ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA

ANTHRACENE ENTRY

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Like a library or most large databases (such as EPA's national STORET water quality database), this document contains information of variable quality from very diverse sources. In compiling this document, mistakes were found in peer reviewed journal articles, as well as in databases with relatively elaborate quality control mechanisms [366,649,940]. A few of these were caught and marked with a "[sic]" notation, but undoubtedly others slipped through. The [sic] notation was inserted by the editors to indicate information or spelling that seemed wrong or misleading, but which was nevertheless cited verbatim rather than arbitrarily changing what the author said.

Most likely additional transcription errors and typos have been added in some of our efforts. Furthermore, with such complex subject matter, it is not always easy to determine what is correct and what is incorrect, especially with the "experts" often disagreeing. It is not uncommon in scientific research for two different researchers to come up with different results which lead them to different conclusions. In compiling the Encyclopedia, the editors did not try to resolve such conflicts, but rather simply reported it all.

It should be kept in mind that data comparability is a major problem in environmental toxicology since laboratory and field methods are constantly changing and since there are so many different "standard methods" published by EPA, other federal agencies, state agencies, and various private groups. What some laboratory and field investigators actually do for standard operating practice is often a unique combination of various standard protocols and impromptu "improvements." In fact, the interagency task force on water methods concluded that [1014]:

> It is the exception rather than the rule that water-quality monitoring data from different programs or time periods can be compared on a scientifically sound basis, and that...
>
> No nationally accepted standard definitions exist for water quality parameters. The different organizations may collect data using identical or standard methods, but identify them by different names, or use the same names for data collected by different methods [1014].

Differences in field and laboratory methods are also major issues related to (the lack of) data comparability from media other than water: soil, sediments, tissues, and air.

In spite of numerous problems and complexities, knowledge is often power in decisions related to chemical contamination. It is therefore often helpful to be aware of a broad universe of conflicting results or conflicting expert opinions rather than having a portion of this information arbitrarily censored by someone else. Frequently one wants to know of the existence of information, even if one later decides not to use it for a particular application. Many would like to see a high percentage of the information available and decide for themselves what to throw out, partly because they don't want to seem uniformed or be caught by surprise by potentially important information. They are in a better position if they can say: "I knew about that data, assessed it based on the following quality assurance criteria, and decided not to use it for this application." This is especially true for users near the end of long decision processes, such as hazardous site cleanups, lengthy ecological risk assessments, or complex natural resource damage assessments.

For some categories, the editors found no information and inserted the phrase "no information found." This does not necessarily mean that no information exists; it simply means that during our efforts, the editors found none. For many topics, there is probably information

"out there" that is not in the Encyclopedia. The more time that passes without encyclopedia updates (none are planned at the moment), the more true this statement will become. Still, the Encyclopedia is unique in that it contains broad ecotoxicology information from more sources than many other reference documents. No updates of this document are currently planned. However, it is hoped that most of the information in the encyclopedia will be useful for some time to come even with out updates, just as one can still find information in the 1972 EPA Blue Book [12] that does not seem well summarized anywhere else.

Although the editors of this document have done their best in the limited time available to insure accuracy of quotes as being "what the original author said," the proposed interagency funding of a bigger project with more elaborate peer review and quality control steps never materialized.

The bottom line: The editors hope users find this document useful, but don't expect or depend on perfection herein. Neither the U.S. Government nor the National Park Service make any claims that this document is free of mistakes.

The following is one topic entry (one file among 118). See the file entitled RERENCE for the indentity of numbered references in brackets. See the README file for an introduction, an explanation of how to search and otherwise use this document, the oganization of each entry, information quality, copyright issues, and other entries (other topics) covered.

HOW TO CITE THIS DOCUMENT: As mentioned above, for critical applications it is better to obtain and cite the original publication after first verifying various data quality assurance concerns. For more routine applications, this document may be cited as:

> **Irwin, R.J., M. VanMouwerik, L. Stevens, M.D. Seese**, and **W. Basham.** 1997. Environmental Contaminants Encyclopedia. National Park Service, Water Resources Division, Fort Collins, Colorado. Distributed within the Federal Government as an Electronic Document (Projected public availability on the internet or NTIS: 1998).

Anthracene (CAS number 120-12-7)

Brief Introduction:

Br.Class: General Introduction and Classification Information:

Anthracene is a low molecular weight, 3-ring polyaromatic hydrocarbon (PAH), and an EPA Priority Pollutant [697,634]. Although formerly anthracene was sometimes treated as a carcinogen for modeling purposes only [446], more recent sources have stated that anthracene is not classifiable as to its carcinogenicity to humans [788,893].

Anthracene is present in petroleum products, in higher quantities in some than in others (see Chem.Detail section below). The most abundant aromatic hydrocarbon families in oil products have two and three fused rings with one to four carbon atom alkyl group substitutions [773]. Anthracene is called the parent compound, while anthracene with alkyl group substitutions added to anthracene are called alkyl anthracene.

Alkyl phenanthrene and alkyl anthracene compounds cannot be differentiated with current (1996) analytical techniques. Phenanthrene, anthracene, and the phenanthrenes/anthracenes alkyl homolog series are included on the expanded scan list used by the Geochemical and Environmental Research Group (GERG) Laboratory at Texas A&M [828]. This list includes most of the PAHs recommended by the NOAA's National Status and Trends program [680].

Anthracene is ubiquitous in the aquatic environment. It has been detected in industrial effluents, in run off waters, in surface water and sediments, in groundwater, and in drinking water. The industrial effluents that are most likely to contain polynuclear aromatic compounds including anthracene are wastewaters from the synthetic fuel industry [366].

Br.Haz: General Hazard/Toxicity Summary:

Within an aromatic series, acute toxicity increases with increasing alkyl substitution on the aromatic nucleus [851]. For example, there is an increase in toxicity as alkylation of the naphthalene structure increases. The order of most toxic to least in a study using grass shrimp (Palaemonetes pugio) and brown shrimp (Penaeus aztecus) was dimethylnaphthalenes > methylnaphthalenes > naphthalenes [853].

Studies conclude that the toxicity of an oil appears to be a function of its di-aromatic and tri-aromatic hydrocarbons, which includes three-ring hydrocarbons such as phenanthrene [770].

The heavier (4-, 5-, and 6-ring) PAHs are more persistent than the lighter (2- and 3-ring) PAHs and tend to have greater carcinogenic and other chronic impact potential [796].

Acute toxicity is rarely reported in humans, fish, or wildlife, as a result of exposure to low levels of a single PAH compound such as this one. PAHs in general are more frequently associated with chronic risks. These risks include cancer and often are the result of exposures to complex mixtures of chronic-risk aromatics (such as PAHs, alkyl PAHs, benzenes, and alkyl benzenes), rather than exposures to low levels of a single compound (Roy Irwin, National Park Service, Personal Communication, 1996, based on an overview of literature on hand). See also "PAHs as a group" entry.

This is a phototoxic PAH [494,887,911]. UV light greatly increases the toxicity of anthracene to bluegill sunfish [841]. Benchmarks developed in the absence of UV light may be under-protective, and biological resources in strong sunlight are at more risk than those that are not.

For additional details on immunological effects of PAHs in general, see ATSDR [881].

Potential effects of PAHs on humans were summarized by the Agency for Toxic Substances and Disease Registry in a 1995 toxicological profile for polycyclic aromatic hydrocarbons [881], so no lengthy summary will be attempted here.

Br.Car: Brief Summary of Carcinogenicity/Cancer Information:

IRIS 1996 information from EPA [893]:

Evidence for classification as to human carcinogenicity; weight-of-evidence classification.

Classification: D; not classifiable as to human carcinogenicity

BASIS: Based on no human data and inadequate data from animal bioassays.

HUMAN CARCINOGENICITY DATA: None.

ANIMAL CARCINOGENICITY DATA: Inadequate.

The International Agency for Research on Cancer (IARC) and recent (1994) EPA weight-of-evidence evaluations have determined that anthracene is not classifiable as to its carcinogenicity to humans [788,881].

This compound has not been treated as a carcinogen for model calculation purposes in some EPA risk-based (RBC and PRG) models [868,903], but this tentative distinction was made for the purpose of choosing a modeling scenario based on current (often inadequate) knowledge rather than for the purpose of strongly stating that this compound is definitely not a carcinogen; the non-carcinogenic benchmarks are sometimes nearly as low as the carcinogenic benchmarks (Stan Smucker, personal communication, EPA, 1996).

A significant increase in the formation of non-neoplastic melanotic tumors was observed among first and second generation progeny of Drosophila melanogaster that had been exposed chronically as larvae to low concentrations of anthracene. It was concluded that anthracene solubilized with detergents could induce autosomal dominant melanotic tumors [366, Corwin HD, Gottlieb FJ; Environ Res 15: 327-31 (1978) as cited in ITC/USEPA; Information Review #227 (Draft) Anthracene p.227 (1981)].

This is a phototoxic PAH [494,887,911]. Although not definitive, phototoxicity represents one clue suggesting possible carcinogenicity.

Br.Dev: Brief Summary of Developmental, Reproductive, Endocrine, and Genotoxicity Information:

Chinese hamster ovary cells were exposed to 29 toxic chemicals which were representative of several classes of compounds listed by the national resources defense council consent decree as priority toxic pollutants. Anthracene at 1000 ug/ml for 20 hr produced very little effect on chinese hamster ovary cell cultures [366].

Br.Fate: Brief Summary of Key Bioconcentration, Fate, Transport, Persistence, Pathway, and Chemical/Physical Information:

The heavier (4-, 5-, and 6-ring) PAHs are more persistent than the lighter (2- and 3-ring) PAHs [796].

Environmental Fate/Exposure Summary [366]:

> Anthracene's release to the environment is quite general since it is a ubiquitous product of incomplete combustion and has extensive natural and anthropogenic sources. It is largely associated with particulate matter, soils, and sediments. If

released to soil it will be expected to adsorb very strongly to the soil and will not be expected to leach appreciably to groundwater. It will not hydrolyze but may be subject to biodegradation in soils with reported half-lives of 3.3-139 days. It may be subject to evaporation from the soil and other surfaces. If released to water it will strongly adsorb to sediment and particulate matter, but will not hydrolyze. It may bioconcentrate in species which lack microsomal oxidase, the presence of which allows organisms to rapidly metabolize polyaromatic hydrocarbons. It will be subject to direct photolysis near the surface of waters and may be subject to significant biodegradation. It may be subjected to significant evaporation with an estimated range of half-lives of 4.3-5.9 days predicted for evaporation from a river 1 m deep, flowing at 1 m/sec with a wind velocity of 3 m/sec. If released to the atmosphere, Anthracene will be subject to direct photolysis and the estimated vapor phase half-life in the atmosphere is 1.67 days as a result of reaction with photochemically produced hydroxyl radicals. Adsorption of anthracene may retard the evaporation, biodegradation, bioconcentration, and photolysis processes. Human exposure will be from inhalation of contaminated air and consumption of contaminated food and water. Especially high exposure will occur through the smoking of cigarettes and the ingestion of certain foods (eg smoked and charcoal broiled meats and fish).

Synonyms/Substance Identification:

Anthracen (German) [366]
Anthracin [366]
Paranaphthalene [366]
Green oil [366]
Tetra olive N2G [366]
Molecular Formula [366]: C14-H10

Associated Chemicals or Topics (Includes Transformation Products):

See also individual entries:

PAHs as a group
PAHs, Alkyl Homologs of
Phenanthrenes/Anthracenes, C1-
Phenanthrenes/Anthracenes, C2-
Phenanthrenes/Anthracenes, C3-
Phenanthrenes/Anthracenes, C4-

Metabolism/Metabolites [366]:

When admin orally to animals ... (70-80% of dose) is excreted unchanged in feces, but metabolites present in rat urine include n-acetyl-s-(1,2-dihydro-2-hydroxy-1-anthryl)-cysteine and conjugates of trans-1,2-dihydroanthracene-1,2-diol, and 1,2-dihydroxyanthracene. The cysteine conjugate is decomposed by mineral acids to yield 1-anthrylmercapturic acid, 1 & 2-anthrols & anthracene. Rats ... metabolize anthracene into trans-9,10-dihydroanthracene-9,10-diol, which gives rise to anthrone and several hydroxylated metabolites. [Parke, D. V. The Biochemistry of Foreign Compounds. Oxford: Pergamon Press, 1968. 220].

In vitro metabolism of anthracene with rat liver microsomes predominantly forms trans-1,2-dihydroxy-1,2-dihydroanthracene with little evidence of metabolism at the 9,10-position. [Akhtar MN et al; J Chem Soc Perkin Trans I 0 (6): 1442-6 (1979)].

... Metabolism of the normally stable, unsubstituted aromatic cyclic hydrocarbon, such as ... anthracene does not result from replacement of a nuclear hydrogen but ... involves first an intermediary oxidation to epoxide. This reaction requires liver microsomes, nadph & oxygen. This product ... Reacts with glutathione in presence of ... Gsh s-epoxidetransferase, to form ... A "premercapturate" ... [LaDu, B.N., H.G. Mandel, and E.L. Way. Fundamentals of Drug Metabolism and Disposition. Baltimore: Williams and Wilkins, 1971. 168].

Water Data Interpretation, Concentrations and Toxicity (All Water Data Subsections Start with "W."):

W.Low (Water Concentrations Considered Low):

No information found.

W.High (Water Concentrations Considered High):

The concentration of anthracene in the soil water of waste pits for natural gas production and processing ranged from undetectable levels to 2200 ug/L(5). [(5) Davani B et al; Inter J Environ Anal Chem 20: 205-23 (1985)] [366].

Groundwater samples taken near wood treatment/ storage sites in Canada contained between 0.015 and 0.360 mg/L anthracene. Other sites contained between 0.02 and 40 mg/L combined anthracene/ phenanthrene [864].

W.Typical (Water Concentrations Considered Typical):

In a recent study by Pham et al. (1993), raw water samples from 5 areas in the St. Lawrence River and its tributaries were analyzed for 12 PAHs. The highest mean total PAH concentrations were observed in samples

collected in the spring (27.3 ng/L) and autumn (21.03 ng/L), which was attributed to snow melt and increased runoff during these respective seasons. The lowest mean total PAH concentration was observed in summer (14.63 ng/L). High molecular weight PAHs were detected more frequently in the spring and autumn samples. Phenanthrene, benzo[b]fluoranthene, fluoranthene, and pyrene were predominant, comprising on average 33.8%, 17.4%, 17.1% and 12.8% of the total PAHs, respectively. With the exception of anthracene and benzo[b]fluoranthene, a general decrease in concentration with increasing molecular weight was observed [881].

