# ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA

# BENZO(A)ANTHRACENE ENTRY

July 1, 1997

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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 chemical topic entry (one file among 118). Before utilizing this entry, the reader is strongly encouraged to read the README file (in this subdirectory) for an introduction, an explanation of how to use this document in general, an explanation of how to search for power key section headings, an explanation of the organization of each entry, an information quality discussion, a discussion of copyright issues, and a listing of other entries (other topics) covered.

See the separate file entitled REFERENC for the identity of numbered references in brackets.

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).

## Benzo(a)anthracene (CAS number 56-55-3)

**Br**ief Introduction:

**Br.Class**: General Introduction and Classification Information:

Benz(a)anthracene is a high-molecular-weight, 4-ring polycyclic aromatic hydrocarbon (PAH) and an EPA Priority Pollutant [697,634]. Benz(a)anthracene is an EPA-classified probable human carcinogen [893].

Because it is formed when gasoline, garbage, or any animal or plant material burns, it is usually found in smoke and soot. This chemical combines with dust particles in the air and is carried into water and soil and onto crops. Benz(a)anthracene is also found in creosote [869].

Of all estimated environmental releases of benzo(a)anthracene, 94% are to air. Of the remaining 6%, approximately equal amounts of B(a)A are released to water and land [869].

At this time (1990), benzo(a)anthracene has been found at 62 out of 1,177 sites on the National Priorities List (NPL) of hazardous waste sites in the United States [869].

Benzo(a)anthracene is 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].

**Br.Haz**: General Hazard/Toxicity Summary:

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.

People may be exposed to benzo(a)anthracene from environmental sources such as air, water, and soil and from cigarette smoke and cooked food. Typically, exposure for workers and the general population is not to benzo(a)anthracene alone, but to a mixture of similar chemicals [869].

No information has been found about specific levels of benzo(a)anthracene that have caused harmful effects in people after breathing, swallowing, or touching the substance [869].

According to one source, pertinent data regarding lethality and decreased longevity in humans or experimental animals following inhalation, oral, or dermal exposure to benzo(a)anthracene could not be located in the available literature [869].

According to one source, no information was found on the systemic effects of benzo(a)anthracene in humans or experimental animals following inhalation, oral, and dermal exposures [869].

PAH effects on humans tend to be chronic effects (like cancer) rather than acute effects (see "PAHs as a group" entry for more details).

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

IRIS 1996 EPA information [893]:

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

Classification: B2; probable human carcinogen

BASIS: Based on no human data and sufficient data from animal bioassays. Benz(a)anthracene produced tumors in mice exposed by gavage; intraperitoneal, subcutaneous or intramuscular injection; and topical application. Benz(a)anthracene produced mutations in bacteria and in mammalian cells, and transformed mammalian cells in culture.

HUMAN CARCINOGENICITY DATA: None. Although there are no human data that specifically link exposure to benz(a)anthracene to human cancers, benz(a)anthracene is a component of mixtures that have been associated with human cancer. These include coal tar, soots, coke oven emissions and cigarette smoke (U.S. EPA, 1984, 1990; IARC, 1984; Lee et al., 1976; Brockhaus and Tomingas, 1976).

ANIMAL CARCINOGENICITY DATA: Sufficient.

The 4- to 7-ring PAHs have been especially implicated in the carcinogenic effect of used oil [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].

The International Agency for Research on Cancer (IARC) and EPA have determined that benzo(a)anthracene is probably carcinogenic to humans [788]. The Department of Health and Human Services (DHHS) has determined that benzo(a)anthracene may reasonably be anticipated to be a carcinogen [788].

This compound has been treated as a carcinogen for model calculation purposes in some EPA risk-based (RBC or risk-based concentration and PRG or Preliminary remediation goals) models [868,903].

This is a phototoxic PAH [891,911,887; 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]. Although not definitive, as discussed above, phototoxicity represents one clue suggesting possible carcinogenicity.

Older reference: No data are available in humans. Sufficient evidence of carcinogenicity in animals. OVERALL EVALUATION: Group 2A: The agent is probably carcinogenic to humans. [366, IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. S7 58 (1987)] [366].

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

One source stated that pertinent data regarding the reproductive and developmental toxicity of benzo(a)anthracene in humans or experimental animals following inhalation, oral, or dermal exposure could not be located in the available literature [869]. Similarly, another source stated that the available data on reproductive toxicity and teratogenicity were inadequate for evaluation [847].

The genotoxicity of benzo(a)anthracene has been demonstrated in various in vivo and in vitro genetic toxicology assays. The majority of the experimental results reported have been positive, but there are negative results as well [869].

**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].

PAHs are degraded fairly quickly in many vertebrates, less quickly and in a different way in some other life forms; however, the breakdown products of many PAHs are more hazardous than the parent compound (see "PAHs as a group" entry).

