Annex XV

Proposal for identification of a substance as a CMR cat 1 or 2, PBT, vPvB or a substance of an equivalent level of concern

Submitted by: Germany

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PROPOSAL FOR IDENTIFICATION OF A SUBSTANCE AS A CMR CAT 1 OR 2, PBT, VPVB OR SUBSTANCE OF AN EQUIVALENT LEVEL OF CONCERN

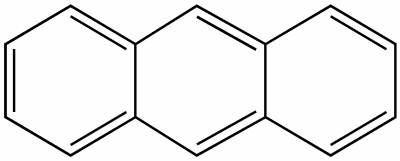
Substance name: Anthracene

EC number: 204-371-1

CAS number: 120-12-7

Molecular formula: $C_{14}H_{10}$

Structural formula:



It is proposed to identify Anthracene as a PBT according to Article 57 (d) REACH-Regulation.

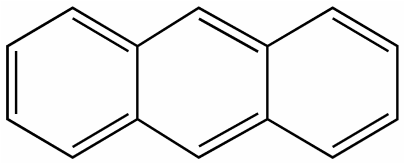
Summary of the evaluation:

Anthracene is considered to be a PBT and vPvB substance. The substance fulfils the P/vP criteria for water, sediment and soil. The vB criterion and the T criterion are also fulfilled.

JUSTIFICATION

1 IDENTIFICATION OF THE SUBSTANCE AND PHYSICAL AND CHEMICAL PROPERTIES

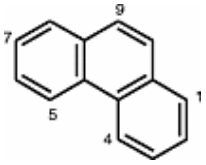
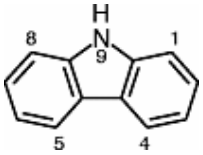
Name: Anthracene
EC Number: 204-371-1
CAS Number: 120-12-7
IUPAC Name: Anthracene
Molecular Formula: C14H10
Structural Formula:

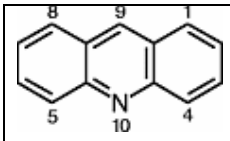
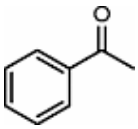


Molecular Weight: 178.24
Synonyms: Paranaphtalene, p-naphtalene, green oil, tetra olive, anthracene

1.1 Purity/Impurities/Additives

Technical grade anthracene has approximately a purity of 97%. The main impurities are

Impurity	Content [%]	CAS no.	EC no.	Molecular formula
phenanthrene 	1.0	85-01-8	201-581-5	C14H10
carbazole 	1.0	86-74-8	201-696-0	C12H9N
naphthothiophene	0.4			
dibenzo[b,c]thiophene	0.3			
acridine	0.2	260-94-6	205-971-6	C13H9N

				
acetophenone 	0.4	98-86-2	202-708-7	C8H8O

1.2 Physico-Chemical properties

Table 1 Summary of physico-chemical properties. For details and references, see European Commission (2007a).

REACH ref Annex, §	Property	Value	Comments
VII, 7.1	Physical state at 20 C and 101.3 Kpa	Colorless crystalline solid with violet fluoresence	
VII, 7.2	Melting / freezing point	216.4 0C	
VII, 7.3	Boiling point	342 ^{0}C	
VII, 7.5	Vapour pressure	9.4 * 10^{-4} Pa	at 25 ^{0}C
VII, 7.7	Water solubility	0.047 mg l^{-1}	at 25 ^{0}C
VII, 7.8	Partition coefficient n-octanol/water (log value)	4.68	
	Dissociation constant	-	

2 MANUFACTURE AND USES

The raw material for anthracene is anthracene oil (CAS 90640-80-5). Anthracene oil is one of the distillation products of coal tar, high temperature (CAS 65996-89-6). Anthracene oil is obtained from coal tar distillation in two boiling fractions, light anthracene oil and heavy anthracene oil. Anthracene is recovered from light anthracene oil fraction containing ca. 6 % anthracene by a combined application of crystallization and vacuum distillation and further refined by re-crystallization.

One producer of anthracene is operating in Europe (EU-15) with a production volume of 1,150 t of pure anthracene in the year 2001. A considerable decrease of the production volume has occurred in the last two decades. For comparison, the production volume in the year 1987 was 8,000 t. No import is known to occur to the EU-15. In the European risk assessment report (European Commission, 2008) production of pure and crude anthracene at the German production site has been taken into account. 1150 t/a pure anthracene and 400 t/a crude anthracene with 50% anthracene content have been produced in 2001 resulting in a production volume of 1350 t/a of anthracene. According to the German producer, almost the complete production volume (99%) of anthracene is exported to Japan and Czech Republic, so only 13.5 t/a remain in EU-15.

Two former main uses in the EU-15, the use for the synthesis of anthraquinone and anthracene-9-aldehyde have ceased. The only present use outside laboratory use in the EU-15 is the use for the manufacture of pyrotechnic products, for which a use volume of 4 t/a is assumed in the European Risk Assessment Report (European Commission, 2008). This would mean that 9.5 t/a of anthracene are used in laboratories in EU-15, which is rather unlikely, so there are some doubts on the accuracy of the quantities mentioned. According to the European risk assessment report (European Commission, 2008) anthracene is used in pyrotechnics used for film and theatre productions as a component of black smokes. No information is given on potential use in smoke grenades for military purposes.