Information from HSDB [366]:

> DRINKING WATER: Tap water, 1.1-59.7 parts per trillion(8). U.S., 9 cities, 78% pos, <1-<2 parts per trillion(12). Great Lakes, 12 municipalities, Jan (Aug), 1980, 2.4-570.8 parts per trillion (0.6-1269 parts per trillion), avg 62.9 parts per trillion (avg 126.1 parts per trillion)(4). New York State, 1979, public drinking water wells, anthracene and phenanthrene 39 wells, 18% pos, 12.0 ppb(2). Identified, not quantified, drinking water concentrates(9). Identified, not quantified, in drinking water(11). The Netherlands, drinking water from bankfiltered Rhine water, 30 parts per trillion(5). Finland, Denmark, Norway, Sweden, May-July, 1980, 0.04-9.7 parts per trillion(6). Norwegian tapwater, 0.35 parts per trillion(10). Ottawa, Canada, Jan-Feb, 1978, >0.52-2.2 ppb(1). Kitakyushu, Japan, 1.7 ppm(3). Eastern Ontario, Canada, 5 municipal treatment plants, 0.1-4.8 parts per trillion, avg 1.6 parts per trillion(7). [(1) Benoit FM et al; Intern J Environ Anal Chem 6: 277-87 (1979) (2) Council on Environmental Quality; in 11th Annual Report (1980) (3) Shinohara R et al; Water Res 15: 535-42 (1981) (4) Williams DT et al; Chemosphere 11: 263-76 (1982) (5) Piet GJ, Morra CF; pp. 29-42 in Artificial Groundwater Recharge; Huisman L, Olsthorn TN eds; Pitman Publ (1983) (6) Kveseth K, Sortland B; Chemosphere 11: 623-39 (1982) (7) Santodonato J et al; Hazard Profiles on PAH Syracuse Res Corp Syracuse NY p. 53 TR 81-633 (1981) (8) IARC; Polynuclear Aromatic Compounds Part 1 Chemical, Environmental and Experimental Data 32: 247-61 (1983) (9) Lucas SV; GC/MS (Gas Chromatography-Mass Spectrometry) Analysis or Organics in Drinking Water Concentrates and Advanced Waste Treatment Concentrates Vol 2 Battelle Columbus Labs OH (1984) (10) National Research Council; Polycyclic Aromatic Hydrocarbons: Evaluation of Sources and Effects, National Acad Press Washington DC (1983) (11) Kool HJ et al; Crit

Rev Environ Control 12: 307-57 (1982) (12) Sorrell RK et al; Environ Internat 4: 245-54 (1980)].

DRINKING WATER: Anthracene was detected in drinking water in Norway(1) and Philadelphia, PA(2). In New York State, 7 of 39 drinking water wells tested positive for anthracene with a maximum concn of 21 ug/L(3). [(1) Johnson S, Grilbbestad IS; Environ Sci Technol 22: 978-81 (1988) (2) Suffet IH et al; Water Res 14: 853-67 (1980) (3) Kim NK, Stone DW; NYS Dept Health pp. 131)].

Effluent Concentrations [366]:

Anthracene at a concentration range of <13-105 ng/l was reported in the effluent from a sewage treatment plant in Norway. It was also reported in the concentration range of <0.03-0.84 ug/l in the effluent from coal oven plants It has been reported to be present in several surface waters. [USEPA; Health and Environmental Effects Profile for Anthracene; p.vi (1987) ECAO-CIN-P230].

Coal tar which contains phenanthrene/anthracene mixtures at an average concn of 25 mg/g is commonly used as a coating to prevent corrosion of storage tanks in water distribution systems in New York State(1). The phenanthrene/anthracene concn of influent and effluent of 125 tanks averaged 0.019 and 0.210 ug/L, respectively(1). Leachate from these tanks also contained anthracene(2). [(1) Alben K; Environ Sci Technol 14: 468-70 (1980) (2) Alben K; Anal Chem 52: 1825-8 (1980)]

SURFACE WATERS: USEPA STORET database. 776 samples, 4.0% pos, median <10.0 ppb(7). Delaware River, 30 samples, 3% pos(4). Lower Tennessee River, water and sediments, 12.1 ppb(5). U.S., 114 heavily industrialized river basins, 204 sites, 1 pos, detected, not quantified(6). Dohkai Bay, Japan, Oct, 1977 identified (not quantified)(1). Tamar Estuary, UK, 4.9 parts per trillion(2). Rhine River, 1981, 15 parts per trillion, 1982, 13 parts per trillion(3). Trace quantities of anthracene were detected in Lakes Michigan(8), Erie(12) and Ontario(12). Anthracene was found in 2 of 4 Mississippi River water samples at concn of 3 and 4 ng/L(9). Anthracene was detected in Baltic waters off the coast of Poland(10); and in the Yellow River, Peoples Republic of China in March, August, and October at concn of 7.7, 0.8, and 9.5 ng/L, respectively(11). [(1) Shinohara R et al; Environ Internat 4: 163-74 (1980) (2) Readman JW et al; Estuarine Coastal Shelf Sci 14: 369-89 (1982) (3) Malle KG; Z Wasser Abwasser Forsch 17: 75-81 (1984)

(4) Dewalle FB, Chian ESK; Proc Ind Waste Conf 32: 908-19 (1978) (5) Goodley PC, Gordon M; Kentucky Acad Sci 37: 11-5 (1976) (6) Ewing BB et al; Monitoring to Detect Previously Unrecognized Pollutants in Surface Waters. Appendix: Organic Analysis Data p. 75 USEPA-560/6-77-015 (1977) (7) Staples CA et al; Environ Toxicol Chem 4: 131042 (1985) (8) Eadie BJ et al; Chemosphere 11: 847-59 (1982) (9) DeLeon IR et al; Chemosphere 15: 795-805 (1986) (10) Lamparczyk H et al; Marine Pollut Bull 19: 2122-6 (1989) (11) Ren-Ming W et al; Inter J Environ Anal Chem 22: 115-26 (1985) (12) LeBel GL et al; Adv Chem Series 214: 309-25 (1987)].

RAINWATER: Portland, OR, Feb-April, 1984, 7 sample periods, 2-5 days long: Anthracene dissolved in rainwater, 2.0-7.9 parts per trillion, avg 5.1 parts per trillion(1); anthracene concn of particulate matter in rain, 1.3-10.0 parts per trillion(2). Great Lakes, 1.3-2.3 parts per trillion, avg 2.0 parts per trillion(3). Southern Norway, Nov 1974-March 1975, detected, not quantified(4). [(1) Ligocki MP et al; Atmos Environ 19: 1609-17 (1985) (2) Ligocki MP et al; Atmospheric Environ 19: 1619-26 (1985) (3) Eisenreich SJ et al; Environ Sci Technol 15: 30-8 (1981) (4) Lunde G et al; Organic Micropollutants in Precipitation in Norway SNSF Project, 17pp FR-9/76 (1977)].

OTHER WATER: Lakes near Mt. St. Helens, WA, sampled beginning 15 months after the first major eruption, samples from Aug, 1981-Aug, 1982, Spirit Lake, epilimnion, 1.5 ppb, hypolimnion, 1.8 ppb, Coldwater Lake, epilimnion, 1.8 ppb(1). [(1) Hindin E; Occurrence of Organic Compounds in Water and Stream Sediments Due to the Mt. St. Helens Eruptions NTIS PB84-190446 (1983)].

In general, anthracene occurs in ambient waters at a frequency of 4% and at a median concentration of <10 ug/l. Anthracene has been reported to be present in groundwater from a few contaminated sites. ... The detection of up to 168.6 ug/l of anthracene /was reported/ in groundwater from a creosote waste site in Conroe, TX. The detection of anthracene in drinking waters throughout the world have been reported. The highest concentration of combined anthracene/phenanthrene at 1269 ng/l was reported in drinking water in Sault Ste. Marie. Finished waters from 13 different locations throughout the United States, however, failed to show the presence of any anthracene. [USEPA; Health and Environmental Effects Profile for Anthracene; p.vi (1987) ECAO-

CIN-P230].

GROUNDWATER: Groundwater near closed coal-tar distillation and wood-treating plant, St. Louis Park, MN, 68 ppb(1). Conroes, TX, near creosote waste site, Oct 1981-March, 1983, 13 wells, 54% pos, 1.7-205.9 ppt; soil cores, ppm (depth, feet). 2.16 (0.7-1.8), 0.14 (5), 0.03 (10) not detected (20), 0.04 (24-25), 0.03 (26.5)(2). [(1) Ehlrich GG et al; Ground Water 20: 703-10 (1982) (2) Bedient PB et al; Ground Water 22: 318-29 (1984)].

USEPA STORET database, 1268 samples, 5.0% pos, median <10.0 ppb(2). Industrial wastewater, avg ug/l, raw (treated), iron/steel manufacturing, 15 samples, 80% pos, <200 (15 samples, 93% pos, <46); aluminum forming, 5 samples, 60% pos, <100 (25 samples, 8% pos, <6.5); foundries, 11 samples, 100% pos, 2400 (10 samples, 100% pos, 12); photography, 9 samples, 22% pos (2 samples, 0% pos), nonferrous metals, 59 samples, 15% samples, >10 ug/l, 160 (55 samples, 1.8% >10 ug/l, 3.8); organic chemicals, 8 detections, 390 (4 detections, 10)(5). Fly ash from municipal incinerator, 8 samples, 100% pos, 4-380 ppb, avg 148 ppb(1). U.S. urban runoff, up to July, 1982, 15 cities, 27% pos, 86 samples, 8% pos, 1-10 ppb(3). Coke plant waste water, 70.2-101 ppb(4). Exhaust emissions from gasoline engines, 534-642 ug/l fuel burned(6). [(1) Eiceman GA et al; Anal Chem 53: 955-9 (1981) (2) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985) (3) Cole RH et al; J Water Pollut Control Fed 56: 898-908 (1984) (4) Walters RW, Luthy RG; Water Res 18: 795-809 (1984) (5) USEPA; Treatability Manual pp I.10.12-2 to 3 USEPA-600/2-82-001a (1981) (6) IARC; Polynuclear Aromatic Compounds Part 1, Chemical, Environmental and Experimental Data 32: 105-21 (1983)].

W.Concern Levels, Water Quality Criteria, LC50 Values, Water Quality Standards, Screening Levels, Dose/Response Data, and Other Water Benchmarks:

W.General (General Water Quality Standards, Criteria, and Benchmarks Related to Protection of Aquatic Biota in General; Includes Water Concentrations Versus Mixed or General Aquatic Biota):

Cautionary note: Anthracene is a very phototoxic compound [494,887,911] (see more detailed discussion of phototoxicity in the "PAHs as a group" entry). Therefore, any of the water criteria which have been developed for it using bioassays performed in the absence of UV light may be under-protective. Phototoxicity of certain PAHs

was discovered when organisms which had survived lab exposures to PAHs died quickly after being moved into sunlight. An increase in toxicity due to photo-induced changes is called phototoxicity. For certain PAHs, tests performed in the presence of UV or other solar radiation show greatly increased toxicity to those same organisms at PAH concentrations below maximum solubility [888,889,911,887; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 6, Newstead, J.L. and J.P. Geisy. Predictive models for photoinduced acute toxicity of polycyclic aromatic hydrocarbons to Daphnia magna. Copyright 1987 SETAC]. The reader should be aware that the authors of this document have not yet been able to determine which of the following criteria and benchmarks were developed in the presence or absence of UV light:

Oak Ridge National Lab, 1994: Ecological Risk Assessment Freshwater Screening Benchmarks for concentrations of contaminants in water [649]. For a definition of meaning of each benchmark, see section entitled: Benchmarks, Ecological Risk Assessment Screening Benchmarks. To be considered unlikely to represent an ecological risk, field concentrations should be below all of the following benchmarks [649]:

> NOTE: Although most of the lab tests done to develop water quality criteria and other benchmarks were originally based on "total" values rather than "dissolved" values, the lab settings were typically fairly clean and the numbers generated by the lab tests are therefore often even more comparable to field "dissolved" values than to field "total" values (Glen Suter, Oak Ridge National Lab, Personal Communication, 1995). For more information on dissolved vs. total concentrations, and EPA suggested conversion fractions for metals, see entry entitled "Dissolved."

Anthracene (micrograms per liter, ug/L)

> 0.024 = Secondary Acute Value
> 0.0013 = Secondary Chronic Value
> 0.09 = Estimated Lowest Chronic Value - Fish
> < 2.1 = Lowest Chronic Value - Daphnids
> 0.35 = Estimated Lowest Test EC20 - Fish
> > 8.2 = LOWEST TEST EC20 - DAPHNIDS

Water Quality Criteria in ug/L:

Freshwater Acute Criteria: None Published [689,893].

Freshwater Chronic Criteria: None Published [689].

Marine Acute criteria: 3.0E+2 ug/L lowest effects concentration (LEC) from the literature [893].

Marine Acute Criteria: None Published [689].

Marine Chronic Criteria: None Published [689].

Criteria Federal Register Notice Number: NA [689].

NOTE: Before citing a concentration as EPA's water quality criteria, it is prudent to make sure you have the latest one. Work on the replacement for the Gold Book [302] was underway in March of 1996.

W.Plants (Water Concentrations vs. Plants):

No information found.

W.Invertebrates (Water Concentrations vs. Invertebrates):

LC50s for Aedes aegypti (mosquito) were 0.150 mg/L (ppm) and <1 ug/L (ppb) (<0.001 mg/L, ppm) for 1-hr and 24-hr exposures, respectively [998].

LC50 for Aedes taeniorhynchus (mosquito) was 0.260 mg/L for a 24-hr exposure [998].

LC50 for Culex quinquefasciatus (mosquito) was 0.037 mg/L (37 ppb) for a 24-hr exposure [998].

LC50 for Artemia salina (brine shrimp) was 0.020 mg/L (20 ppb) for a 1-hr exposure [998].

LC50 for Crassostrea gigas (Pacific oyster) was >5.00 mg/L (5000 ppb) for a 48-hr exposure [998].

LC50 for Daphnia magna (water flea) was 0.020 mg/L (20 ppb) for a 1-hr exposure [998].

Information from HSDB [366]:

LC50 Culicid mosquito larvae 26.8 ug/l/24 hr /Phototoxicity study; Conditions of bioassay not

specified/ [Oris JT et al: Stud Environ Sci 25 (Biosphere: Probl Solutions): 639-58 (1984)].

