TC NES SUBGROUP ON IDENTIFICATION OF PBT AND VPVB SUBSTANCES

RESULTS OF THE EVALUATION OF THE PBT/VPVB PROPERTIES OF:

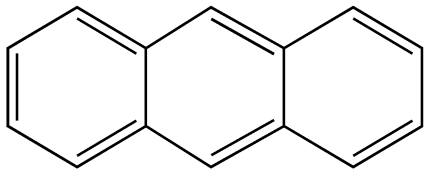
Substance name: Anthracene, pure

EC number: 204-371-1

CAS number: 120-12-7

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

Structural formula:



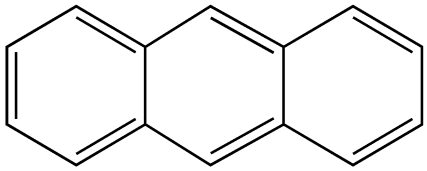
Summary of the evaluation:

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, pure
EC Number: 204-371-1
CAS Number: 120-12-7
IUPAC Name:
Molecular Formula:
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 phenanthrene (1.0%), carbazole (1.0%), naphthothiophene (0.4%), dibenzo[b,c]thiophene (0.3%), acridine (0.2%), acetophenone (0.4%).

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 C	
VII, 7.3	Boiling point	342 C	
VII, 7.5	Vapour pressure	$9.4 * 10^{-4}$ Pa	at 25^0C
VII, 7.7	Water solubility	0.047 mg l^{-1}	at 25^0C
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 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 approximately 6% anthracene by a combined application of crystallisation and vacuum distillation and further refined by re-crystallisation. One producer of anthracene is operating in Europe with a production volume of 1,150 tonnes 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 tonnes. No import is known to occur to the EU.

According to the producer, almost the complete production volume of anthracene is exported out of the EU at the present. Two former main uses, the use for the synthesis of anthraquinone and anthracene-9-aldehyde have ceased. The only present use outside laboratory use in the EU is the use for the manufacture of pyrotechnic products, for which a use volume of approximately 0.2 tonnes/annum has been reported.

3 CLASSIFICATION AND LABELLING

Proposed classification (European Commission, 2007a):

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

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 approximately 3.4 hours (at 52°C) has been derived in the risk assessment of anthracene using the default 5×10^5 OH^- molecules cm^{-3} and the experimentally derived rate constant of 1.12×10^{-10} cm^3/(molecule*sec) at 52°C (European Commission, 2007a). Using EpiSuite a half-life of 9.63 h can be calculated at 25°C (rate constant of 40×10^{-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 25ºC. 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 27ºC and for the samples from Savannah 28ºC. For biodegradation test in water, authors observed little, if any, degradation, whereas for the sediment test, mineralisation 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 18ºC resulted mineralisation 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 1,000 ppm (1 to 1,000 µg per g dwt sediment) were used and incubation times were between 7 and 28 days depending on the test. Parent compound disappearance and mineralisation in oxic and anoxic conditions was measured with non-adapted slurry with a test concentration of 100 ppm in a temperature of 25ºC. Mineralisation 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), mineralisation was concluded to be mainly influenced by oxygen concentration and temperature. The test on temperature dependence showed a doubling at 20ºC and tripling at 30ºC of the mineralisation rate compared to the lowest test temperature of 10ºC. In all trial variations, slurries pre-adapted to 100 ppm anthracene were also tested resulting faster rates of mineralisation and anthracene disappearance. Two test sets, where the slurries were pre-adapted to 1 to 1,000 ppm anthracene and re-exposed with 100 ppm showed that mineralisation 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 mineralisation 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 (approximately 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 1,000 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 mineralisation 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 12-hour:12-hour light and dark cycle at 28°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 [1]

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 mineralisation 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.

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

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.

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 25ºC), 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[2]

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

4.3.2 Measured bioaccumulation data[3]

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	6,760	S	k_1/k_2 (parent)	2	De Maagd et al. (1996)
P. reticulate	4,550 (pref)	R	Equi (parent)	2	De Voogt et al. (1991)
P. reticulata	6,000	S	Equi (parent)	2	De Voogt et al. (1991)
B. rerio	10,400	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	9,000-9,200	R	k_1/k_2 (parent)	3	Linder et al. (1985)
O. mykiss	779	R	Equi (parent)	3	Linder et al. (1985)
P. reticulata	7,260	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)
L. melanotus	910	S	k_1/k_2 (unclear)	4	Freitag et al. (1982)

Table 2 continued overleaf

2 For example, log K_{ow} values, predicted BCFs

3 For example, fish bioconcentration factor

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

Species	BCF	Test system	Type	Val.	References
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	1,800-10,985	F	k_1/k_2	3	Landrum and Scavia (1983)
P. hoyi	16,857-39,727	F	k_1/k_2	3	Landrum (1982, 1988)
Algae					
Selanastrum capricornutum	5,100-10,500	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[4]

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 ENVIRONMENTAL HAZARD ASSESSMENT

6.1 AQUATIC COMPARTMENT (INCLUDING SEDIMENT)

6.1.1 Toxicity test results

Exposure to anthracene under UV-radiation enhances the ecotoxicity of anthracene, i.e. 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.

[4]For example, measured concentrations in biota

6.1.1.1 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 hours	LC_{50}	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 hours	LC_{50}	0.003-0.026	Exposure under simulated sunlight	Oris and Giesy, 1985
Lepomis macrochirus	24 h ourslight: 0 hours dark 6 hours light: 18 hours dark	NOEC NOEC	0.0012 0.0135	Exposure under simulated sunlight; extrapolated values	Oris, and Giesy, 1986
Lepomis macrochirus	48 hours	LC_{50}	0.00127	Natural sunlight conditions in artificial test channel; no toxicity to photodegradation products	Bowling et al., 1983
Pimephales promelas	24 hours	LC_{50}	0.360	Simulated sunlight	Oris and Giesy, 1987
Oryzias latipes	24 hours	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 hours	NOEC	Survival	0.0012 - 0.0135	UV exposure	Oris and Giesy, 1986
Pimephales promelas	63 days	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 days	LOEC	Survival and hatching	0.012	Effects occurred in the presence and absence of UV exposure	Hall et al., 1990; Hall and Oris, 1991

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

6.1.1.3 Algae and aquatic plants

Results between EC_{50} (22-hour) of 0.004 mg l^{-1} for *Selenastrum capricornutum* (Gala and Giesy, 1992) and EC_{50} (24-hour) 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).

6.1.2 Sediment organisms

Data not reviewed for this report.

6.1.3 Other aquatic organisms

Data not reviewed for this report.

6.2 TERRESTRIAL COMPARTMENT

Data not reviewed for this report.

6.3 ATMOSPHERIC COMPARTMENT

Data not reviewed for this report.

7 PBT AND VPVB

7.1 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 mineralisation. Mineralisation 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*, 21-day NOECs of approximately 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} (48-hour) 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.

INFORMATION ON USE AND EXPOSURE

Data not reviewed for this report. A detailed assessment of uses and exposure are provided in European Commission (2007a).

OTHER INFORMATION

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

European Commission (2007a) European Risk Assessment Report, Draft of November 2007, Anthracene, CAS No: 120-12-7, EINECS No: 204-371-1.

European Commission (2007b) European Union Risk Assessment Report, Draft of November 2007, Coal tar pitch, high temperature, CAS No: 65996-93-2, EINECS No: 266-028-2.

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