Only EU-15 is considered in the European risk assessment report although it is known that there is a Czech anthracene producer with a maximum capacity of 2.450 metric tons per year. Last years, the real production was from 1033 to 1885 metric tons per year. There are probably several additional downstream users in EU-25 (e.g. exports from the German producer to Czech Republic). These neglected downstream users may not only be producers of pyrotechnics, but may use anthracene for other purposes, e.g. as an intermediate for the production of anthraquinone. Anthracene is mainly used as a basic material for the production of dyes, especially anthraquinone dyes. Anthraquinone is also used as a catalyst in production of wood pulp and as a bird repellant on seeds (Römpp online, 2008). A derivative of anthraquinone (2-ethylanthraquinone) is used to produce hydrogen peroxide commercially. In summary probably less than 50% of all deliberate production and use of pure anthracene in EU-25 is covered by the European risk assessment report (European Commission, 2008).

3 CLASSIFICATION AND LABELLING

Proposed classification (European Commission, 2007a)[1]:

Classification

Xi; R38	Irritating to skin
N; R50-53	Very toxic to aquatic organisms. May cause long-term adverse effects in the aquatic environment

Labelling

Xn; N
R: 38-50/53
S: 37-60-61

[1] "In November 2005 the human health (HH) Classification and Labelling Group (TC C&L) in the context of directive 67/548/EEC agreed that the rapporteur Classification proposal Xi; R38 should not be applied to reflect photo irritancy." (European Commission, 2008). The discussion about the classification and labelling of anthracene is still open. (Anthracene was not included into the 30th or 31th ATP.)

4 ENVIRONMENTAL FATE PROPERTIES

4.1 Degradation (P)

4.1.1 Abiotic degradation

Anthracene undergoes indirect photo-oxidation induced by OH^- and NO_3 -radicals and O_3 in the atmosphere. Half-life of ca. 3.4 hours (at 52 ^oC) has been derived in the risk assessment of anthracene using the default 5 x 10^5 OH^- molecules cm^{-3} and the experimentally derived rate constant of 1.12 x 10^{-10} cm^3/(molecule*sec) at 52 ^oC (European Commission, 2007a). Using EpiSuite a half-life of 9.63 h can be calculated at 25 ^oC (rate constant of 40 x 10^{-12} cm^3/(molecule*sec)). Transformation rate in particle phase is expected to be lower. Particle phase transformation is, however, not assumed to be of relevance for the overall atmospheric lifetime, because only up to 3 % of atmospheric anthracene has been observed to appear in particle phase (European Commission, 2007b).

Anthracene is stable against hydrolysis, but photochemical transformation in water and sediments has been observed in laboratory and “in situ”. Half-lives for primary photodegradation in water have been reported in the range of 20 minutes to 125 hours depending on the experimental conditions used. The highest value corresponds to photolysis in winter conditions. Anthraquinone has been identified as the main abiotic degradation product of anthracene (European Commission, 2007a).

Environmentally relevant exposure occurs in the whole water column and, in the case of anthracene, especially in sediment and soil. Photodegradation of anthracene can be expected to be a relevant removal pathway in the environment only in very shallow clear waters and in the first few centimetres layer of the water column. Therefore aquatic photodegradation is not considered to have relevant impact on the overall persistency of anthracene in the environment.

4.1.2 Biotic degradation

Degradation by aquatic organisms

Degradation of 1.9 % of initial anthracene concentration measured as BOD was observed in a 14 day ready biodegradability test (MITI I, OECD 301C) using 100 mg l^{-1} anthracene and 30 mg l^{-1} sludge (CITI, 1992). Sludge employed in the test was likely to be predominantly domestic.

Significant degradation due to gradual adaptation was reported for anthracene in a biodegradation test by Tabak et al. (1981). A static screening procedure based on BOD monitoring was used. The inoculum used was settled domestic sewage sludge. The cultures were incubated for seven days in the dark at 25 ºC. A subculture of the inoculum was taken after 7 days and incubated for a further 7 days. A total of three subcultures were taken, i.e. at the end of the incubation period of the third subculture the inoculum had been adapted for 28 days. Test concentrations of 5 and 10 mg l^{-1} were introduced to the flasks using dispersant. Degradation in the range of 26 % (at

day 7) up to 92 % (at day 28) resulted. This study demonstrates that waste water treatment plant micro-organisms can adapt to biodegrade anthracene but the rate of biodegradation cannot be judged on the basis of the study.

Lee and Ryan (1983) studied biodegradation of ^{14}C-labelled anthracene in water and sediment measuring the evolution of $^{14}CO_2$ and degradation products. Water and sediment were collected for the study from one heavily with oil contaminated estuarine in Charleston, SC, and from a "cleaner" estuarine of Savannah, GA. For the biodegradation test in water, ^{14}C-labelled anthracene was added to 100 ml samples in 250 ml flasks in a concentration of 25 µg l^{-1}. For the test in sediment, ^{14}C-labelled anthracene was added to a sediment-seawater slurry consisting of 1 g of sediment and 50 ml of seawater in 125 ml bottles. Test concentration was 2.5 mg kg^{-1} (no information whether dwt or wwt). The flasks were carried out as triplicates. Incubation temperature was for the samples from Charleston 27 ºC and for the samples from Savannah 28 ºC. For biodegradation test in water, authors observed little, if any, degradation, whereas for the sediment test, mineralization half-lives of 210 days (the "cleaner" Savannah sediment) and 57 days (the contaminated Charleston sediment) were extrapolated. Similar test with sediment sampled initially from Narragansett Bay, RI, but contained in MERL-mesocosms before flask tests at temperature of 18 ºC resulted mineralization half-lives of 79, 95 and 99 days for test concentrations of 1, 2.5 and 5.0 mg kg^{-1}, respectively. For mesocosm sediments pre-adapted by fuel oil addition, half-lives of 5, 6, and 7 days, respectively, resulted for test concentrations of 1, 2.5 and 5.0 mg kg^{-1}. According to the authors, biodegradation was at negligible or low level for water samples tested from the mesocosms. They concluded that degradation rates of all PAHs tested were influenced by temperature and in warm conditions by the concentration of inorganic nutrients.