Paramecium caudatum (protozoan) exposed to 0.1 ug/l of anthracene for 60 minutes, exhibited a 90% lethal photodynamic response. [Epstein SS et al; Cancer Res 23: 35 (1963) as cited in USEPA; Ambient Water Quality Criteria Doc: Polynuclear Aromatic Hydrocarbons p.B-3 (1980)].

Photoinduced anthracene toxicity to Daphnia pulex was investigated using organisms that were exposed to 3 nominal anthracene concentrations (3.0, 9.6, and 30.0 ug/l) in static bioassays on clear, partly cloudy, and cloudy days. A shell coating technique was used to achieve concentrations within the aqueous solubility range of anthracene and to obviate the need for a carrier solvent. Photoinduced anthracene toxicity was not observed under laboratory lighting conditions; it occurred only in the presence of solar radiation. A dose response relation existed for both anthracene concn and solar radiation intensity. Anthracene was only slightly less toxic to organisms transferred into water containing no anthracene before exposure to solar radiation. This indicates that toxicity resulted from activation by solar radiation of material present on or within the animals and not in the water. Activation appeared to be of anthracene molecules and not anthracene degradation products, since similar concentrations of anthraquinone, the primary and most stable degradation product of anthracene, were not toxic at similar solar radiation intensities. ... A series of filters was used to selectively remove UV wavelengths from solar radiation to determine the photoactive wavelengths. Mylar film absorbs in the UV-B region (285-315 nm) of solar radiation and Corning 0-52 glass absorbs essentially the entire spectrum of UV wavelengths (285-380 nm). Placement of Mylar film over bioassay beakers diminished photoinduced anthracene toxicity only slightly, whereas Corning 0-52 glass reduced toxicity proportionate to the reduction in UV intensity. Thus, wavelengths in the UV-A region (315-380) are primarly responsible for photoinduced anthracene toxicity. [Allred PM, Giesy JP; Environ Toxicol Chem 4 (2): 219-26 (1985)].

W.Fish (Water Concentrations vs. Fish):

Photoinduced toxicity occurs for anthracene. Studies in illuminated stream microcosms have shown both juvenile bluegill sunfish and the invertebrate

Daphnia pulex to be hundreds of times more sensitive to the toxic effects of anthracene. Anthracene was acutely toxic (100% mortality) to the bluegill at concentrations of 12 ug/L in less than 9 hrs [779]. UV light greatly increases the toxicity of anthracene to bluegill sunfish [841].

Information from HSDB [366]:

> LC50 Leponis macrochirus (Bluegill sunfish, juvenile) 11.9 ug/l/96 hr /Phototoxicity study; Conditions of bioassay not specified/ [Oris JT et al; Stud Environ Sci 25 (Biosphere: Probl Solutions): 639-58 (1984)].
>
> Acute mortality of bluegill sunfish, Lepomis macrochirus, dosed with anthracene at 12.7 ug/l and exposed to natural sunlight conditions was observed during a study of anthracene fate in outdoor channel microcosms. No mortality was observed under control conditions (natural sunlight and no anthracene). Fish survived when held in the shade downstream of sunlit contaminated water, arguing against mortality due to toxic anthracene photoproducts in the water. Fish held 48 hr in anthracene contaminated water (12 ug/l), in a shaded channel, died when placed in clean water and exposed to sunlight. After 144 hr depuration in darkness, fish anthracene concentrations had decreased to preexposure concentrations, and no mortality was observed when fish were subsequently exposed to sunlight. This observed phototoxic response in anthracene contaminated fish may represent a significant environmental hazard of polycyclic aromatic hydrocarbons in aquatic environments. [Bowling JW et al; Aquat Toxicol 3 (1): 79-90 (1983)].

LC50s for Lepomis macrochirus (bluegill) ranged from 3.36 to 12.02 ug/L (ppb) for 48-hr exposures, with most values above 9 ug/L [998].

LC50s for Lepomis macrochirus (bluegill) ranged from 1.27 to 46 ug/L (ppb) for 96-hr exposures, with most values below 9 ug/L [998].

LC50s for Lepomis sp. (sunfish) were 11.92, 18.23 and 26.47 ug/L (ppb) for 96-hr exposures [998].

W.Wildlife (Water Concentrations vs. Wildlife or Domestic Animals):

LC50 Rana pipiens (Leopard frog) 0.065 ppm/30 min; 0.025 ppm/5 hr /Both toxicity values based on phototoxicity study; Conditions of bioassay not specified/ [Kagan J et al; J Chem Ecol 10 (7): 1115-22 (1984)] [366].

W.Human (Drinking Water and Other Human Concern Levels):

Numeric Water Quality Criteria in Arizona [881]:

Domestic water supply: 2100 ug/L
Fish consumption: 6300 ug/L
Full body contact: 420000 ug/L

Criteria for human health protection in Missouri [881]:

Fish consumption: 0.03 ug/L
Drinking water supply: 0.003 ug/L
Groundwater: 0.003 ug/L

1970 World Health Organization (WHO) ... standard for drinking water: not to exceed 0.2 ug/l. /Polyaromatic nuclear hydrocarbons/ [Sittig, M. Handbook of Toxic and Hazardous Chemicals and Carcinogens, 1985. 2nd ed. Park Ridge, NJ: Noyes Data Corporation, 1985. 741] [366].

Human Health (E-6 Risk Level for Carcinogens) Water Quality Criteria, EPA:

Published Criteria for Water and Organism: 0.0028 ug/L [446,689]. Water & Fish: 2.8E-3 ug/liter [893].

Published Criteria for Organism Only: 0.0311 ug/L [446,689]. Fish Only: 3.11E-2 ug/liter [893].

Ambient Water Quality Criteria for Human Health: Water & Fish: 2.8E-3 ug/liter Fish Only: 3.11E-2 ug/liter [893].

Drinking Water MCL: None Published [689,893].

EPA Region 9 Preliminary remediation goal (PRG) for Tap Water [868]: 1.8E+03 ug/L

IRIS note: For the maximum protection from the potential carcinogenic properties of this chemical, the ambient water concentration should be zero. However, zero may not be obtainable at this time, so the recommended criteria represents a E-6 estimated incremental increase of cancer over a

lifetime. The values given represent polynuclear aromatic hydrocarbons as a class [893].

Average Daily Intake for Water: (assume 1.1-94.5 ppb) 2.2-189 ug. [(1) Tamakawa K et al; Eisei Kagaku 33: 66-70 (1987)] [366].

W.Misc. (Other Non-Concentration Water Information):

Trace amounts of anthracene were found in samples of rain and snow from Norway, probably originating from combustion of fossil fuels [500].

Caution: anthracene is a very phototoxic PAH [887; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 6, Newstead, J.L. and J.P. Geisy. Predictive models for photoinduced acute toxicity of polycyclic aromatic hydrocarbons to Daphnia magna. Copyright 1987 SETAC]. Phototoxic [494,911]. UV light greatly increases the toxicity of anthracene to bluegill sunfish [841]. See also: cautionary note under w.general section above.

Sediment Data Interpretation, Concentrations and Toxicity (All Sediment Data Subsections Start with "Sed."):

Sed.Low (Sediment Concentrations Considered Low):

No information found.

Sed.High (Sediment Concentrations Considered High):

Drainage stream sediments of a wood-preserving facility near Pensacola, Florida, contained various PAHs at individual levels up to 140,000 ug/kg (anthracene) [788].

Sediment samples taken near wood treatment/ storage sites in Canada contained between 0.066 and 1,124 mg/kg dry weight anthracene [864]. Other sites contained between 0.13 and 2.50 mg/kg dry weight phenanthrene/ anthracene [864].

Sed.Typical (Sediment Concentrations Considered Typical):

Anthracene was detected in 86.1 percent of urban-bay samples from the Puget Sound area. The mean concentration was 1615 ug/kg dry weight (ppb), while the median concentration was 140 ug/kg (ppb) [852].

Anthracene was detected in 59.0 percent of non-urban-bay samples from the Puget Sound area. The mean concentration was 1842 ug/kg dry weight (ppb), while the median concentration was 56.5 ug/kg (ppb) [852].

NOTE: The above values are not normalized for total organic carbon (TOC) content. Urban bay concentrations may be lower than non-urban bay concentrations due to more frequent dredging practices in urban bays, and also to the fact that most of the urban bays are at the mouths of rivers which are continually depositing "clean" sediment into these bays.

In an assessment of STORET data covering the period 1980-1982, Staples et al. (1985) reported median concentrations in sediment of less than or equal to 500 ug/kg dry weight for 15 PAHs (acenaphthene, acenaphthylene, anthracene, benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[g,h,i]perylene, benzo[a]pyrene, chrysene, fluoranthene, fluorene, indenopyrene, naphthalene, phenanthrene, and pyrene). The number of sample ranged from 236 (anthracene) to 360 (benzo[a]pyrene, fluoranthene); the percentage of samples in which these PAHs were detected ranged from 6.0 (acenaphthene, benzo[b]fluoranthene, benzo[k]fluoranthene, indeno[1,2,3-c,d]pyrene) to 22.0 (fluoranthene, pyrene) [881].

Information from HSDB [366]:

SEDIMENT: USEPA STORET database, 236 samples, 12.0% pos, median 500.0 ppb(16). Lower Tennessee River, water and sediments (seds), 12.1 ppb(1). Buzzards Bay, Cape Cod, MA, esturaine seds, 0.5 miles offshore, 170 ppb(4). Strait of Juan de Fuca Islands, Northern Puget Sound, WA, April 1977-Feb 1978, 23 locations, 38% pos, 0.03-79 ppb, 4.01 ppb(7). Cayuga Lake, NY, Sept 1978, near Milliken Station (coal fired power plant), deepwater seds, 16 km North - 8 km South, 10 samples 90% pos, 13-42 ppb, avg of pos 27.6 ppb, littoral seds, 48 km North-8 km South, 12 samples, 83% pos, <6-165 ppb, avg of 9 quantitative samples, 22.7 ppb(10). Casco Bay, ME, 30 stations, 6.7% pos, April 1980, surficial seds, 34 and 775 ppb (wet wt)(11). Duwamish River, Seattle, WA, 2 sets of subtidal seds (dry wt), set 1, 12 data set avgs, 100% pos, 38 replications, 32-520 ppb, avg 121 ppb; set 2, 9 data set avgs, 110-360 ppb, avg 290 ppb(12). Lake Pontchartrain, LA, May-June 1980, 10 samples, 80% pos, avg 14 ppb (dry wt)(13). Northwestern Atlantic ses, 0-620 km from Boston, MA 11 stations, 100% pos, 7-3000 ppb (dry wt), (max at 0 km), median, 32 ppb; >1000 km, <0.1-6 ppb(14). Adirondack Mts, NY, March 1978: Sagamore Lake, 21 ppb (0-4 cm depth), 7 ppb (4-8 cm), 1-2 ppm (8-75 cm), Woods Lake, 32 ppb (0.4 cm), 8 ppb (4-8 cm), 2-3 ppb (8-84 cm)(20). Racoon Creek, Brideport, NJ, anthracene and phenanthrene, 2.6 ppb(2). Georges Bank region,

1977-82, 22 stations, 46 samples, 100% pos, anthracene and phenanthrene, <1-35 ppb(9). Niagara River, Niagara-on-the-Lake, 1975-82. Anthracene and phenanthrene, trace-4.0 parts per trillion(17). Tamar Estuary, UK, suspended solids, 497 ppb, sediments (seds), 120 ppb(3). Baltic Sea, Gulf of Finland, 4-13 ppb(5). Lake seds, 0.03 ppm, river seds, 0.02 ppm, river particulates, 0.33, Atlantic shelf seds, 0.0011-0.0013 ppb(8). Norwegian and Swedish fjords, 10 stations, 100% pos, 1.15-10,700 ppb (dry wt)(15). Suadafjord, Norway, Oct 1984, ppb (dry wt), 6 stations, 100% pos, 12.5-727.9 (0-2 cm depth), 7.2-1075.2 (2-4 cm), 11.6-1119.6 (4-6 cm), 13.0-524 (6-8 cm)(18). Lake seds, Greifensee, Switzerland, 30 ppb(19). Severn Estuary and River Taff, 9 sites, anthracene and phenanthrene 0.1-6.4 ppm(6). SOILS: Nova Scotia, Oct 1976, 30 samples, <0.1-110 ppb (dry wt), median 12 ppb(14). [(1) Goodley PC, Gordon M; Kentucky Acad Sci 37: 11-5 (1976) (2) Hochreiter JJ Jr; Chemical Quality Reconnaissance of the Water and Surficial Bed Material in the Delaware River Estuary and Adjacent New Jersey Tributaries 1980-81 USGS/WRI/NTIS 82-36 (1982) (3) Readman JW et al; Estuarine Coastal Shelf Sci 14: 369-89 (1982) (4) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (5) Poutanen EL et al; Chemosphere 10: 347-54 (1981) (6) John ED et al) Bull Environ Contam Toxicol 22: 653-9 (1979) (7) Brown DW et al; Investigation of Petroleum in the Marine Environs of the Strait of Juan de Fuca and Northern Puget Sound USEPA-600/7-79-164 (1979) (8) Santodonato J et al; Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons Lee SD, Grant L eds; Pathotox Publ Park Forest South IL (1981) (9) Boehm PD, Farrington JW; Environ Sci Technol 18: 840-45 (1984) (10) Heit M; Water Air Soil Pollut 24: 41-61 (11) Larsen PF et al; Bull Environ Contam Toxicol 30: 530-5 (1983) (12) MacLeod MD et al; Anal Chem 54: 386-92 (1982) (13) McFall JA et al; Chemosphere 14: 1561-9 (1985) (14) Windsor JG, Hits RA; Geochim Cosmochim Acta 43: 27-33 (1979) (15) Sporstol S et al; Environ Technol 17: 282-6 (1983) (16) Staples CA et al; Envir on Toxicol Chem 4: 131-42 (1985) (17) Kuntz KW; Toxic Contaminants in the Niagara River 1975-82 Burlington Ontario Tech Bull No. 134 (1984) (18) Bjorseth A et al; Sci Total Environ 13: 71-86 (1979) (19) Carlson RM et al; Implications to the Aquatic Environment of Polynuclear Aromatic Hydrocarbons Liberated from Northern Great Plains Coal USEPA-600/3-79-093 (1979) (20) Tan YL, Heit M; Geochim Cosmochimica Acta 45: 2267-79 (1981)].

