg.kg ⁻¹ _{dw} (m)	2 acc ^{ing} to RIVM	Paumen <i>et al.</i> , 2008b
	Crustaceans	<i>Hyalella azteca</i> / 10d / normalized 5% organic carbon LC ₅₀ = 25 mg.kg ⁻¹ _{dw} (m)	1-2 acc ^{ing} to EU-RAR 2 acc ^{ing} to RIVM	Hatch and Burton Jr., 1999
	Insects	<i>Chironomus riparius</i> / 28d / normalized 5% organic carbon LC ₁₀ = 4.3 mg.kg ⁻¹ _{dw} (m)	1-2 acc ^{ing} to EU-RAR 2 acc ^{ing} to RIVM	Bleeker <i>et al.</i> , 2003
		<i>Chironomus riparius</i> / 28d / normalized 5% organic carbon NOEC _{emergence} = 2.2 mg.kg ⁻¹ _{dw} (m)	2 acc ^{ing} to RIVM	Paumen <i>et al.</i> , 2008a

As regards sediment, one semi-chronic LC₅₀ value and 3 chronic NOEC or LC₁₀ values are available. Given that these data correspond to different taxa that represent different trophic conditions, an assessment factor of 50 applied to the lowest NOEC of 1.2 mg.kg⁻¹_{dw} is relevant, resulting in a a QS_{freshwater, sed} of 140 µg.kg⁻¹_{dw} can be derived.

For marine sediment species no data are available. Based on such a dataset (two long term freshwater data), the TGD-EQS would recommend the application of an assessment factor of 500. However, given the substantial number of freshwater and marine ecotoxicological data for organisms living in the water column, it can be considered that marine species do not seem more sensitive than freshwater species. Moreover, a structural analogy with fluoranthene should be considered as well, where no additional assessment factor was applied for marine QS derivation (cf. EQS dossier for fluoranthene). Therefore, the QS_{marine water, sed} is also derived by applying an assessment factor of 50 to the NOEC, which results in a standard of 24 µg.kg⁻¹_{dw}.

Tentative QS _{water} Assessment factor method	Relevant study for derivation of QS	AF	Tentative QS
AA-QS _{freshwater, sed.}	<i>Lumbriculus variegatus</i> / 28d / normalized 5% organic carbon NOEC _{reproduction} = 1.2 mg.kg ⁻¹ _{dw}	50	24 µg.kg ⁻¹ _{dw} 9.23 µg.kg ⁻¹ _{dw} 0.016 µg.l ⁻¹
AA-QS _{marine water, sed.}		50	24 µg.kg ⁻¹ _{dw} 9.23 µg.kg ⁻¹ _{dw} 0.016 µg.l ⁻¹

Given that the values back-calculated in water (0.016 µg.l⁻¹ for both freshwaters and marine waters) from QS_{sediment} (24 µg.kg⁻¹_{dw} for both freshwater and marine sediments) are lower than QS_{water, eco} of 0.1 µg.l⁻¹, the sensitivity of sediment-dwelling organisms compared to organisms living in the water column is questionable.

There are acute and chronic data available for water spiked tested on sediment-dwelling insects, *Chironomus riparius* and *Chironomus tentans*, respectively. These data are higher (2.5 to 110 µg.l⁻¹) than the lowest aquatic organisms' ecotoxicological value for *Daphnia pulex*, which is 1 µg.l⁻¹. Therefore, based on *Chironomus* values, water spiked tested sediment-dwelling insects do not show a greater sensitivity for sediment-dwelling organisms compared to organisms living in the water column, for acute exposures. This assumption may be extended to *Lumbriculus* for which chronic spiked sediment data are rather similar to data for *Chironomus*. Moreover, the substance being highly hydrophobic (log K_{OW} = 4.68), it is rather likely

that spiked sediment tests imply a multiple routes exposure (via pore water and trophic pathway) of organisms leading to a higher sensitivity of the individuals. Thus, there are reasons to think that the QS_{sediment} values expressed in water are lower because of high uncertainties in the back-calculation linked to the equilibrium partitioning approach and because of the assessment factors chosen for sediment, rather than because sediment-dwelling organisms are more sensitive species than pelagic organisms are. Finally it should be noted that these back-calculations rely on a K_{OC} value of 29 512 calculated from a K_{OW} , calculated itself with a QSAR model. It can therefore be concluded that $QS_{\text{water, eco}}$ is most likely to be protective enough to cover sediment-dwelling organisms' sensitivity.