It must be noted that the test conditions of Lee and Ryan (1983) did not resemble conditions required at the present for simulation tests. The batch size was small and the water-sediment batches were agitated. Hence, the test system produced enhanced biodegradation rates compared to environmentally relevant conditions. In addition, the degree of pre-adaptation of the samples cannot be judged, because the characteristics of the sites were not reported in detail.

Bauer et al. (1985) conducted a trial sequence for testing the impact of temperature, oxygen, NO_3^-, glucose and pre-adaptation on biodegradation of anthracene. The tests were conducted using sediment-water slurries (1:2 wwt/vol) with oxic and anoxic sediment and seawater (28 ‰) sampled from the intertidal Flax Bond Saltmarsh (NY). The slurry volume of 2.5 to 10 ml was employed in the tests and all slurry incubations were conducted in 20 ml vials in the dark under continuous shaking. Test and pre-adaptation concentrations of 1 to 1000 ppm (1 to 1000 µg per g dwt sediment) were used and incubation times were between 7 and 28 days depending on the test. Parent compound disappearance and mineralization in oxic and anoxic conditions was measured with non-adapted slurry with a test concentration of 100 ppm in a temperature of 25 ºC. Mineralization in the oxic vials reached according to the authors in 28 days 11 % of initial concentration measured by means of C^{14}-labelled CO_2 – monitoring, whereas parent compound disappearance from slurry, measured by means of HPLC-UV monitoring of anthracene, reached 99 % of the initial amount. $^{14}CO_2$-evolution lagged 18 to 20 days, but anthracene disappearance did not show any lag. It must be noted, that the pool of anthracene in the extraction residues was not measured and thus it is not possible to estimate the quantity of total primary degradation. The

authors observed a complete lack of degradation in anaerobic conditions but degradation started immediately after oxygen addition indicating that facultative micro-organisms capable to degrade anthracene were present in anaerobic sediment.

Of the environmental factors tested by Bauer et al. (1985), mineralization was concluded to be mainly influenced by oxygen concentration and temperature. The test on temperature dependence showed a doubling at 20 ºC and tripling at 30 ºC of the mineralization rate compared to the lowest test temperature of 10 ºC. In all trial variations, slurries pre-adapted to 100 ppm anthracene were also tested resulting faster rates of mineralization and anthracene disappearance. Two test sets, where the slurries were pre-adapted to 1 to 1000 ppm anthracene and re-exposed with 100 ppm showed that mineralization rate increased by increasing acclimation concentration. When the length of pre-adaptation time was varied with a pre-exposure concentration of 100 ppm, it was observed, that 14 days resulted the maximum mineralization rate and the maximum total amount mineralised (4, 7, 14, 22 and 26 days acclimation tested in this set). The maximum amount observed to be mineralised (ca. 47 % of initial concentration) in the whole study was achieved in a test with 14 days pre-adaptation to 100 ppm (result was nearly identical for re-exposure concentrations of 10 to 1000 ppm).

It must be noted, that in the study of Bauer et al. (1985), the very small size of the batches, large relation of sediment:water volumes and shaking is assumed to have enhanced the biodegradation compared to the environmental conditions. In addition, the quality of seawater and sediment samples was not reported.

Similar aquatic biodegradation studies have been summarised in the risk assessment of anthracene (European Commission, 2007a) and coal tar pitch, high temperature (European Commission, 2007b). It must be noted that the fast half-lives reported in the literature refer to the disappeareance of anthracene from the culture medium (either by biotransformation or uptake to organisms) and not to the mineralization rates. In line with the results of Bauer et al. (1985), PAH in general are considered to be persistent under anaerobic conditions (e.g., Neff, 1979; Volkering and Breure, 2003), with the consequence that they persist in sediments, which are, except of the top few millimeters of “aerobic sediments” anoxic.

Marine cyanobacteria *Oscillatoria salina* Biswas, *Plectonnema terebrans* Bornet et Flahault, and *Aphanocapsa* species degraded Bombay High crude oil in flasks containing seawater with a salinity of 25 ‰ and pH of 5.7-8.2. The cultures were maintained under 12h:12h light and dark cycle at 28^{o} C. Light was provided by two fluorescent lamps of 40 W placed at distance of approximately 40 cm. After 10 days 90.6 % of anthracene contained in the crude oil added was degraded by *Oscillatoria salina*, 62.7 % by *Plectonnema terebrans* and 41.9 % by *Aphanocapsa species* (Raghukumar et al., 2001). In addition, methanogenic bacteria retrieved from marine sediment by Rockne et al. (1998) and *Rhodococcus* species, sampled from polluted river sediment by Dean-Ross et al. (2001), have been observed to degrade anthracene. These studies are considered as evidence of that anthracene can be biodegraded by certain organisms but the rate of biodegradation in environmentally relevant conditions cannot be determined on the basis of this information.

Biodegradation in soil

Bacteria, fungi, yeasts and algae are known to degrade PAH. Bacteria are generally assumed to be the most important group of soil micro-organisms contributing in the biodegradation of PAHs in soils (European Commission, 2007b).