Anthracene was detected in the sediments of the Black River, OH(1), western Lake Ontario(2),

Charles River basin, Boston MA(5), southern Lake Michigan(6,7), Elizabeth River, VA, and marine sediments off the coasts of Marseilles, FRA(3), POL(4) and SWE(8). In Nov 1979- Apr 1980, anthracene was detected in 10 of 29 sediment samples from Shatt Al-Arab River and the NW region of the Arabian Gulf at concn ranging from 0.01 to 8.53 ng\g(10). Anthracene was detected in sediments from a harbor in SW Netherlands at an average concn of 144 ppm(11). Anthracene was detected in 5 of 5 estuarine sediments from the Atlantic coast of FRA at concn ranging from 0.01 to 728 ng\g(12). Anthracene was detected in 14 of 14 sediments from Tokyo Bay, Japan at concn ranging from 0.068 to 0.364 mg\kg(13). Anthracene was detected in estuarine sediments from the Fraser River Canada at an average concn of 154 ng\g(14). [(1) West WR et al; Environ Sci Technol 22: 224-8 (1988) (2) Onuska FI et al; J Great Lakes Res 9: 169-82 (1983) (3) Milano JC, Vernet JL; Oceanis 14: 19-27 (1988) (4) Lamparczyk H et al; Marine Pollut Bull 19: 222-6 (1988) (5) Hites RA, Biemann WG; Adv Chem Ser 147: 188-201 (1975) (6) Helfrich J, Armstrong DE; J Great Lakes Res 12: 192-9 (1986) (7) Eadie, BJ et al; Chemosphere 11: 847-58 (1982) (8) Broman D et al; Environ Sci Technol 22: 1219-28 (1988) (9) Bier R et al; Intern J Environ Anal Chem 26: 97-113 (1986) (10) Al-Saad HT; Marine Pollut Bull 18: 248-51 (1987) (11) DeLeeuw JW et al; Anal Chem 58: 1825-57 (1986) (12) Garrigues P et al; Intern J Environ Anal Chem 28: 121-131 (1987) (13) Matsushima H; Agric Biol Chem 46: 1489-94 (1982) (14) Rodgers IH, Hall KJ; Water Poll Res J Canada 22: 197-210 (1987)].

Anthracene was detected in 16 of 24 sediment samples from Boston harbor at concn ranging from 8 to 507 ng/g(1). Anthracene was detected in 1 of 15 sediment samples from Outdoor Resorts Marina, SC at a concn of 142 ug/kg(2). Anthracene was detected in sediments from Los Angeles area at average concn ranging from 1 to 1100 ng/g(3). Anthracene was detected in 46 of 96 sediment samples from the coast of Maine at concn up to 8 ppb(4). Anthracene was detected at of sediment sampling station in the Chesapeake Bay at average concn ranging from 1.14 to 9.00 ug/g(5). Anthracene was detected in Black and Buffalo River sediments at average concn of 3848 and 1950 ng/g, respectively(6). [(1) Shiaris MP, Jambard-Sweet P; Marine Pollut Bull 17: 469-72 (1986) (2) Marcus K et al; Arch Environ Contam Toxicol 17: 103-13 (1988) (3) Malins DC et al: Environ Sci Technol 21: 765-70 (1987) (4) Larsen PF et al; Marine Environ Res 18: 231-44 (1986) (5) Foster GD, Wright DA; Marine Pollut Bull 19: 459-65

(1988) (6) Black J et al; Chem Environ Impact Health Eff Proc Conf 5: 415-27 (1985). [366].

Sed.Concern Levels, Sediment Quality Criteria, LC50 Values, Sediment Quality Standards, Screening Levels, Dose/Response Data and Other Sediment Benchmarks:

Sed.General (General Sediment Quality Standards, Criteria, and Benchmarks Related to Protection of Aquatic Biota in General; Includes Sediment Concentrations Versus Mixed or General Aquatic Biota):

Oak Ridge National Lab, 1994: Risk Assessment Screening Benchmarks for Sediment Concentrations. To be considered unlikely to represent an ecological risk, field concentrations should be below all of the following benchmarks in mg/kg (ppm) dry weight [652]:

Anthracene (value in mg/kg dry wt.): 0.0003 is the estimated equivalent sediment quality criterion at 1% Organic Carbon

Other Concern levels for sediment concentrations:

AET, EPA 1988: The apparent effects threshold concentrations for anthracene in sediments proposed for Puget Sound ranged from .960 mg/kg dry weight (microtox) to 13.000 mg/kg dry weight (amphipod) [416]. Although the authors of the Puget Sound AETs have cautioned that Puget Sound AETs may not be appropriate for comparison with data from other geographic areas, so few concern levels for this chemical have been published that the proposed Puget Sound concern level is included in this text as a reference item.

The Canadian AET concentration, adapted from NOAA (1990), for anthracene sorbed to marine sediments is 0.300 mg/kg dry weight [864]. An AET is defined as the lowest concentration of a compound in sediment at which biological effects (usually changes in composition of benthic invertebrate communities) are observed to occur [864].

NOTE: Even lower concentrations of this PAH may be of concern related to its contribution to "total PAH" sums (see "PAHs as a group" entry).

NOAA 1995 Concern Levels for Coastal and Estuarine Environments: After studying its own data from the National Status and Trends Program as well as many

literature references concerning different approaches to determining sediment criteria, NOAA suggested that the potential for biological effects of this contaminant sorbed to sediments was highest in sediments where its concentration exceeded the 1100 ppb dry weight Effects Range-Median (ERM) concentration and was lowest in sediments where its concentration was less than the 85.3 ppb dry weight Effects Range-Low (ERL) concentration [664]. To improve the original 1990 guidelines [233], the 1995 report included percent (ratios) incidence of effects for ranges below, above, and between the ERL and ERM values. These numbers represent the number of data entries within each concentration range in which biological effects were observed divided by the total number of entries within each range [664] (see also entries entitled ERM and ERL):

<ERL	25.0
ERL-ERM	44.2
>ERM	85.2

Ontario Ministry of the Environment Freshwater Sediment Guidelines, 1993. Lowest effect level: 220 ug/kg dry weight. Severe effect level: 370 mg/kg organic carbon [761].

St. Lawrence River Interim Freshwater Sediment Criteria, 1992. No effect level: 20 ug/kg dry weight [761].

Sed.Plants (Sediment Concentrations vs. Plants):

No information found.

Sed.Invertebrates (Sediment Concentrations vs. Invertebrates):

No information found.

Sed.Fish (Sediment Concentrations vs. Fish):

No information found.

Sed.Wildlife (Sediment Concentrations vs. Wildlife or Domestic Animals):

No information found.

Sed.Human (Sediment Concentrations vs. Humans):

No information found.

Sed.Misc. (Other Non-Concentration Sediment Information):

No information found.

Soil Data Interpretation, Concentrations and Toxicity (All Soil Data Subsections Start with "Soil."):

Soil.Low (Soil Concentrations Considered Low):

No information found.

Soil.High (Soil Concentrations Considered High):

Soil samples taken near wood treatment/ storage sites in Canada contained between 0.5 and 1,910 mg/kg dry weight anthracene. Other sites contained between 34.91 and 5,300 mg/kg dry weight phenanthrene/ anthracene [864].

Soil Concentrations (mg/kg dry weight) Polycyclic Aromatic Hydrocarbons (PAHs) at Contaminated Sites. Highest values found at wood preserving, gas works, and coking site plants (mg/kg dry weight) [881]:

Anthracene	3,037

Soil.Typical (Soil Concentrations Considered Typical):

Anthracene in agricultural soil: 11-13 ug/kg [881].

Information from HSDB [366]:

> Anthracene was detected in the soil at a former pine-tar manufacturing site in Gainesville, FL(1). Anthracene concn was monitored in an agricultural soil for a hundred year period(2). Concn in 1846, 1881, 1893, 1944, 1956, 1966, 1980 and 1986 were 4.5, 13, 9, 4, 10, 9, 13 and 11 ng/g, respectively(2). [(1) McCreary, JJ et al; Chemosphere 12: 1619-32 (1983) (2) Jones KC et al; Environ Sci Technol 23: 95-101 (1989)].
>
> The concn of anthracene in the soil surrounding waste pits for natural gas production and processing ranged between 260 and 670 ug/kg(3) and 36 to 105 ug/g(4). The concn of anthracene in the soil water of the same pits ranged from undetectable levels to 2200 ug/L(5). [(3) Eiceman GA et al; Environ Sci Technol 20: 508-14 (1986) (4) Davani B et al; Water Air Soil Pollut 27: 267-76 (1986) (5) Davani B et al; Inter J Environ Anal Chem 20: 205-23 (1985)].

Soil criteria for evaluating the severity of contamination under the Dutch Soil Cleanup (Interim) Act

(1982): 0.1 ppm of anthracene indicates a background concentration. 10 ppm indicates a moderate soil contamination of anthracene. 100 ppm indicates a threshold value for anthracene contamination which requires immediate cleanup [347].

Soil.Concern Levels, Soil Quality Criteria, LC50 Values, Soil Quality Standards, Screening Levels, Dose/Response Data and Other Soil Benchmarks:

Soil.General (General Soil Quality Standards, Criteria, and Benchmarks Related to Protection of Soil-dwelling Biota in General; Includes Soil Concentrations Versus Mixed or General Soil-dwelling Biota):

Soil criteria for evaluating the severity of contamination under the Dutch Soil Cleanup (Interim) Act (1982): 0.1 ppm of anthracene indicates a background concentration. 10 ppm indicates a moderate soil contamination of anthracene. 100 ppm indicates a threshold value for anthracene contamination which requires immediate cleanup [347].

Soil.Plants (Soil Concentrations vs. Plants):

No information found.

Soil.Invertebrates (Soil Concentrations vs. Invertebrates):

Concentrations of PAH's in bioassay earthworms and bioassay soil from 15 sites at the Times Beach Confined Disposal Facility in Buffalo, N.Y. (1987): The mean concentration of anthracene in the soil was 0.92 ppm (dry weight) and the range was 0.10-1.5 ppm. The mean concentration of anthracene in earthworms was 0.047 ppm (ash-free dry weight) the range was 0.008-0.37 ppm [347].

Soil.Wildlife (Soil Concentrations vs. Wildlife or Domestic Animals):

No information found.

Soil.Human (Soil Concentrations vs. Humans):

EPA 1996 National Generic Soil Screening Level (SSL) designed to be conservative and protective at the majority of sites in the U.S. but not necessarily protective of all known human exposure pathways, land uses, or ecological threats [952]:

SSL = 23,000 mg/kg for ingestion pathway

[952].

SSL = 590 to 12,000 mg/kg for protection from migration to groundwater at 1 to 20 Dilution-Attenuation Factor (DAF) [952].

EPA 1995 Region 9 Preliminary remediation goals (PRGs) [868]:

Residential Soil: 1.9E+01 mg/kg wet wt.

Industrial Soil: 1.9E+01 mg/kg wet wt.

NOTE:

1) PRGs focus on the human exposure pathways of ingestion, inhalation of particulates and volatiles, and dermal absorption. Values do not consider impact to groundwater or ecological receptors.

2) PRGs for residential and industrial landuses are lower concentrations than EPA Region III RBCs, which consider fewer aspects (are more restricted to ingestion route) [903].

EPA 1995 Region III Risk Based Concentration (RBC) to protect from transfers to groundwater:

4300 mg/Kg dry weight [903].

Soil.Misc. (Other Non-concentration Soil Information):

No information found.

Tissue and Food Concentrations (All Tissue Data Interpretation Subsections Start with "Tis."):

Tis.Plants:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Plants:

No information found.

B) Body Burden Residues in Plants: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

Leaves: post oak, 70 ppb, little bluestem, 50 ppb(1). [(1) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983)] [366].

Tis.Invertebrates:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Invertebrates:

No information found.

B) Concentrations or Doses of Concern in Food Items Eaten by Invertebrates:

No information found.

C) Body Burden Residues in Invertebrates: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

Measured anthracene concentrations were (in wet weight) 0.039 ug/g in clams from various Canadian and American creosote-contaminated sites [864].

No detections of this compound were made in certain samples of Exxon Valdez fish or mussels [971].

See also Tis.Fish, C) section below.

Concentrations [366]:

Oligocheate worm, 20-25 ppb, midges, 10-25 ppb(1). Polycheates, New York Bight, June 1977, May 1978, 7 sample sets, 86% positive 1.0-14 ppb (dry wt)(2). [(1) Eadie BJ et al; Chemosphere 11: 185-91 (1982) (2) Farrington JW et al; Environ Sci Technol 20: 69-72 (1986)].

The U.S. National Mussel watch program collected mussels from >100 sites on the East, West, and Gulf coasts. The concentration of anthracene in these mussel composites was 7.0-32 ug/kg. [Galloway WB et al; Environ Toxicol Chem 2: 395-410 (1983) as cited in USEPA; Health and Environmental Effects Profile for Anthracene; p.vii (1987) ECAO-CIN-P230].

Anthracene concn in clams from the harbor of Heron Isle and a beach on Lizard Isle along the great barrier reef, Australia was 0.4 and 3.2 ug/kg(1). Anthracene was detected in the digestive gland oil of Lobsters at concn ranging from 197 1012.1 ng/g(2). Concn of anthracene in the tissues of snails from offshore at Pensacola, FL were 9.03, 24.7, 13.8 and 12.7 ug/kg wet weight(3). Mussels from 3 of 7 sites of the Finnish Archipelago contained anthracene at average concn of 14, 15 and 9 ug/kg wet weight(4). Anthracene was detected in 92% of the mussels sampled from

the Dutch coast(5). Rock oysters from 6 sites off the coast of NW Australia contained anthracene at average concn ranging from 0.1 to 0.9 ug/kg(6). [(1) Baag J, Smith JD; ACS Natl Meet Preprint 28: 328-30 (1988) (2) Uthe JF, Musial CJ; J Assoc Off Anal Chem 71: 363-8 (1988) (3) Rostad CE, Pereira WE; Chemosphere 16: 2397-404 (1987) (4) Rainio K et al; Bull Environ Contam Toxicol 37: 337-43 (1986) (5) Boom MM Intern J Environ Anal Chem 31: 251-61 (1987) (6) Kagi R et al; Intern J Environ Anal Chem 22: 135-53 (1985)].

Tis.Fish:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Fish (Includes FDA Action Levels for Fish and Similar Benchmark Levels From Other Countries):

No information found.

B) Concentrations or Doses of Concern in Food Items Eaten by Fish:

No information found.