7.2 SECONDARY POISONING

Secondary poisoning of top predators		Master reference
Mammalian oral toxicity	<p>Mice / Oral (gavage) / 13 weeks</p> <p>Doses: 0, 250, 500 and 1 000 $\text{mg.kg}_{\text{bw}}^{-1}.\text{d}^{-1}$</p> <p>Observation of mortality, clinical signs, body weights, food consumption, ophthalmology findings, hematology and clinical chemistry results, organ weights, organ-to-body weight ratios, gross pathology, and histopathology findings.</p> <p>No significant treatment-related effects on any of these parameters. At 500 $\text{mg.kg}_{\text{bw}}^{-1}.\text{d}^{-1}$, statistically significant increase in mean ovary weight as well as non-dose-related changes in serum globulin a total protein concentrations, and numbers of segmented neutrophils. However, these observations were considered incidental and of no pathological significance.</p> <p>NOAEL = 1 000 $\text{mg.kg}_{\text{bw}}^{-1}.\text{d}^{-1}$</p> <p>NOEC = 8 300 $\text{mg.kg}^{-1}_{\text{feed ww}}$ ($CF_{\text{NOAEL} \rightarrow \text{NOEC}}=8.3$)</p>	E.C., 2008a
Avian oral toxicity	No available information	

For the back calculation of $QS_{\text{biota, sec. pois.}}$ into water, the BCF values of 3 042 (fish) and 19 000 (molluscs) are used as well as $BMF_1 = BMF_2 = 1$ (cf. section 5.1). It should be noted that it has not been clarified if the value of 19 000 in molluscs represents a BCF or a BAF value, (cf. section 5.1). The following calculation uses the value of 19 000 in mollusc as BCF as a worst case. This calculation shows that $QS_{\text{biota secpois}}$ does not drive the overall EQS proposal and this study was not further investigated.

Tentative $QS_{\text{biota secpois}}$	Relevant study for derivation of QS	AF	Tentative QS
Biota	NOEC = 8 300 $\text{mg.kg}^{-1}_{\text{feed ww}}$	90	<p>92 222 $\mu\text{g.kg}^{-1}_{\text{food}}$</p> <p>corresponding to</p> <ul style="list-style-type: none"> - 4.9 $\mu\text{g.l}^{-1}$ (using molluscs BCF)⁽¹⁾ - 30.3 $\mu\text{g.l}^{-1}$ (using fish BCF) <p>(freshwater and marine waters)</p>

⁽¹⁾ Considered a worst case calculation

Anthracene EU-RAR (E.C., 2008a) states that in the absence of reprotoxicity data for anthracene, such a high standard ($92 \text{ mg.kg}^{-1}_{\text{food}}$) "might not be adequately protective".

7.3 HUMAN HEALTH

Human health via consumption of fishery products		Master reference
Mammalian oral toxicity	<p>Mice / Oral (gavage) / 13 weeks</p> <p>Doses: 0, 250, 500 and 1 000 $\text{mg.kg}_{\text{bw}}^{-1}.\text{d}^{-1}$</p>	E.C., 2008a

	<p>Observation of mortality, clinical signs, body weights, food consumption, ophthalmology findings, hematology and clinical chemistry results, organ weights, organ-to-body weight ratios, gross pathology, and histopathology findings.</p> <p>No significant treatment-related effects on any of these parameters. At 500 mg.kg_{bw}⁻¹.d⁻¹, statistically significant increase in mean ovary weight as well as non-dose-related changes in serum globulin a total protein concentrations, and numbers of segmented neutrophils. However, these observations were considered incidental and of no pathological significance.</p> <p>NOAEL = 1 000 mg.kg_{bw}⁻¹.d⁻¹</p>	
	<p>A RIVM report (Baars <i>et al.</i>, 2001) has used the TPHCWG method (TPHCWG, 1997) ⁽¹⁾ to calculate a TPH fraction specific RfD for non carcinogenic PAHs, which is deemed applicable to anthracene.</p> <p>On this basis, the TL_{hh} proposed by RIVM is 0.04 mg.kg_{bw}⁻¹.d⁻¹</p>	Baars <i>et al.</i> , 2001
CMR	<p>Not classified as carcinogenic, mutagenic nor reprotoxic.</p> <p>As long as anthracene is considered to be not carcinogenic, then it is deemed acceptable to use the TDI.</p>	E.C., 2008c

⁽¹⁾ TPH = Total Petroleum Hydrocarbons; TPHCWG = Total Petroleum Hydrocarbons Criteria Working Group, Toxicology Technical Action Group

For the back calculation of QS_{biota, sec. pois.} into water, the BCF values of 3 042 (fish) and 19 000 (molluscs) are used as well as BMF₁ = BMF₂ = 1 (cf. section 5.1). It should be noted that it has not been clarified if this value of 19 000 in molluscs represents a BCF or a BAF value, (cf. section 5.1). The following calculation uses the value of 19 000 in mollusc as BCF as a worst case. This calculation shows that QS_{biota hh} does not drive the overall EQS proposal, and this study was not further investigated.

Tentative QS _{biota hh}	Relevant data for derivation of QS	AF	Threshold Level (mg.kg _{bw} ⁻¹ .d ⁻¹)	Tentative QS _{biota, hh}
Human health		-	0.04	2 434.8 µg.kg _{food} ⁻¹ corresponding to - 0.128 µg.l ⁻¹ (using molluscs BCF) ⁽¹⁾ - 0.8 µg.l ⁻¹ (using fish BCF) (freshwater and marine waters)

⁽¹⁾ Considered a worst case calculation

Human health via consumption of drinking water		Master reference
Existing drinking water standard(s)	No existing regulatory standard	Directive 98/83/EC or WHO guidelines
Calculated drinking water standard(s)	140 µg.l ⁻¹	Calculated according to TGD EQS (E.C., 2011)

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