Biodegradation rate of anthracene and other PAH in soil depend on several factors like soil type, pH, moisture content, oxygen and nutrient contents and soil microbial population. In addition, vegetation has been observed to enhance microbial biodegradation in rhizosphere. Some of these factors may also explain why the half-lives observed under laboratory conditions are much shorter than those obtained from long-term field-based experiments (European Commission, 2007b). The results of Wild et al. (1991) and Wild and Jones (1993) demonstrate the difference of tests conducted for several PAHs in field conditions compared to laboratory tests. Wild et al. (1991) observed a half-life of 7.9 years for anthracene in a field experiment with soils enriched with PAH-contaminated sludge, whereas Wild and Jones (1993) derived half-lives of 48-120 days in their microcosm study with three soil types.

Various studies on PAH-contaminated soils have shown that the number of PAH-degrading micro-organisms and the degrading capacity are much higher in PAH-contaminated soils than in pristine soils indicating that adaptation has occurred. This finding is applicable also to anthracene (European Commission, 2007a, 2007b).

4.1.3 Other information [2]

Data not reviewed for this report.

4.1.4 Summary and discussion of persistence

On the basis of the two available biodegradation screening studies using sludge, it can be concluded that anthracene is not readily biodegradable.

The available aquatic biodegradation studies employing surface water and/or sediment samples have resulted in negligible or slow mineralization rates under aerobic conditions despite of very warm test temperatures in some of the studies. In addition, anthracene does not biodegrade in anaerobic sediment. The test conditions in the aquatic studies available do not closely enough resemble environmentally relevant conditions. In order to determine environmentally more relevant biodegradation rates, results from aquatic biodegradation simulation tests would be needed. However, further testing is not required because it is considered, that the available data already provide the evidence that anthracene is very persistent in sediment and persistent in water. Further test results would be expected to result in lower biodegradation rates and thus would not change the conclusion.

Anthracene is also considered to be very persistent in soil based on a field study with half-life of 7.9 years.

[2] For example, half life from field studies or monitoring data

Mackay et al. (1992) allocated anthracene to persistency class 4 for water, class 6 for soil and class 7 for sediment corresponding to half-lives of 13-42 days (water), 125-420 days (soil) and 420-1,250 days (sediment). These half-lives were applied in the risk assessments of anthracene and coal tar pitch, high temperature (European Commission, 2007a, 2007b).

In 2007, several studies concerning the persistence of anthracene were provided by industry for evaluation. The following studies have been assessed: a fate study in marine waters by Lee and Gardener (1978), a marine sediment study from Männistro et al. (1996), a soil microcosm study conducted by Wild and Jones (1993), a biodegradation study from the MITI-list (2002) and a mesocosm study in water and sediment from Bestari et al. (1998). The results of all these studies do not provide sufficient evidence or information to change the current status of anthracene considered to be persistent.

4.2 Environmental distribution

4.2.1 Adsorption

Organic carbon partitioning coefficient logKoc of 4.47 (Koc 29,512) was calculated using the equation logKoc = logKow – 0.21 (Karickhoff et al., 1979) and the logKow of 4.68. The equation was developed based on sediment data, but data from soils also fit the equation (Karickhoff, 1981). An overview of other methods for determining the Koc for PAH has been described by European Commission (2007b). It can be concluded that anthracene has a high potential to adsorb to organic matter and it is not mobile in soil and sediment.

Adsoprtion of PAH to black carbon has been reported in several studies to be considerably higher than adsorption to organic carbon available in the environment. However, the bioavailability studies carried out so far did not show decreased bioavailability in the presence of black carbon. In addition, the residence time of PAHs in soil and sediment seems to enhance sorption. This phenomenon is called aging and it has been observed to affect the bioavailability of PAHs in some conditions (European Commission, 2007b).

4.2.2 Volatilisation

According to its vapour pressure ($9.4 * 10^{-4}$ Pa at 25 ºC), anthracene is slightly volatile. The Henry's law coefficient of 3.56 Pa m^3 mol^{-1} (at 25 °C) calculated using water solubility of 0.047 mg l^{-1}) indicates that anthracene is volatile from water. This result is in agreement with another reported the value (4.3 Pa m^3 mol^{-1} at 25 °C; Mackay, 1992).

Due to the high partitioning to solids, very low concentrations of anthracene in aqueous solutions are expected and the share of anthracene volatilised remains therefore very small. Volatilisation is not considered as a relevant route of distribution for anthracene. Accordingly, EUSES 2.0 predicts that in the waste water treatment plant only 1.5% of anthracene is volatilised (European Commission, 2007a).

4.2.3 Long-range environmental transport

A short half-life in air (3.4 hours) has been determined for anthracene and it is therefore not expected to be subject to long-range atmospheric transport.

4.3 Bioaccumulation (B)

4.3.1 Screening data[3]

Based on the logKow of 4.68, anthracene is expected to bioaccumulate.

4.3.2 Measured bioaccumulation data[4]

Bioaccumulation of anthracene has been studied in various species. These studies are discussed in detail in the risk assessment of anthracene (European Commission, 2007a). Table 2 presents the results.

Table 2 Bioconcentration factors of anthracene. For details and references, see European Commission, 2007a.