C) Body Burden Residues in Fish: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

The anthracene concentration in mosquitofish with extremely elevated total PAH concentrations (60.79 mg/kg) was 1.1 mg/kg [201].

Measured anthracene concentrations were (in wet weight) 6.8 ug/g in guppies, and 9.58 ug/g in English sole from various Canadian and American creosote-contaminated sites [864].

No detections of this compound were made in certain samples of Exxon Valdez fish or mussels [971].

Fish/Seafood Concentrations [366]:

Strait of Juan de Fuca, San Juan Islands, Northern Puget Sound, WA, April 1977-Feb 1978, 23 locations, 5% pos, mussels, 30-200 ppb(3). Smoked fish: eel, 4 ppb, lumpfish, trace, trout, 26 ppb, redfish, 1.5 ppb, mackerel, 1.9-2.3 ppb(5). Lake Pontchartrain, LA, May-June 1980, oysters and clams, 10 samples, avgs 36-44 ppb (wet wt)(7). Lake Erie white suckers stomach contents, 3 stations, 100% pos, 22 samples, avgs 1.95-2.17 ppb (wet wt), overall avg 45.0 ppb(10). Penobscot Bay, ME,

June-July 1982, 49 stations, 98.0% pos, 1-49 ppb (dry wt), avg 11.75 ppb(11). Washington State, 1983: Presidents Point, 150 ppb (dry wt), Eagle Harbor (creosote contaminated), 3 sites, 100% pos, 15 samples, 120-12,000 ppb (dry wt)(12). Narragansett Bay. anthracene and phenanthrene concentrate of large number of mussels avg 18 ppb (dry wt)(8). Thermaikos Gulf, Greece, mussels, 57 samples, 54.4% pos, avg 9 ppb (wet wt)(6). Japanese horse mackerel, broiler type, smoke, 1.9-2.3 ppb, scorch, 0.2-2.0 ppb(2). Nigerian freshwater fish, ppb, dry wt, smoked, 15.14-30.13, solar dried, 0.2-11.22, oven-dried, 0.20-0.75(1). Saudafjord, Norway, Oct 1976, mussels, 5 samples, 80% pos, 7-524 ppb (dry wt), avg pos 144 ppb(9). [(1) Afolabii OA et al; J Agric Food Chem 31: 1083-90 (1983) (2) Fazio T, Howard JW, pp. 461-505 in Handbook of Polycyclic Aromatic Hydrocarbons; Bjorseth A ed (1983) (3) Brown DW et al; Investigation of Petroleum in Marine Environs of the Strait of Juan de Fuca and Northern Puget Sound USEPA-600/7-79-164 (1979) (4) Konasewich D et al; Status Report on Organic and Heavy Metal Contaminants in the Lakes Erie, Michigan, Huron and Superior Basins. Great Lakes Quality Board (1978) (5) Santodonato J et al; Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons Lee Sd, Grand L eds; Pathotox Publ Park Forest South IL (1981) (6) Iosifidou HG et al; Bull Environ Contam Toxicol 28: 535-41 (1982) (7) McFall JA et al; Chemosphere 14: 1561-9 (1985) (8) Galloway WB et al; Environ Technol Chem 2: 395-410 (1983) (9) Bjorseth A et al; Sci Total Environ 13: 71-86 (1979) (10) Maccubin AE et al; Bull Environ Contam Toxicol 343: 876-82 (1985) (11) Johnson AC et al; Marine Environ Res 15: 1-16 (1985) (12) Malins et al; Carcinogenesis 6: 1463-9 (1985)].

Tis.Wildlife: Terrestrial and Aquatic Wildlife, Domestic Animals and all Birds Whether Aquatic or not:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Wildlife, Domestic Animals, or Birds:

No information found.

B) Concentrations or Doses of Concern in Food Items Eaten by Wildlife, Birds, or Domestic Animals (Includes LD50 Values Which do not Fit Well into Other Categories, Includes Oral Doses Administered in Laboratory

Experiments):

> Intragastric admin of ... pure anthracene does not cause animals to die after a single administration of the maximum possible dose (17 g/kg). ... Repeated poisoning of albino rats gives rise to a decrease in hemoglobin, reticulocytosis, leukopenia, and increase in residual blood nitrogen. [International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983. 163] [366].

C) Body Burden Residues in Wildlife, Birds, or Domestic Animals: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

> In the rat, 0.5 Mg when injected subcutaneously decreased the antioxidative activity of the pancreas during the last 25 days after injection. The pancreatic insular cells showed increases in the cell, nucleus, and nucleolus size. [Clayton, G. D. and F. E. Clayton (eds.). Patty's Industrial Hygiene and Toxicology: Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982. 3354] [366].

Tis.Human:

A) Typical Concentrations in Human Food Survey Items:

> See also Tis.Invertebrates, C) and Tis.Fish, C), above.
>
> Food Survey Results [366]:
>
> > Charcoal-broiled steaks, 4.5 ppb, barbecued ribs, 7.1 ppb(1). Edible oils, 0.2-402 ppb(2). Coconut oil, 36 ppb(3). Smoked meats, ppb; mutton, 13.0, mutton sausages, 2.0, salami, 2.6, heavily smoked bacon, 20.0(3). Bakers yeast, 2.6-557 ppb (max Scotland)(3). [(1) Fazio T, Howard JW; pp. 461-505 in Handbook of Polycyclic Aromatic Hydrocarbons; Bjoresth A ed (1983) (2) IARC; Polynuclear Aromatic Compounds Part 1, Chemical, Environmental and Experimental Data 32: 247-61 (1983) (3) Santodonato J et al; Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons Lee Sd, Grant Leds; Pathotox Publ Park Forest South IL (1981)].
>
> > Kale: 2.4-97.5 ppb [USEPA; Ambient Water

Quality Criteria Doc: Polynuclear Aromatic Hydrocarbons (Draft) p.C-23 (1980)].

A survey of alcoholic drinks in France showed anthracene and related compounds in the range of 1-10 ppb. [Toussaint G, Walker EA; J Chromat 171: 448-452 (1979) as cited in ITC/USEPA; Information Review #227 (Draft) Anthracene p.20 (1981)].

Anthracene has been reported to be present in smoked foods, liquid smoke, charcoal broiled steaks and in edible aquatic organisms collected from certain contaiminated waters. [USEPA; Health and Environmental Effects Profile for Anthracene; p.25 (1987) ECAO-CIN-p230].

The concentration of anthracene in charcoal broiled steaks and barbecued ribs were reported to be 4.5 and 7.1 ug/kg, respectively. [USEPA; Health and Environmental Effects Profile for Anthracene; p.vii (1987) ECAO-CIN-p230].

In 1983, anthracene was detected in 13 of 25 samples from Finnish margarine, butter, and vegetable oils at concn ranging from 0.04 to 460 ug/kg(1). The max and average concn for 17, 5, 4, 4, 4, and 3 samples of lettuce (Lactuca sativa) grown at 8, 15, 25, 35, 45, and 65 m from a Swedish highway were 0.5, 0.2; 0.2, 0.1; 0.2, 0.1; 0.4, 0.1, 0.2, 0.1; and undetected ug/kg of fresh weight, respectively(2). Beef patties containing 10, 20 and 30% fat and cooked over mesquite wood contained anthracene at an average concn of 20, 28 and 31 ug/kg, respectively(3). Anthracene was not detected in beef patties with 10 and 20% fat that were cooked over hardwood charcoal(3). Beef patties with 30% fat and cooked over hardwood charcoal contained anthracene at an average concn of 2 ug/kg(3). Anthracene was detected in Japanese smoked and/or broiled fish at concn ranging from 0.2-435 ppb(4). Laboratory prepared charcoal broiled steaks and commercial barbecued ribs contained anthracene at respective concn of 4.5 and 7.1 ppb(4). Home smoked meats contained anthracene at concn ranging from 2 to 388 ppb(4). Cold and hot smoked sausages with the casings contained 25.4 and 10.6 ppb, respectively; 2.4 and 5.6 ppb, respectively with casings removed(4). Anthracene was detected in 3 of 23 samples of

Finnish leaf lettuce (Lactuga sativa var. crispa) at concn of 0.09, 0.10, and 0.19 ug/kg of fresh weight(5). [(1) Hopia A et al; JAOC 63: 889-93 (1986) (2) Larsson BK; J Sci Food Agric 36: 463-70 (1985) (3) Maga JA; J Agric Food Chem 34: 249-51 (1986) (4) Lo M, Sandi E; Res Rev 69: 35-86 (1978) (5) Wickstrom K et al; Z Levensm Unters Forsch 183: 182-5 (1986)].

B) Concentrations or Doses of Concern in Food Items Eaten by Humans (Includes Allowable Tolerances in Human Food, FDA, State and Standards of Other Countries):

For risk to human adults eating fish, separate carcinogenic and non-carcinogenic risk-based fish tissue concentrations were calculated [903]. The following EPA Region III fish tissue risk-based concentration (RBC) benchmark utilizes the lower of the two (carcinogenic vs. non-carcinogenic) concentrations, rounded to two significant figures [903]: 410 mg/kg wet weight. Fish would seldom if ever accumulate this much (see Tis.Fish section). A greater risk, if any, would be from invertebrates, PAH metabolites, or routes other than fish. However, the reader should keep in mind that elevated concentrations of individual PAHs often occur in the presence of complex mixtures of PAHs, and that complex mixtures of PAHs often display carcinogenic and phototoxic properties (see "PAHs as a group" entry).

This compound has as RfD (Reference Dose; similar to an Acceptable Daily Intake) of:

0.3 mg/kg/day [868,903].

IRIS RfD: 3E-1 mg/kg-day Confidence: Low [893].

Crit. Dose: 1000 mg/kg-day [Study 1 NOAEL] UF: 3000 [893].

C) Body Burden Residues in Humans: Typical, Elevated, or of Concern Related to the Well-being of Humans:

EPA has suggested that taking into your body 0.3 mg/kg body weight of anthracene each day is not likely to cause any significant (noncancer) harmful health effects [788].

Information from HSDB [366]:

Human atherosclerotic aorta, 2 subjects, 10 and 30 ppb(1). Anthracene was detected in the

urine of both smoking and non-smoking workers of an aluminum plant in Soederberg, Norway at concn of approximately 0.1 ug/mmole of creatinine(2). Anthracene was detected in the urine of workers at an anode producing plant in Italy(3). [(1) Ferrario JB et al; Arch Environ Contam Toxicol 14: 529-34 (1985) (2) Becher G, Bjorseth AJ; pp. 145-55 in Polycyclic Aromatic Hydrocarbons Cooke M, Dennis AJ eds Columbus, OH: Battelle Press (1985) (3) Clonfero E et al; pp. 439-43 in Occup Environ Chem Haz. UK Publ (1987)] [366].

Five normal adult volunteers without cutaneous disease applied 2% crude tar to the skin for eight hour periods on two consecutive days. Blood extracts subjected to gas chromatography and mass spectrometry yielded evidence of adsorption in all five volunteers. Phenanthrene, anthracene, pyrene, and fluoranthene, were found in four volunteers. [Storer JS et al; Arch Dermatol 120 (7): 874-7 (1984)].

The daily dietary intake of six Japanese women between 25 and 56v years of age was monitored for one week in July 1985(1). The intake of anthracene ranged from undetectable levels to 1.8 ug/day/female with a mean and median concn of 0.23 and 0.13 ug/day/female, respectively(1,SRC). [(1) Tamakawa K et al; Eisei Kagaku 33: 66-70 (1987)].

Average Daily Intake for Food: insufficient data. [(1) Tamakawa K et al; Eisei Kagaku 33: 66-70 (1987)].

Tis.Misc. (Other Tissue Information):

This is a very phototoxic PAH [887; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 6, Newstead, J.L. and J.P. Geisy. Predictive models for photoinduced acute toxicity of polycyclic aromatic hydrocarbons to Daphnia magna. Copyright 1987 SETAC]. Phototoxic [494,911]. Although not definitive, phototoxicity represents one clue suggesting possible carcinogenicity. UV light greatly increases the toxicity of anthracene to bluegill sunfish [841]. See also cautionary note under w.general section above.

Bio.Detail: Detailed Information on Bioconcentration, Biomagnification, or Bioavailability:

During the Exxon Valdez spill, bioconcentration explained the

buildup of PAHs in tissues better than biomagnification; most accumulation was of an equilibrium partitioning nature across the gills rather than from the food chain [971]. Immature fish seem to have higher bioconcentration of PAHs than adults, perhaps because their PAH breakdown systems are not fully developed and at times perhaps because of a higher percentage of lipid tissues (yolk tissues, etc) [971] (confirmed by Jerry Neff, Battelle Ocean Sciences, Duxbury, MA, personal communication 1996).

Bioconcentration factors for anthracene range up to 3500 in the mayfly (Hexagenia sp.) [754].

Bioconcentration [366]:

> Effects of temperature and anthracene concentration on uptake and depuration rate constants and bioconcentration factor were determined for larvae of the midge, chironomus riparius. At 25 deg c, the uptake rate constant estimated from 10 hr and 30 hr exposure and by the initial rates methods increased with concentration between 1.7 And 30.5 Ug/l. At constant concentration (22 ug/l), the uptake rate constant was max at 25 deg c and less at 16 and 30 deg c. [Gerould S et al; Environ Pollut Ser A 30 (3): 175-88 (1983)].
>
> Uptake, depuration, and biotransformation rates of (14)carbon -labeled anthracene were determined for pontoporeia hoyi, the dominant benthic invertebrate in the great lakes, at 4, 7, 10, and 15 deg c. The uptake rate constants increased from 136/hr to 215/hr over the temp range studied and were seasonally dependent. The depuration rate constant at the apparent optimum temp of 7 deg c was 0.015/Hr for anthracene. The biotransformation ability of pontoporeia hoyi is low, and degradation of anthracene was undetectable even after exposures of 48 hr. The bioconcentration factor can be predicted from the uptake and depuration kinetics to be approx 16,800 at 4 deg c. Thus, pontoporeria hoyi may be very important in food chain biomagnification of some toxic organics. [Landrum PF; Chemosphere 11 (10): 1049-57 (1982)].
>
> Bluegills (Lepomis macrochirus) were exposed to (14)carbon-labeled anthracene in water. Rates of uptake and biotransformation within the fish were followed by (14)carbon counting and thin layer and liquid chromatography. The initial uptake rate coefficient for anthracene was independent of exposure concn. Biotransformation of the anthracene was constant at 0.22 Nmol/g/hr, with approx 92% of the residue unmetabolized at 4 hr. 6% Of the anthracene was found in liver and gall bladder. Depuration rates were first -order and yielded half-life of 17 hr for anthracene. The estimated bioconcentration factor for anthracene in whole fish (ku/kd) was 900, for total (14)carbon activity, but only

675 for parent material. This bioconcentration factor was considerably lower than that predicted from the octanol water partition coefficient, because of biotransformation. [Spacie A et al; Ecotoxicol Environ SAF 7 (3): 330-41 (1983)].