Species	BCF	Test system	Type	Val.	References
Fish					
L. macrochirus	**900**	**S**	**k_1/k_2 (total)**	**2**	**Spacie *et al.* (1983)**
P. promelas	**6760**	**S**	**k_1/k_2 (parent)**	**2**	**De Maagd *et al.* (1996)**
P. reticulate	**4550 (pref)**	**R**	**Equi (parent)**	**2**	**De Voogt *et al.* (1991)**
P. reticulata	**6000**	**S**	**Equi (parent)**	**2**	**De Voogt *et al.* (1991)**
B. rerio	**10400**	**S**	**k_1/k_2 (total)**	**3**	**Djomo *et al.* (1996)**
L. macrochirus	**675**	**S**	**k_1/k_2 (corrected)**	**3**	**Spacie *et al.* (1983)**
O. mykiss	**9000-9200**	**R**	**k_1/k_2 (parent)**	**3**	**Linder *et al.* (1985)**
O. mykiss	**779**	**R**	**Equi (parent)**	**3**	**Linder *et al.* (1985)**
P. reticulata	**7260**	**S**	**k_1/k_2 (parent)**	**3**	**De Voogt *et al.* (1991)**
Salmo gairdneri	**9,000-9,200**				**Linder *et al.* (1985)**
Salmo gairdneri	**143µg/fish**	**OECD**			**Nimi *et al.* (1986)**
Cyprinus carpio	**1,660-2,820**	**OECD**			**Japan Chemical industry (1992)**
Cyprinus carpio	**903-2,710**	**OECD**			**Japan Chemical industry (1992)**
Carassius auratus	**162**	**S**		**4**	**Ogata *et al.* (1984)**

[3] For example, log K_{ow} values, predicted BCFs

[4] For example, fish bioconcentration factor

Species	BCF	Test system	Type	Val.	References
L. melanotus	**910**	**S**	**k_1/k_2 (unclear)**	**4**	**Freitag *et al.* (1982)**
Mollusca					
U. imbecilis (larv.)	**345 (highest 420)**	**R**	**Equi (parent)**	**2**	**Weinstein & Polk (2001)**
Macona balthica (marine bivalve)	**260**	**F**		**3**	**Clement *et al.* (1980)**
Anodonta imbecilla (clam)	**Little to no biotransformation**	**S**		**2**	**Giesy *et al.* (1982)**
Crustacea					
Daphnia magna	**970**	**B**		**3**	**Newsted and Giesy (1987)**
Daphnia magna	**511**	**S**		**3**	**Mc Carthy *et al,* (1985)**
Daphnia pulex	**1,192**			**4**	**Southworth (1978)**
Daphnia pulex	**1,085**	**S**		**4**	**Southworth (1978)**
Daphnia pulex	**988**	**S**		**4**	**Southworth (1978)**
Daphnia pulex	**917**	**S**		**4**	**Southworth (1979)**
Daphnia magna	**319-607**	**F**		**2**	**Leversee *et al.* (1982)**
H. azteca	**1800-10985**	**F**	**k_1/k_2**	**3**	**Landrum & Scavia (1983)**
P. hoyi	**16857-39727**	**F**	**k_1/k_2**	**3**	**Landrum (1982, 1988)**
Algae					
Selanastrum capricornutum	**5100-10500**	**S**		**3**	**Mailhot *et al.* 1987**
Chlorellafusca var.vacuolata	**7,770**	**S**		**3**	**Freitag *et al.* (1985)**

S: static exposure system; F: flow-through system; B: batch test; R: static renewal system; k_1/k_2, kinetic: uptake rate/depuration rate; Equi: equilibrium; Val: validity (1: Reliable without restrictions, 2: Reliable with restrictions, 3: Not reliable, 4: Not assignable); OECD: OECD Guideline 305 C

Biomagnification of PAHs does not occur in the aquatic food webs containing fish probably due to high rates of metabolism and excretion of PAHs in fish. PAHs are known to be biotransformed to more soluble metabolites in biota, although this capability does not cover all species. Hence biomagification in some food webs have been observed (European Commission, 2007b). Food web transfer of PAH metabolites has been hardly investigated. Prey species may contain high levels of metabolites that could be accumulated by predators. This was examined by McElroy and Sisson (1989), who fed polychaetes (*Nereis virens*) containing benzo[*a*]pyrene and accompanying metabolites to winter flounder (*Pseudopleuronectes americanus*) and found that fish had accumulated the metabolites. For anthracene, no data on food web transfer of metabolites are available.

4.3.3 Other supporting information[5]

Data not reviewed for this assessment.

4.3.4 Summary and discussion of bioaccumulation

Bioconcentration tests with fish have resulted in BCF values in the range of 675 to > 6,760 for the parent compound.

It should also be recognised, that bioaccumulation and food web transfer of the biotransformation products of anthracene may occur but this area has been not been studied.

5 HUMAN HEALTH HAZARD ASSESSMENT

Data not reviewed for this report.

6 HUMAN HEALTH HAZARD ASSESSMENT OF PHYSICOCHEMICAL PROPERTIES

Not relevant for this type of dossier.

[5]For example, measured concentrations in biota

7 ENVIRONMENTAL HAZARD ASSESSMENT

7.1 Aquatic compartment (including sediment)

7.1.1 Toxicity test results

Exposure to anthracene under UV-radiation enhances the ecotoxicity of anthracene, i.a., in fish, invertebrates and algae (European Commission, 2007a, 2007b). The mechanisms of photo-enhanced toxicity are not fully known. For example, Huang et al. (1997) observed that photomodified anthracene exposure leads to the inhibition of the photosystem II in *Lemna gibba*. The mechanism in animals can be expected to be very different. According to some studies, photodegradation products of anthracene forming under UV-light do not seem to cause this higher toxicity (e.g., Bowling et al., 1983; Allred and Giesy, 1985; Kagan et al., 1985) but also contradictory results have been presented (Huang et al., 1995). Enhanced effects have been attained already with very short exposures to natural sunlight or UV-light (0.5 to 6 hours) and in light intensities corresponding conditions in several meters depth of natural water column. Hence, photoenhanced toxicity is considered relevant for the environment unlike photodegradation, which is expected to be relevant only down to the few first centimetres depth of typical natural waters.

Studies available on the ecotoxicity to fish, invertebrates and algae are described in detail in the risk assessment of anthracene (European Commission, 2007a). The most reliable acute and chronic toxicity data to fish and acute toxicity data to invertebrates are listed in Tables 3 to 5.

7.1.1.1 Fish

Acute toxicity

Table 3. Acute toxicity of anthracene to fish (European Commission, 2007a)

Species	Test duration	Measure of effect	Concentration (mg/l)	Remark	Reference
Lepomis macrochirus	96 h	LC50	0.0119-0.0265	UV radiation at similar level as in 0.6 m depth of an eutrophic lake	Oris et al., 1984
Lepomis macrochirus	96 h	LC50	0.003-0.026	Exposure under simulated sunlight	Oris and Giesy, 1985
Lepomis macrochirus	24 h light:0 h dark	NOEC	0.0012	Exposure under simulated sunlight; extrapolated values	Oris, and Giesy, 1986
	6 h light:18 h dark	NOEC	0.0135		
Lepomis macrochirus	48 h	LC_{50}	0.00127	Natural sunlight conditions in artificial test channel; no toxicity to photodegradation products	Bowling et al., 1983
Pimephales promelas	24 h	LC 50	0.360	Simulated sunlight	Oris and Giesy, 1987
Oryzias latipes	24 h	LC 50	0.210		Ruetgerswerke, 1991

Long-term toxicity

Table 4. Chronic toxicity of anthracene to fish (European Commission, 2007a).

Species	Exposure duration	Endpoint	Effect	Conc. (mg/l)	Remarks	References
Lepomis macrochirus	200 h	NOEC	Survival	0.0012 - 0.0135	UV exposure	Oris and Giesy, 1986
Pimephales promelas	63 d	NOEC	Deformities	<0.006	Effects occurred in the presence and absence of UV exposure	Hall et al., 1990; Hall and Oris, 1991
Pimephales promelas	63 d	LOEC	Survival and hatching	0.012	Effects occurred in the presence and absence of UV exposure	Hall et al., 1990; Hall and Oris, 1991

7.1.1.2 Aquatic invertebrates

Acute toxicity

Table 5. Acute toxicity of anthracene to invertebrates (European Commission, 2007a).

Species	Exposure duration	Measure of effect	Concentration (mg l^{-1})	Remark	References
Daphnia pulex		LC_{50}	0.001	Exposure under sunlight	Allred and Giesy, 1985
Daphnia magna	48 h	LC_{50}	0.036	Exposure in the dark	Abernethy et al., 1986
Daphnia magna	14 min	EC_{50}	0.0012	Exposure under UV light	Oris, et al., 1984
Daphnia magna	24-25 h	EC_{50}	0.0012	Effects both under sunlight and dark	Oris, et al., 1984
Daphnia magna	24 h 48 h	EC_{50}	0.211 0.0095		Munoz and Tarazona, 1993
Daphnia magna	48 h	EC_{50}	0.754		Smith et al., 1988
Daphnia magna	23 ± 1 h	EC_{50}	22µM		Huovinen et al., 2001
Daphnia magna	24 h	LT_{50}	0.015	298.5 min in the given concentration	Newsted and Giesy, 1987
Artemia salina	1 h	EC_{50}	0.020	Exposure under UV light	Diamond et al., 2000
Artemia salina	48 h	LC_{50}	>0.05		Abernethy et al., 1986
Artemia salina	10 h	EC_{10}	0.023		Peachy and Crosby, 1996
*Mysidopsis bahia**	48 h	LC_{50}	0.0036	Exposure under UV light	Pelletier et al., 1997
*Mysidopsis bahia**	48 h	LC_{50}	0.535	Exposure under fluorescent light	Pelletier et al., 1997
Culicid mosquito (larvae)	24 h	LC_{50}	0.0268		Oris et al., 1984
Aedes aegypti	24 h	LC_{50}	<0.001	Effects both under sunlight and dark	Kagan et al., 1985
Utterbackia imbecillis	24 h	LC_{50}	0.00193	Exposure under UV light	Weinstein, et al., 2001
Mulinia lateralis * (embryo-larvae)	48 h	LC_{50}	0.00647	Exposure under UV light	Pelletier et al., 1997
*Mulinia lateralis** (embryo-larvae)	48 h	LC_{50}	4.260	Exposure under fluorescent light	Pelletier et al., 1997
Mulinia lateralis * (juvenile)	96 h	LC_{50}	0.0689	Exposure under UV light	Pelletier et al., 1997
*Mulinia lateralis** (juvenile)	96 h	LC_{50}	13.3	Exposure under fluorescent light	Pelletier et al., 1997
Nereis areaceodentata	96 h	LC_{50}	0.051		DEFRA

* Marine species

Long-term toxicity

Daphnia magna were exposed to anthracene in the presence and absence of ecologically relevant intensities of UV radiation for 21 days. Exposure to 8.2 μg l^{-1} anthracene in the absence of UV radiation reduced the number of neonates produced by 13.8 %. Exposure to UV radiation in the absence of anthracene had no significant effect on the fecundity. Simultaneous exposure to UV radiation and anthracene resulted in further reduced survival and fecundity. Exposure to 7.2 μg l^{-1} anthracene and 117μW cm^{-2} UV-radiation resulted in 70% mortality and 69% decrease in production of neonates by adults that survived (Holst and Giesy, 1989).