BCF (bioconcentration factor): Goldfish, 162(1), Gambusia (fish), 1029(2), Rainbow trout, 4400-9200(3), Daphnia pulex, 759-912(5,7), Chlorella fusca variety vacuolata (green algae), 7760(6), Golden orfe, 912(8), Pontoporeia hoyi (scud), 17,000(9), midge (Chironomous riparius), 46.7(10). BCF dec with inc concn Aldrich humic acids: BCF (dissolved organic carbon, mg/l), 607 (0.2), 319 (2.0)(4). [(1) Ogata M et al; Bull Environ Contam Toxicol 33: 561-7 (1984) (2) Lu PY et al; Environ Health Perspect 24: 201-8 (1978) (3) Linder G et al; Environ Toxicol Chem 4: 549-58 (1985) (4) Leversee GJ et al; Can J Fish Aquat Sci 40: 63-9 (1983) (5) Herbes SE, Risi GF; Bull Environ Contam Toxicol; 19: 147-55 (1978) (6) Geyer et al; Chemosphere 10: 1307-13 (1981) (7) Southworth GR et al; Water Res 12: 973-7 (1978) (8) Freitag D et al; Ecotox Environ Safety 6: 60-81 (1982) (9) Landrum PF; Chemosphere 11: 1049-59 (1982) (10) Gerould S et al; Environ Pollut A 30: 175-88 (1983)].

Information from HSDB [366]:

Soybeans grown in liquid culture and in soil containing (14)carbon anthracene (14)carbon assimilated (14)carbon and translocated it to stems and leaves. Soybeans grown in liquid culture and exposed to an amount containing (14)carbon assimilated /it/ through the leaves and translocated it to stems and roots. Measurement of (14)carbon dioxide efflux from the soil grown plants and tlc of extracts of the plants grown in liquid culture demonstrated that soybean plants can catabolize. (14)Carbon uptake rates of (14)carbon from liquid culture were correlated with concentration of (14)carbon in the solution. Uptake from liquid culture exceeded uptake from soil. Greater uptake and catabolism of (14)carbon was observed from soil at field capacity than from flooded soil. [Edwards NT et al; Environ Exp Bot 22 (3): 349-57 (1982)].

(14)Carbon -labeled anthracene was administered to young coho salmon in food and by ip injection. The accumulated (14) carbon in key organs (eg, liver and brain) increased over various time periods. After ip injection, the highest percent of metabolites occurred in gallbladder; however, significant amounts were also found in the liver, brain, flesh, and carcass. It appears that aromatic metabolites are broadly distributed throughout fish exposed to polynuclear aromatic hydrocarbons. [Roubal WT et al; Arch Environ Contam Toxicol 5 (4): 513-29 (1977)].

All 6 hydrocarbons, anthracene, phenol, cresol, toluene, napthalene, and benzo(a)pyrene, tested were excreted from the gills of dolly varden char (Salvelinus malma), although less of the largest and least polar compounds were excreted. 1.9% of the administered (14)carbon - labeled anthracene was excreted from gills. The size of the hydrocarbon appeared to be a more important factor in gill excretion than partition coefficient. A small amount was recovered from the cloacal chamber. [Thomas RE, Rice SD; Physiol Mech Mar Pollut Toxic (Proc Symp Pollut Mar Org): 161-76 (1982)].

Bluegills (Lepomis macrochirus) were exposed to (14)carbon-labeled anthracene in water. Depuration rates were first order and yielded a half-life of 17 hr for anthracene. [Spacie A et al; Ecotoxicol Environ SAF 7 (3): 330-41 (1983)].

Interactions:

Photoinduced toxicity occurs for anthracene. Studies in illuminated stream microcosms have shown both juvenile bluegill sunfish and the invertebrate Daphnia pulex to be hundreds of times more sensitive to the toxic effects of anthracene. Anthracene was acutely toxic (100% mortality) to the bluegill at concentrations of 12 ug/L in less than 9 hrs [779].

Information from HSDB [366]:

Acute mortality of bluegill sunfish, Lepomis macrochirus, dosed with anthracene at 12.7 ug/l and exposed to natural sunlight conditions was observed during a study of anthracene fate in outdoor channel microcosms. No mortality was observed under control conditions (natural sunlight and no anthracene). Fish survived when held in the shade downstream of sunlit contaminated water, arguing against mortality due to toxic anthracene photoproducts in the water. Fish held 48 hr in anthracene contaminated water (12 ug/l), in a shaded channel, died when placed in clean water and exposed to sunlight. After 144 hr depuration in darkness, fish anthracene concentrations had decreased to preexposure concentrations, and no mortality was observed when fish were subsequently exposed to sunlight. This observed phototoxic response in anthracene contaminated fish may represent a significant environmental hazard of polycyclic aromatic hydrocarbons in aquatic environments. [Bowling JW et al; Aquat Toxicol 3 (1): 79-90 (1983)].

Photoinduced anthracene toxicity to Daphnia pulex was investigated using organisms that were exposed to 3 nominal anthracene concentrations (3.0, 9.6, and 30.0 ug/l) in static bioassays on clear, partly cloudy, and cloudy days. A shell coating technique was used to

achieve concentrations within the aqueous solubility range of anthracene and to obviate the need for a carrier solvent. Photoinduced anthracene toxicity was not observed under laboratory lighting conditions; it occurred only in the presence of solar radiation. A dose response relation existed for both anthracene concn and solar radiation intensity. Anthracene was only slightly less toxic to organisms transferred into water containing no anthracene before exposure to solar radiation. This indicates that toxicity resulted from activation by solar radiation of material present on or within the animals and not in the water. Activation appeared to be of anthracene molecules and not anthracene degradation products, since similar concentrations of anthraquinone, the primary and most stable degradation product of anthracene, were not toxic at similar solar radiation intensities. ... A series of filters was used to selectively remove UV wavelengths from solar radiation to determine the photoactive wavelengths. Mylar film absorbs in the UV-B region (285-315 nm) of solar radiation and Corning 0-52 glass absorbs essentially the entire spectrum of UV wavelengths (285-380 nm). Placement of Mylar film over bioassay beakers diminished photoinduced anthracene toxicity only slightly, whereas Corning 0-52 glass reduced toxicity proportionate to the reduction in UV intensity. Thus, wavelengths in the UV-A region (315-380) are primarly responsible for photoinduced anthracene toxicity. [Allred PM, Giesy JP; Environ Toxicol Chem 4 (2): 219-26 (1985)].

The DNA cell binding assay is based on earlier observations which indicated that DNA and other nucleic acids exposed to active carcinogens strongly react with other macromolecules, producing nucleic acid and nucleic acid protein adducts. Anthracene at concn of 10 and 100 umol produced a negative result for low dose and questionable result for high dose when tested using escherichia coli q13 cells and Escherichia coli DNA. [Kubinski H ET AL; Mutat Res. 89 (2): 95-136 (1981)].

Experiments on rabbits have established that chemically pure anthracene & phenanthrene have a less pronounced photosensitizing effect than technical anthracene, 93% anthracene, or pure carbazole. [International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971. 106].

Uses/Sources:

See Chem.Detail section below for anthracene concentrations in various petroleum products.

Air: Several studies provide evidence that atmospheric

concentrations of particle-phase PAHs are higher in winter than in summer. In a 1981-82 study conducted in the Los Angeles area, atmospheric concentrations of 10 PAHs (anthracene, fluoranthene, pyrene, chrysene, benz[a]anthracene, combined benzo[a]pyrene and perylene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, and combined benzo[g,h,i]perylene, and indeno[1,2,3-c,d]pyrene) ranged from 0.14 to 1.45 ng/m3 (with an average of 0.43 ng/m3) during the summer (August-September), and from 0.40 to 4.46 ng/m3 (with an average of 1.28 ng/m3 during the winter (February-March) [881]. A similar seasonal variation in particle-phase PAH concentrations in the Los Angeles atmosphere was seen in an earlier 1974-75 study [881]. Quarterly geometric mean concentrations of 11 PAHs (pyrene, fluoranthene, benz[a]anthracene, chrysene, benzo[a]pyrene, benzo[e]pyrene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, benzo[g,h,i]perylene, and indeno[1,2,3-c,d]pyrene) ranged from 0.06 to 2.71 ng/m3 (with an average of 0.45 ng/m3) during the May-October period, and from 0.26 to 8.25 ng/m3 (with an average of 1.46 ng/m3) during the November-April period. The highest and lowest concentrations were observed during the fourth (November-January) and second (May-July) quarters, respectively. Ratios of fourth quarterly and second quarterly geometric mean concentrations ranged from 3.9 for indeno[1,2,3-c,d]pyrene to 7.5 for benzo[a]pyrene and 9.8 for benz[a]anthracene. Possible factors contributing to these seasonal variations in PAH levels include the following: changes in emission patterns; changes in meteorological conditions (i.e., daylight hours and temperature); and changes in space heating emissions, volatilization, and photochemical activity [881].

Certain monitoring data suggest that ambient levels of some PAHs may be decreasing. Faoro and Manning (1981) analyzed a limited sample of U.S. National Air Surveillance Network data updated through 1977, which indicated that benzo[a]pyrene concentrations have shown consistent, sizable declines during the period from 1967 to 1977 at 26 urban sites and 3 background sites studied (data not provided) [881].

Over the past two decades, the ambient air levels of PAHs in a number of major cities have been characterized. Although data from studies in different areas cannot be used to indicate definitive temporal trends in PAH air levels, a comparison of the results of these studies yields no strong suggestion that the ambient air levels of PAHs may be decreasing, except in traffic tunnels [881].

In a 1981-82 study that characterized air levels of 13 PAHs in Los Angeles, Grosjean (1983) reported mean ambient particle-phase PAH concentrations ranging from 0.32 ng/m3 for benzo[k]fluoranthene to 3.04 ng/m3 for combined benzo[g,h,i]perylene and indeno[1,2,3-c,d]pyrene. Mean concentrations of anthracene, fluoranthene, pyrene, chrysene, benz[a]anthracene, combined perylene and benzo[e]pyrene, benzo[b]fluoranthene, and benzo[a]pyrene were 0.54; 0.94, 1.62, 0.97, 0.48, 0.43. 0.94, and 0.64 ng/m3, respectively. Similar results were obtained in an obtained in an earlier (1974-1975) study of atmospheric particle-phase PAHs in the Los Angeles area, where ambient annual geometric mean concentrations ranged from 0.17

ng/m3 for benzo[j]fluoranthene to 3.27 ng/m3 for benzo[g,h,i]perylene [881]. The annual geometric mean concentration of benzo[a]pyrene was 0.46 ng/m3; most individual PAHs had annual geometric mean concentrations of less than 0.6 ng/m3. The relatively high levels of benzo[g,h,i]perylene found in these studies have been attributed to high levels of automobile emissions, which are known to contain high levels of benzo[g,h,i]perylene relative to other PAHs [881]. During the same time period, Fox and Staley (1976) reported somewhat higher ambient average concentrations of particle-phase PAHs in College Park, Maryland, ranging from 3.2 ng/m3 for benzo[a]pyrene to 5.2 ng/m3 for pyrene [881].

Trace amounts of anthracene were found in samples of rain and snow from Norway, probably originating from combustion of fossil fuels [500].

In a recent limited study, mean concentrations of particle-phase PAHs in New York City air were reported to range from 0.11 ng/m3 for anthracene to 4.05 ng/m3 for benzo[g,h,i]perylene [881].

Atmospheric PAH concentrations have been found to be significantly elevated in areas of enclosed traffic tunnels. In a 1985-86 study in the Baltimore Harbor Tunnel the average concentrations of particle-phase PAHs ranged from 2.9 ng/m3 for anthracene to 27 ng/m3 for pyrene [881]. These values are up to an order of magnitude lower than those obtained in 1975 [881].

Natural Sources [366]:

> A high boiling fraction of coal tar, consisting of anthracene, phenanthrene, & other solid hydrocarbons, as well as acridine. [Gosselin, R.E., R.P. Smith, H.C. Hodge. Clinical Toxicology of Commercial Products. 5th ed. Baltimore: Williams and Wilkins, 1984.,p. II-157].
>
> Since anthracene is a product of incomplete combustion, there will be natural sources arising from volcanoes and forest fires. (SRC)

Artificial Sources [366]:

> Ubiquitous product of incomplete combustion, occuring in exhaust from motor vehicles and other gasoline and diesel engines, cigarette, marijuana and cigar smoke, emissions from coal, oil, and wood burning stoves, furnaces and power plants; generally released from soot and smoke of industrial, municipal and domestic origin, and found in cooked foods, especially charcoal broiled foods(1). Coke ovens and asphalt processing and use(2). Coal gasification and liquification processes(3). [(1) IARC; Polynuclear Aromatic Compounds Part 1, Chemical, Environmental and Experimental Data 32: 105-21 (1983) (2) Verschueren K; Handbook of Environmental Data on Organic Chemicals. 2nd ed Von Nostrand Reinhold NY pp 208-11 (1983) (3) Cerniglia CE; Rev Biochem Toxicol 3: 321-61

(1981)].

Air pollution sources: In coke oven emissions: 46.4-942.8 ug/g of sample; Emissions from space heating installation burning: coal (underfeed) stoker): 0.85 mg/10 X 10+6 Btu input; gasoil: 3.9 mg/10 X 10+6 Btu input; In gasoline: 1.55 mg/l; In exhaust condensate of gasoline engine: 0.53-0.64 mg/l gasoline consumed; Emissions from typical European gasoline engine 1608 cu cm following European driving cycles using leaded and unleaded commercial gasolines: 18.2-392.5 ug/l fuel burnt; In gasoline (high octane number) 2.59 mg/l; In an outlet waterspray tower of asphalt hot road mix process: 1600 ng/cu m; In an outlet of asphalt air blowing process: 220,000 ng/cu m. [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 208].

Liberation from extraction and packaging from coal tar fraction of coking; a binding agent in manufacture of coal briquettes used for fuel; a dielectric in the manufacture of battery electrodes, electric arc furnace electrodes, and for alumina reduction; manufacture of felts and papers and roofing. /Coal tar pitch volatiles/ [Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) PublicationNo. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981. 4].

... Protective coatings for pipes for underground conduits and drainage; ... a coating on concrete as waterproofing and corrosion resistant material; ... in road paving and sealing; manufacture and repair of refractory brick; production of foundry cores; ... in manufacture of carbon ceramic /products/. /Coal tar pitch volatiles/ [Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) PublicationNo. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981. 4].

The industrial effluents that are most likely to contain polynuclear aromatic compounds including anthracene are wastewaters from the synfuel industry; shale oil plants, petroleum processing plants, other industries using coal derived products, wastewater treatment plants and aluminum reduction plants, however, anthracene has been reported in effluents from only a few industries. [USEPA; Health and Environmental Effects Profile for Anthracene; p 21 (1987) ECAO-CIN-P230].

Other Environmental Concentrations [366]:

Cigarette main stream smoke, 2.3-23.5 ug/100 cigarettes;

cigar smoke, 11.9 ug/100 g; pipe smoke, 110 ug/100 g; marijuana smoke, 3.3 ug/100 cigarettes(1). [(1) IARC; Polynuclear Aromatic Compounds Part 1, Chemical, Environmental and Experimental Data 32: 37 (1983)].

Forms/Preparations/Formulations:

No information found.

Chem.Detail: Detailed Information on Chemical/Physical Properties:

Solubility [848]: 0.043 - 0.075 mg/L at 25 degrees C.

Density [848]: 1.283 g/cm3 at 20 degrees C.

Melting point [848]: 216-219 degrees C.

Boiling point [848]: 340 degrees C.

Octanol/Water partition coefficient (log Kow) [848]: 4.45

Log Kow value [971] = 4.54

Sorption partition coefficient (log Koc) [848]: 4.42

Molecular Weight [848]: 178.24

Information from HSDB [366]:

Koc = 26,000 [Kenaga EE, Goring CAI; Aquatic Toxicology p.78-115 (1980)].

A Koc of 1600(1) suggests anthracene should be immobile in soil(2). [(1) Karickhoff SW; Chemosphere 10: 833-40 (1981) (2) Swann RL et al; Res Rev 85: 16-28 (1983)].

Details of anthracene and phenanthrene/anthracene homolog content (ng/mg or ppm) in one fresh sample of NSFO (Fuel Oil 5, Chuck Rafkind, National Park Service, Personal Communication, 1996):

Anthracene:	96.2
C1-Phenanthrene/anthracene:	2116.3 (includes both)
C2-Phenanthrene/anthracene:	2716.7 "
C3-Phenanthrene/anthracene:	1923.3 "
C4-Phenanthrene/anthracene:	820.5 "

Anthracene content in one sample of groundwater subjected to long term contamination of NSFO (Fuel Oil 5), possibly mixed with some JP-4, motorgas, and JP-8, Colonial National Historical Park Groundwater Site MW-10 (Chuck Rafkind, National Park Service, Personal Communication, 1996): 1972.5 ng/L or ppt.

NOTE: The above PAHs and alkyl PAHs were analyzed by a

GC/MS/SIM NOAA protocol [828] modified with methylene chloride extraction for use with water samples (Guy Denoux, Geochemical and Environmental Research Group, Texas A&M University, personal communication 1996).

Anthracene content (mg/kg or ppm) in one fresh sample of Exxon Valdez Crude Oil [971]: 0 mg/kg = ppm

Anthracene concentration in Used Engine Oil: 22.0 ppm [519; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 12, Upshall, C., J.F. Payne and J. Hellou. Induction of MFO enzymes and production of bile metabolites in rainbow trout (Oncorhynchus mykiss) exposed to waste crankcase oil. Copyright 1992 SETAC].

Anthracene is found in unleaded, premium unleaded, and leaded gasolines at a range of 1.55 to 1.84 % volume of the gasoline [796].

The anthracene concentration measured in a study using Prudhoe Bay Crude oil was 84 ug/g (ppb) [854].

PAH concentrations (ug/g oil sampled) were determined for three different crude oil sample types (weathered and unweathered oil) taken from the Exxon Valdez oil spill. Anthracene was not detected in any of them [790; Reprinted with permission from Environmental Toxicology and Chemistry, Vol.14(11), W.A. Stubblefield, G.A. Hancock, W.H. Ford, and R.K. Ringer, "Acute and Subchronic Toxicity of Naturally Weathered Exxon Valdez Crude Oil in Mallards and Ferrets." Copyright 1995 SETAC].

Fate.Detail: Detailed Information on Fate, Transport, Persistence, and/or Pathways:

Half-lives for volatilization of anthracene (a low molecular weight PAH) were estimated to be 18 hrs in a stream with moderate current and wind, versus about 300 hrs in a body of water with a depth of 1 meter and no current [788].

In general, volatilization half-lives from surfaces are shorter than 100 h for low-molecular-weight PAHs, such as naphthalene and anthracene. However, this number may vary depending upon surface wind velocity and turbulence [754].

Sorption of PAHs to soil and sediments increases with increasing organic carbon content and is also directly dependent on particle size. One researcher found from 3 to 4 times more anthracene was retained by marsh sediment than by sand [788].

Volatilization of anthracene from soil may be substantial. Lower molecular weight compounds (like anthracene) may also volatilize from sediments; this process is not significant for the higher molecular weight compounds [788].

Environmental Fate [366]:

TERRESTRIAL FATE: If released to soil, anthracene will be

expected to adsorb very strongly to the soil and, therefore, will not be expected to leach through soil. It will not hydrolyze. It will be subject to biodegradation with reported range of half-lives of 108-139 days for biodegradation in soils, with one half-life of 3.3 days also reported. Evaporation from soil surfaces and other surfaces may be important. Adsorption to soil will be expected to retard both evaporation and biodegradation processes. (SRC)

AQUATIC FATE: If released to water, anthracene will be expected to adsorb very strongly to sediments and particulate matter. It will not hydrolyze but may bioconcentrate in aquatic organisms which lack microsomal oxidase (this enzyme enables the rapid metabolism of polyaromatic hydrocarbons). It will be subject to direct photolysis near the surface of natural waters and may be subject to significant biodegradation based on laboratory tests. It may be subject to significant evaporation with an estimated range of half-lives of 4.3-5.9 days for evaporation from a model river 1 m deep, flowing at 1 m/sec with a wind velocity of 3 m/sec. Adsorption of anthracene on suspended solids or sediments may retard photolysis, biodegradation, and evaporation processes. (SRC)

ATMOSPHERIC FATE: Anthracene released to the atmosphere should be partially associated with particulate matter and may be subject to long distance transport, depending on the particle size distribution and climactic conditions which will determine the rates of wet and dry deposition. It may be subject to considerable direct photolysis and the estimated vapor phase half-life in the atmosphere is 1.67 days as a result of reaction with photochemically produced hydroxyl radicals. Adsorption of anthracene to particulates may considerably retard direct photolysis and reaction with vapor phase species. (SRC)

The fate and transport of anthracene in surface waters will depend on the nature of the water. In most waters, the loss of anthracene is mainly due to photolysis and biodegradation, however, in every shallow fast flowing clear water, volatilization and photolysis will play dominant roles in determining the fate of anthracene. [USEPA; Health and Environmental Effects Profile for Anthracene; p.iv (1987) ECAO-CIN-p230].

In air, anthracene is expected to be present both in the vapor and the particle sorbed state. Over 78% of atmospheric anthracene may be present in the vapor state. Both chemical processes including ozone and hydroxide radical and photochemical reaction will degrade atmospheric anthracene. The degradation of vapor phase atmospheric anthracene is expected to be faster than

particle sorbed anthracene. The atmospheric half-life of anthracene may vary from hours to days. The long range transport of anthracene indicates that particle sorbed anthracene may have a half-life of the order of days. [USEPA; Health and Environmental Effects Profile for Anthracene; p.V (1987) ECAO-CIN-p230].

Biodegredation [366]:

Half-lives for biodegradation in soils, 5 determinations, 108-175 days, avg 139 days; also reported half-life of 3.3 days(1). No degradation in Skidway River, GA, estuarine water collected in April in 24 hours(5). Degradation in Georgia coast sediment with crude oil added, 2.0-2.6%/wk(6). 31% degradation after 5 hr of incubation with sediment collected 0.5 km below coking plant discharge(7). Degradation in sed contaminated by oil, 13% in 24 hours, 66% in 7 days(8). Degradation after 10 weeks in fresh and ripe composts of municipal waste, 8.3-19.0% in fresh, 37.2-58.1% in ripe(10). Theoretical BOD 2% using inoculum from 3 polluted surface waters (BOD5 tests)(9). Significant degradation with gradual adaptation reported for anthracene (5 and 10 mg/l) incubated with sewage seed, 43% and 26% degradation after 7 days, 92% and 51% degradation after 28 days and 3 weekly subcultures(11). Anthracene was confirmed to be poorly or non-biodegradable in MITI tests(12). No degradation was reported for anthracene exposed to 7 mixed cultures enriched in fuel oil (5 deg C, 2 weeks, mineral medium)(2). Slight degradation was reported with benzene acclimated sludge in 8 hr at 20 deg C(3); 5% conversion to CO2 in 18 hr in Third Creek water and no degradation in water from Walker Branch(4). [(1) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (2) Mulkins-Phillips GJ, Stewart JE; Appl Microbiol 28: 915-22 (1974) (3) Malaney DC, McKinney RE; Water Sew Works 113: 302-9 (1966) (4) Southworth GR; pp. 359-80 in Methodol Biomass Determinations Microbial Act Sediments ASTM STP-667 Aquatic Toxicology Marking LL, Kimberle RA eds Philadelphia (1979) (5) Lee RF; Proc 1977 Oil Spill Conf Amer Petrol Inst pp. 611-6 (1977) (6) Gardner WS et al; Water Soil Air Pollut 11: 339-47 (1979) (7) Schwall LR, Herbes SE; pp. 167-83 in ASTM STP-673 (1979) (8) Herbes SE, Schwall LR; Appl Environ Microbiol 35: 306-16 (1978) (9) Dore M et al; Trib Cebedeau 28: 3-11 (1975) (10) Martens R; Chemosphere 11: 761 (1982) (11) Tabak HH et al; pp. 267-328 in Proc Symp AOAC 94th Ann Mtg Washington DC pp. 267-328 (1981) (12) Sasaki S; pp. 283-98 in Aquatic Pollutants: Transformation and Biological Effects. Hutzinger O et al; eds Oxford Pergammon Press (1978)].

The biodegradability of anthracene with natural sediments and natural esturine waters has been studied. The biodegradation of anthracene in aquatic media is

controlled by the temperature, oxygen content and acclimatization or nonacclimatization of the microorganisms. Higher biodegradation rates were observed at 30 deg C than at 20 and 10 deg C. The biodegradation process was found to be aerobic and higher oxygen concentration up to a certain optimum value tended to increase the oxidation rates. Similarly, the biodegradation rates were reported to be faster with acclimatized microorganisms. The incubation of anthracene with intertidal sediment slurries for a reasonable period of time (approx 1 month) not only produces the mineralization product carbon dioxide but also produces intermediate metabolites A large portion of the initial material or its intermediate metabolites (which could not be identified because (14)carbon counting of the combustion products of residue was used as the method of quantification) remained cellular bound. [USEPA; Health and Environmental Effects Profile for Anthracene; p.8 (1987) ECAO-CIN-P230].

The mineralization half-life of anthracene has been reported to be 57-210 days in unacclimatized sediments and 5-7 days in oil treated sediments. The mineralization half-life of anthracene was also reported to be 200 days in oil- reated water and 20 fold higher in uncontaminated water. The overall biotransformation (both carbon dioxide and intermediate metabolite formation) half-life of anthracene in petroleum contaminated sediment was reported to be 12 days. In pristine sediments, the overall biotransformation half-life was 10 fold higher. The overall biotransformation half-life of anthracene in sediments contaminated with a coal coking wastewater was 2 days. The anthracene transformation rate was 20 times lower in the water. [USEPA; Health and Environmental Effects Profile for Anthracene; p.9 (1987) ECAO-CIN-P230].

The proposed pathway for bacterial catabolism of anthracene from pure culture studies is as follows; anthracene, 1,2-dihydroxyanthracene, 2-hydroxy-3-naphthaldehyde, 2-hydroxy-3-naphthoic acid, 2,3-dihydroxynaphthalene salicylic acid. [USEPA; Health and Environmental Effects Profile for Anthracene; p.7 (1987) ECAO-CIN-P230].

The biodegradability of anthracene with mixed microorganisms was studied. Anthracene is biodegradable in sewage treatment plants provided suitable acclimatization can be achieved with settled domestic wastewater as microbial inoculum and a static culture lask screening procedure, 43% of anthracene was found to be biodegradable in 7 days at an initial concentration of 5 ppm. After 7 days of acclimatization, the same solution showed 70% degradaton in 7 days. The corresponding degradation was only 26 and 30% at an

initial anthracene concentration of 10 ppm. Activated sludge from three municipal treatment plants /was used/ as microbial inoculum and the Warburg method as a means for estimating the rate of biodegradation. Anthracene was reported to be appreciably resistant to biodegradation with the third activated sludge. Only 0.3% carbon dioxide formation (relative to applied dose) on incubation of anthracene for 5 days with activated sludge /was reported/. [USEPA; Health and Environmental Effects Profile for Anthracene; p.7 (1987) ECAO-CIN-P230].

Abiotic Degredation [366]:

Polyaromatic hydrocarbons do not contain hydrolyzable groups and would, therefore, not be expected to hydrolyze(1). Recovery of anthracene in heptane solution exposed to sunlight for 1 month (Nov) was 0%; recovery after 4 days exposure in Oct, <0.1%(2). Anthracene in air sample from Texas exposed to sunlight degraded 90% in 4 days(3). Anthracene adsorbed on fly ash exposed to sunlight was 12% degraded in 46 days(4). Rapid degradation (half-life, 35 min) in distilled water exposed to midday sunlight, 35 deg N latitude; 4-fold inc in half-life with 100 cm creek water over distilled water sample; 19-fold inc in turbid water sample (50 mg/l clay suspension)(5). The estimated vapor phase half-life in the atmosphere is 1.67 days as a result of reaction with photochemically produced hydroxyl radicals(6). [(1) Callahan MA et al; pp. 98-8 in Water-Related Environmental Fate of 129 Priority Pollutants Vol 2 USEPA-440/4-79-029b (1979) (2) Muel B, Saguem S; Intern J Environ Anal Chem 19: 111-31 (1985) (3) Fox MA, Olive S; Science 205: 582-3 (1979) (4) Korfmacher WA et al; Environ Sci Technol 14: 1049-9 (1980) (5) Southworth GR; pp 359-80 in Aquatic Toxicology Marking LL, Kimberle RA eds; Philadelphia PA ASTM STP-667 (1979) (6) GEMS; Graphical Exposure Modeling System. Fate of Atmospheric Pollutants (FAP) Data Base. Office of Toxic Substances. USEPA (1986)].