Photoenhanced effects of anthracene exposure on reproduction of *Daphnia magna* in terms of total clutch size and survival over a 21 d period was reported by Foran, et al. (1991). NOEC under UV exposure was detected at 1.9-2.2 μg l^{-1}. NOEC without UV exposure was at 2.2 μg l^{-1}.

7.1.1.3 Algae and aquatic plants

Results between EC_{50}(22h) of 0.004 mg l^{-1} for *Selenastrum capricornutum* (Gala and Giesy, 1992) and EC_{50}(24h) of 2.53 mg l^{-1} for *Chlorella protothecoides* (Yan et al., 1999) have been observed with and without simultaneous exposure to UV –radiation. A NOEC of 0.0015 mg l^{-1} was derived for *Selenastrum capricornutum* by the same authors (Gala and Giesy, 1992).

7.1.2 Sediment organisms

Data not reviewed for this report.

7.1.3 Other aquatic organisms

Data not reviewed for this report.

7.2 Terrestrial compartment

Data not reviewed for this report.

7.3 Atmospheric compartment

Data not reviewed for this report.

8 PBT AND vPvB

8.1 PBT, vPvB assessment

Persistence: Two biodegradation screening tests with sludge indicate that anthracene is not readily degradable. Biodegradation tests employing water and sediment-water mixture are available showing slow to very slow mineralization. Mineralization half-lives up to 210 days have been reported for aerobic sediment, whereas in anaerobic conditions anthracene is completely recalcitrant. In addition, a half-life of 7.9 years has been observed in a soil field study. Based on these data, anthracene is considered to be persistent in water and very persistent in sediment and soil. It must be noted that the available aquatic studies do not resemble closely enough the environment. Aquatic biodegradation simulation testing would be needed to determine biodegradation rates in more realistic conditions. Such testing is, however, not considered necessary because the results would very likely not change the conclusion.

Bioaccumulation: BCFs up to 6,760 have been measured for fish and up to 39,727 for invertebrates. It is concluded that anthracene fulfils the vB criterion.

Toxicity: NOECs in the range of 0.0012 to 0.012 mg l^{-1} from three long-term tests with fish are available. For *Daphnia magna*, 21d-NOECs of ca. 2 µg l^{-1} have been determined. For algae, acute toxicities have been repoted with EC_{50} –values from 0.004 to 2.53 mg l^{-1}. The most sensitive species is *Daphnia pulex* with LC_{50}(48h) of 1 µg l^{-1} under sunlight.

Summary: Anthracene is considered to meet the vP criterion, the vB criterion and the T criterion. Hence, anthracene is concluded to be a PBT and vPvB substance.

9 INFORMATION ON USE, EXPOSURE, ALTERNATIVES AND RISKS

9.1 Information on Exposure

Production and use of pure anthracene is not the only source of anthracene emissions to the environment. There are several products containing anthracene as part of complex mixtures but not involving addition of isolated commercial anthracene: coal tar itself, coal tar distillation products, coal tar-containing products (paints, waterproof membranes etc.) and creosote. Such products are outside the scope of the anthracene RAR. Nevertheless, all these products may affect the background environmental concentrations through anthracene releases during their production and use.

High temperature coal tar pitch contains about 1.5% anthracene. More than 1.7 million tonnes of coal-tar, containing over 25,000 tonnes of anthracene, were distilled in EU-15 during 1999. Thus the production and use of coal-tar derivatives (especially creosote, 107,000 t/a used for wood treatment in Europe) represent a significantly greater potential source of environmental release of anthracene than production and use of pure anthracene. In 1998 and 1999 less than 10% of all distilled coal tar was distilled for the ultimate purpose of production of anthracene.

Background environmental concentrations of anthracene can also be affected by releases arising from incomplete combustion of organic matter, as occurring during fossil fuel combustion or in various workplaces (e.g. carbon anode/graphite, silicon carbide, aluminium, iron and steel production plants and others). 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. 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

In summary much less than 10% of all European anthracene emissions are covered by the anthracene European Risk Assessment Report (European Commission, 2008), because it concerns only deliberate production and use of pure anthracene.

Only EU-15 is considered in the European Risk Assessment Report (European Commission, 2008) although it is known that there is at least one further production plant in EU-25 which potentially has even a higher production amount than the German plant considered in the European Risk Assessment Report. There are probably several additional downstream users in EU-25 (e.g. the German producer announced that almost the complete production volume of anthracene is exported to Japan and Czech Republic). These neglected downstream users may not only be producers of pyrotechnics, but may use anthracene for other purposes, e.g. as an intermediate for the production of anthraquinone. In summary probably less than 50% of all deliberate production and use of pure anthracene in EU-25 is covered by the European Risk Assessment Report (European Commission, 2008).