... Anthracene in distilled water was rapidly degraded under exposure to natural sunlight, with a photolysis half-life of about 35 minutes under midday sunlight in midsummer at 35 deg north latitude. Under average winter solar conditions at the same latitude coordinates, anthracene's photolytic half-life was 4.8 hr and 1.6 hr for summer conditions. [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume I. EPA-440/4 79-029a. Washington, DC: U.S.Environmental Protection Agency, December 1979.,p. 96-4].

Soil Adsorption/Mobility [366]:

The possibility of leaching of anthracene from soil to

groundwater will depend on soil type. The Koc value for anthracene is 26,000. This indicates that anthracene will be adsorped strongly to soil and the compound may degrade before it reaches groundwater. Filtration of polluted surface water containing anthracene through sandy soil at a residence time of 100 days did not completely eliminate anthracene in the filtered water. The passage of anthracene through the soil was explained as a breakthrough of the chemical because of the saturation of active sorption sites. [USEPA; Health and Environmental Effects Profile for Anthracene; p.18 (1987) ECAO-CIN-P230].

Koc = 26,000 [Kenaga EE, Goring CAI; Aquatic Toxicology p.78-115 (1980)].

A Koc of 1600(1) suggests anthracene should be immobile in soil(2). [(1) Karickhoff SW; Chemosphere 10: 833-40 (1981) (2) Swann RL et al; Res Rev 85: 16-28 (1983)].

Volatilization from Water/Soil [366]:

Half-life of 2.8 hr calculated from measured volatilization from depth of 11.0 cm, reaeration rate 13.8 cm/hr, gas transfer coefficient 10,800 cm/hr(1). Using a reported range of vapor pressures of 1.95X10-4 to 7.65X10-4 mm Hg at 20 deg C(2,3) and a range of reported water solubilities of 0.066-0.0796 ppm(4,5), a range of Henry's Law constants of 2.72X10-3 to 5.75X10-4 atm-cu m.mol was calculated(6,SRC). Using this range of Henry's Law constants an estimated range of half-lives of 4.3-5.9 hr was calculated for evaporation from a river 1 m deep, flowing at 1 m/sec with a wind velocity of 3 m/sec(6,SRC). [(1) Smith JH et al; Chemosphere 10: 281-9 (1981) (2) Sims RC, Overcash MR Res Rev 88: 1-68 (1983) (3) Grayson BT, Fosbraey LA; Pestic Sci 13: 269-78 (1982) (4) Pearlman RS et al; J Chem Ref Data 13: 555-62 (1984) (5) Hine J, Mookerjee PK; J Org Chem 40: 292-8 (1975) (6) Lyman WJ et al; Handbook of Chemical Property Estimation Methods. Environmental Behavior of Organic Compounds NY: McGraw-Hill pp. 15-1 to 15-34 (1982)].

The rates of volatilization of anthracene from bodies of water were studied. Besides the water temperatures, the rates of volatilization are dependent on the depth of the water, the current of the flowing water, the wind velocity above the water and the nature, and among of the suspended solids present in the water. Decrease in water depths, increases in current and water velocity, and decreases in absorption onto suspended particles in water are expected to increase the volatilization rates. None of the available estimation methods for the determination of evaporative half-life of anthracene in water bodies however incorporates the effect of sorption on volatilization. [USEPA; Health and Environmental Effects

Profile for Anthracene; p 9 (1987) ECAO-CIN-P230].

Absorption, Distribution and Excretion: [940]:

1. Polycyclic aromatic hydrocarbons were detected in human fat and liver and their average concn were 1100 and 380 ppt, respectively. Anthracene was found at high levels in the liver and fat. (Obana h et al; bull environ contam toxicol 27 (1): 23-7, 1981) [940].

2. Soybeans grown in liquid culture and in soil containing (14)carbon anthracene (14)carbon assimilated (14)carbon and translocated it to stems and leaves. Soybeans grown in liquid culture and exposed to an amount containing (14)carbon assimilated /it/ through the leaves and translocated it to stems and roots. Measurement of (14)carbon dioxide efflux from the soil grown plants and tlc of extracts of the plants grown in liquid culture demonstrated that soybean plants can catabolize. (14)Carbon uptake rates of (14)carbon from liquid culture were correlated with concentration of (14)carbon in the solution. Uptake from liquid culture exceeded uptake from soil. Greater uptake and catabolism of (14)carbon was observed from soil at field capacity than from flooded soil. (Edwards nt et al; environ exp bot 22 (3): 349-57, 1982) [940].

3. (14)Carbon -labeled anthracene was administered to young coho salmon in food and by ip injection. The accumulated (14) carbon in key organs (eg, liver and brain) increased over various time periods. After ip injection, the highest percent of metabolites occurred in gallbladder; however, significant amounts were also found in the liver, brain, flesh, and carcass. It appears that aromatic metabolites are broadly distributed throughout fish exposed to polynuclear aromatic hydrocarbons. (Roubal wt et al; arch environ contam toxicol 5 (4): 513-29, 1977) [940].

4. All 6 hydrocarbons, anthracene, phenol, cresol, toluene, napthalene, and benzo(a)pyrene, tested were excreted from the gills of dolly varden char (salvelinus malma), although less of the largest and least polar compounds were excreted. 1.9% Of the administered (14)carbon -labeled anthracene was excreted from gills. The size of the hydrocarbon appeared to be a more important factor in gill excretion than partition coefficient. A small amount was recovered from the cloacal chamber. (Thomas re, rice sd; physiol mech mar pollut toxic (proc symp pollut mar org): 161-76 (1982) [940].

5. The waxy surface of some plant leaves and fruits can concentrate polyaromatic hydrocarbons through surface adsorption. /Polynuclear aromatic hydrocarbons/ (USEPA;

Ambient Water Quality Criteria Doc: Polynuclear Aromatic Hydrocarbons p.C-11 (1980) [940].

6. Five normal adult volunteers without cutaneous disease applied 2% crude tar to the skin for eight hour periods on two consecutive days. Blood extracts subjected to gas chromatography and mass spectrometry yielded evidence of adsorption in all five volunteers. Phenanthrene, anthracene, pyrene, and fluoranthene, were found in four volunteers. (Storer JS et al; Arch Dermatol 120 (7): 874-7 ,1984) [940].

Laboratory and/or Field Analyses:

Recommended detection limits:

Most of the PAH methods which have been commonly used historically for routine monitoring, including PAH parent compound standard methods:

EPA 8270 (8270 includes several PAH parent compounds along with a long list of other organics) for solid waste/RCRA applications [1013], and

EPA NPDES method 610 as specified in 40 CFR Part 136 (method 610 includes 16 PAH parent compounds) [1010],

EPA method 625 for Base/Neutral Extractables (method 625 includes several PAH parent compounds along with a long list of other organics) as specified in 40 CFR Part 136 [1010],

are all inadequate for generating scientifically defensible information for Natural Resource Damage Assessments [468]. These standard EPA scans do not cover important alkyl PAHs and do not utilize low-enough detection limits. When biological effects, ecological risk assessment, damage assessment, or bio-remediation are being considered, detection limit should be no higher than 1-10 ng/L (ppt) for water and 1 ug/kg (ppb) dry weight for solids such as tissues, sediments, and soil.

Note: Utilizing up to date techniques, many of the better labs can use detection limits of 0.3 to 1 ppb for tissues, sediments, and soils. When no biological resources are at risk, detection limits for solids should nevertheless generally not be above 10 ppb. One reason that low detection limits are needed for PAHs is that so many of the criteria, standards, and screening benchmarks are in the lower ppb range (see various entries on individual PAHs).

In the past, many methods have been used to analyze for PAHs [861,1010,1013]. However, recent (1991) studies have indicated that EPA approved methods used for oil spill assessments (including total petroleum hydrocarbons method 418.1, semivolatile priority pollutant organics methods 625 and 8270, and volatile organic priority pollutant methods 602, 1624, and 8240) are all inadequate for generating scientifically defensible information for Natural Resource Damage Assessments [468]. These general organic chemical methods are deficient in chemical selectivity (types of constituents analyzed) and sensitivity (detection limits); the deficiencies in these two areas lead to an inability to interpret the environmental significance of the data in a scientifically defensible manner [468].

For risk, damage assessment, drinking water, or to determine if biodegradation has occurred, the NOAA expanded scan for PAHs and alkyl PAHs [828], or equivalent rigorous and comprehensive scans. (such as SW-846 method 8270 modified for Selective Ion Mode detection limits and an equivalent list of parent compound and alkyl PAH analytes), are recommended.

If a Park Service groundwater investigation at Colonial National Historical Park performed in response to contamination by Fuel Oil 5 had utilized EPA semi-volatile scan 8270 or any of the other typical EPA scans (625, etc.) all of which only include parent compounds and typically utilize detection limits in the 170-600 ppb range, the false conclusion reached would have been that no PAHs were present in significant (detection limit) amounts. This false negative conclusion would have been made because the parent compound PAHs present constituted only 7.6% of the PAHs detected in groundwater by the expanded scan [828], and the highest concentration found for any parent compound was 8.4 ppb, far below the detection limits used on the older standard EPA scans. Utilizing the NOAA protocol expanded scan [828], it was determined that 92.4% of the total concentration values of the PAHs detected in groundwater were alkyl PAHs, and that all 39 PAHs and alkyl PAHs were present. Of course, all 39 PAHs were also present in the fresh product, in much higher concentrations, and also having alkyl compounds with the highest percentage of higher values compared to parent compounds.

In a similar vein, if the Park Service sediment investigation at Petersburg National Historical Battlefield (see Chem.Detail section in PAHs entry, this study was performed in response to contamination by Diesel) had utilized EPA semi-volatile scan 8270 or any of the other typical EPA scans (625, etc.), all of which only include parent compounds and often utilize detection limits no lower than the 170-600 ppb range, the false conclusion reached would have been that only one PAH was present in significant (detection limit) amounts. This false negative conclusion would have been made because the parent compound PAHs present constituted only 2.4% of the PAHs detected in sediments, and the highest concentration found for any parent compound except pyrene was 85.5 ppb, far below the detection limits used on the older standard EPA scans. Pyrene was 185 ppb, which would have been non-detected on many of the EPA scans, but not all. However, utilizing the NOAA protocol expanded scan [828], it was determined that 97.6% of total quantity of PAHs detected in sediments were alkyl PAHs, and that

all 39 PAHs and alkyl PAHs were present in these sediments.

When taking sediment samples for toxic organics such as PCBs, PAHs, and organochlorines, one should also routinely ask for total organic carbon analyses so that sediment values may be normalized for carbon. This will allow comparison with the newer EPA interim criteria [86,127]. TOC in sediments influences the dose at which many compounds are toxic (Dr. Denny Buckler, FWS Columbia, personal communication).

In some cases (where the expanded scans are too expensive) an alternative recommendation is that one screen sediments with a size-exclusion high-performance liquid chromatography (HPLC)/fluorescence method. The utility and practicality of the HPLC bile and sediment screening analyses were demonstrated on board the NOAA R/V Mt. Mitchell during the Arabian Gulf Project. Estimates of petroleum contamination in sediment and fish were available rapidly, allowing modification of the sampling strategy based on these results [522].

Variation in concentrations of organic contaminants may sometimes be due to the typically great differences in how individual investigators treat samples in the field and in the lab rather than true differences in environmental concentrations. This is particularly true for volatiles and for the relatively lighter semi-volatiles such as the naphthalene PAHs, which are so easily lost at various steps along the way. Contaminants data from different labs, different states, and different agencies, collected by different people, are often not very comparable (see disclaimer section at the top of this entry).

As of 1997, the problem of lack of data comparability (not only for water methods but also for soil, sediment, and tissue methods) between different "standard methods" recommended by different agencies seemed to be getting worse, if anything, rather than better. The trend in quality assurance seemed to be for various agencies, including the EPA and others, to insist on quality assurance plans for each project. In addition to quality control steps (blanks, duplicates, spikes, etc.), these quality assurance plans call for a step of insuring data comparability [1015,1017]. However, the data comparability step is often not given sufficient consideration. The tendency of agency guidance (such as EPA SW-846 methods and some other new EPA methods for bio-concentratable substances) to allow more and more flexibility to select options at various points along the way, makes it harder in insure data comparability or method validity. Even volunteer monitoring programs are now strongly encouraged to develop and use quality assurance project plans [1015,1017].

At minimum, before using contaminants data from diverse sources, one should determine that field collection methods, detection limits, and lab quality control techniques were acceptable and comparable. The goal is that the analysis in the concentration range of the comparison benchmark concentration should be very precise and accurate.

It should be kept in mind that quality control field and lab blanks and duplicates will not help in the data quality assurance goal as well as intended if one is using a method prone to false negatives. Methods may be prone to false negatives due to the use of detection limits that are too high, the loss of contaminants

through inappropriate handling, or the use of an inappropriate methods such as many of the EPA standard scans. This is one reason for using the NOAA expanded scan for PAHs [828]; or method 8270 [1013] modified for Selective Ion Mode (SIM) detection limits (10 ppt for water, 0.3 to 1 ppb for solids) and additional alkyl PAH analytes; or alternative rigorous scans. These types of rigorous scans are less prone to false negatives than many of the standard EPA scans for PAH parent compounds (Roy Irwin, National Park Service, Personal Communication, 1997).

For a much more detailed discussion of the great many different lab and field methods for PAHs in general, see the entry entitled PAHs as a group (file name starting with letter string: PAHS). There the reader will find much more detailed discussions of lab methods, holding times, containers, comparability of data from different methods, field sampling methods, quality assurance procedures, the relationship of various methods to each other, the various EPA standard methods for various EPA programs, the pros and cons of various methods, and additional documentation concerning why many standard EPA methods are inadequate for certain applications. A decision tree key for selecting the most appropriate methods for oil or oil products spills is also provided in the lab section of the PAHs entry. Due to the length of these discussions, they are not repeated here (see PAHs entry).