In EU-15 pure anthracene is produced by one German company only. At the production site there is no separate waste water stream for anthracene production, i.e. all process waste waters are combined, going into the on-site biological WWTP. The recipient water is no natural river, but a huge sewage canal which subsequently passes a public WWTP before reaching the final surface water (river). There are no direct emissions to soil from the site and the concentrations in soil arise mainly from atmospheric deposition (or the application of sewage sludge if this is appropriate).
The release of anthracene in water during the manufacturing of pyrotechnics (mixing of components) is not more than 0.25%, because this is a dry mixing process which is operated in a closed system. During the mixing process no anthracene is emitted. The amounts released are solely a result of cleaning processes. It has been assumed that there are about 10 plants using anthracene in EU-15 for the production of pyrotechnics. Site specific information is available for one plant in Germany, where 400 kg/a of anthracene are used. This tonnage was considered representative for the use on a local scale, so it has been assumed that a total amount of 4,000 kg of anhracene is used for the production of pyrotechnics in EU-15.

The use of pyrotechnics is widespread throughout EU-15 so no local assessment has been carried out. The figure of 400 kg is the regional release, as it is 10% of the evaluated total amount of anthracene (4000 kg) used for the production of pyrotechnics in EU-15. The use of the substance as a component of black smokes suggests that external use is most likely, such as on film locations etc, but it may be used indoors in theatres and in film studios. It seems unlikely that there will be continuous use (not all productions call for such smoke) and so a disperse use pattern

seems reasonable. No information is given in the European Risk Assessment Report as to whether anthracene is used for the production of smoke grenades for military purposes.

Releases of anthracene from major sources under worst case conditions are summarised for the local, regional and continental environments in Tables 6-8. Site specific emissions for the production of anthracene and default emissions for the production and use of pyrotechnics are used for PEC calculations in the European Risk Assessment Report (European Commission, 2008).

Table 6. Summary of emission estimates in air (European Commission, 2008).

Process	tonnes	Emissions calculated from site specific information	Emissions calculated from default values
Production of anthracene	1350	Local 37 g/day*	90 g/day
		Regional 13 kg/year	27 kg/year
		Continental -	-
Production of pyrotechnics (formulation)	4	-	Local 0.0033 kg/day
		-	Regional 1 kg/year
		-	Continental 9 kg/year
Use of pyrotechnics	4	-	
		-	Regional 0.4 kg/year
		-	Continental 3.6 kg/year

*: 37 g/day represent not only anthracene production, but is the related to tar-distillation and pitch production, as the process emissions cannot be easily allocated to single operations. Therefore, this value is supposed to represent a high worst-case when solely linked to anthracene production

Table 7. Summary of emission estimates in water (European Commission, 2008).

Process	Tonnes	Emissions calculated from site specific information	Emissions calculated from default values
Production of anthracene	1350	Local 3.6g/day	Local 33,200 g/day
		Regional 1.08 kg/year	Regional 4,050 kg/year
Production of pyrotechnics (formulation)	4	-	Local 3 g/day
		-	Regional 1 kg/year
		-	Continental 9 kg/year
Use of pyrotechnics	4	-	
		-	Regional 1 kg/year
		-	Continental 9 kg/year

Table 8. Summary of emission estimates in soil (European Commission, 2008).

Process	tonnes	Emissions calculated from site specific information	Emissions calculated from default values
Production of anthracene	1350	Local (agricultural soil) $51x10^{-9}$ g/day/dwt Local (grassland) 10^{-7} g/day/dwt	Local 1,110 g/day
		Regional -	Regional 135kg/year
		Continental -	Continental ?
Production of pyrotechnics (formulation)	4	-	
		-	Regional 0.04 kg/year
		-	Continental 0.36 kg/year
Use of pyrotechnics	4	-	
		-	Regional 4 kg/year
		-	Continental 36 kg/year

A detailed assessment of exposure is provided in the European risk assessment report (European Commission, 2008).

9.2 Information on alternatives

Use of anthracene within the EU-15 seems to focus on rather specialised, none essential uses such as manufacture of pyrotechnic products. As information on the use within the EU-25 needs further exploration, no information on alternatives can be provided at this stage.

9.3 Risk related information

Existing legislative controls:

Classification

For anthracene the following classification and labeling, according to Annex VI of Directive 67/548/EEC was proposed and agreed by the TC C& L (04.2006, ECBI/92/06 Rev.1): R50/53. The relevant safety phrases prescribe that the respective material and its container must be disposed of as hazardous waste and advise to avoid releases to the environment (reference to special instructions in the SDS).

Water Framework Directive (WFD)

According to Decision 2455/2001/EC anthracene is on the priority list of the Water Framework Directive 2000/60/EC. Moreover, according to the latest common position adopted by the Council, it has been identified as a "priority hazardous substance" under the WFD, which means that cessation or phasing-out of discharges, emissions and losses of anthracene has to be envisaged (Common position adopted by the Council of 29th November 2007, 11486/07). As a first step in this direction environmental quality standards for anthracene are proposed in the common position: the annual average concentration of anthracene should not exceed 0.1 µg/l, while the maximum allowable concentration must not exceed 0.4 µg/l in inland and other

surface waters.

Existing Substances Regulation (ESR)

Potential risk reduction measures for anthracene have been discussed at the last risk reduction meeting under ESR (April 2008). In the risk reduction strategy the Rapporteur argues that existing regulations are sufficient to cope with releases of anthracene from production and processing of pure anthracene: REACH (SDS, if necessary inclusion in Annex XIV), WFD, IPPC, Directive on Dangerous Waste. Therefore the Rapporteur proposed no additional measures. However, at the meeting many Member States opted for restrictions on pure anthracene, so the proposals of the Rapporteur were not adopted.

10 OTHER INFORMATION

The information used in this report was mainly taken from the following four sources:

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