Environmental Fate/Exposure Summary [366]:

> The pattern of benz(a)anthracene (BA) release into air and water is quite general since it is a universal product of combustion of organic matter. Both in air and water it is largely associated with particulate matter. When released into water it will rapidly become adsorbed to sediment or particulate matter in the water column, and bioconcentrate into aquatic organisms. In the unadsorbed state, it will degrade by photolysis in a matter of hours to days. Its slow desorption from sediment and particulate matter will maintain a low concentration of BA in the water. Because it is strongly adsorbed to soil it will remain in the upper few centimeters of soil and not leach into groundwater. BA will very slowly biodegrade when colonies of microorganisms are acclimated but this is too slow a process (half-life ca 1 yr to be significant). Benz(a)anthracene in the atmosphere will be transported long distances and will probably be subject to photolysis and photooxidation although there is little documentation about the rate of these processes in the literature. Humans will be exposed to benz(a)anthracene in ambient air, particularly in industrial areas, from stoves, cigarette smoke, food (particularly when smoked or charcoal broiled), and drinking water (SRC).

**Syn**onyms/Substance Identification:

1,2-Benz(a)anthracene [366]
1,2-Benzanthracene [366]
1,2-Benzanthrene [366]
1,2-Benzoanthracene [366]
2,3-Benzophenanthrene [366]
BA [366]
B(a)A [870]
Benzanthracene [366]
Benzanthrene [366]
Benz(a)anthracene [366]
Benzo(b)phenanthrene [366]
Benzoanthracene [366]
Tetraphene [366]
Naphthanthracene [847]

Molecular Formula:
C18-H12 [366]

**As**sociated Chemicals or Topics (Includes Transformation Products):

See also individual entry:

PAHs as a group

Metabolites [366]:

/Polycyclic aromatic hydrocarbons (pah)/ ... Are metabolized initially by cytochrome-p-450-dependent monooxygenases ... These enzymes are often designated as aryl hydrocarbon hydroxylases. ... In initial step of activation process, the hepatic cytochrome-p-450-dependent monooxygenases oxidize pah to reactive metab. The pah epoxides can undergo ... Further reactions, incl hydration by the enzyme, epoxide hydrolase ... To form trans-dihydrodiols. These in turn are oxidized by cytochrome-p-450-dependent monooxygenases to form highly reactive diol epoxides, the ultimate carcinogens. /Polycyclic aromatic hydrocarbons/ [National Research Council. Drinking Water & Health, Volume 4. Washington, DC: National Academy Press, 1981. 258].

Yields 3-hydroxybenzanthracene in rats, rabbits, & mice; 8-hydroxybenzanthracene in rats; 9-hydroxybenzanthracene in rats; 11-hydroxybenzanthracene probably in rats & mice; yields 7,12-dihydro-7,12-dihydroxybenzanthracene probably in rats & mice; yields trans-8,9-dihydro-8,9-dihydroxybenzanthracene in rats, rabbits & mice; yields trans-5,6-dihydro-5,6-dihydroxybenzanthracene in rats, rabbits, mice; yields 10,11-dihydro-10,11-dihydroxybenzanthracene in rabbits & mice; yields s-(5,6-dihydro-6-hydroxybenzanthr-5-yl)glutathione in rats, rabbits & mice; yields 4-hydroxybenzanthracene in rats, rabbits, & mice: boyland e, sims p; biochem j 91: 493

(1964) /from table/ [Goodwin, B.L. Handbook of Intermediary Metabolism of Aromatic Compounds. New York: Wiley, 1976.,p. B-3].

Yields benzanthracene-5,6-oxide in rats: sims p et al; biochem j 125: 28 (1971). Yields 1,2-dihydro-1,2-dihydroxybenzanthracene probably in rat; 3,4-dihydro-3,4-dihydroxybenzanthracene in rats: Boyland E, Sims P; Biochem J 97: 7 (1965). /From table/ [Goodwin, B.L. Handbook of Intermediary Metabolism of Aromatic Compounds. New York: Wiley, 1976.,p. B-3].

In normal rat microsomes the 10,11-dihydrodiol is main metab, followed by 5,6- & 8,9-dihydrodiols. Secondary metab, ie, formation of dihydrodiol epoxides, is observed only after 5 min. In contrast, microsomes from 3,3',4,4'-tetrachlorobiphenyl (tcbp) treated rats produce predominately 5,6-dihydrodiol followed by 8,9-dihydrodiol; formation of 10,11-dihydrodiol is suppressed. Metab deriving from oxidn of 5,6-position incr 15-20 fold; again secondary metab occur between 5th & 10th min of incubation. Data suggest the formation of the ultimate carcinogen, 3,4-dihydroxy-1,2-epoxy-1,2,3, 4-tetrahydrobenz(a)anthracene, as concluded from detection of its rearrangement product, the 2,3,4-triol. In polychlorinated biphenyl (pcb) treated rats secondary metab is observed within 2.5 Min. 5,6-Oxidn is incr 27 fold, 8,9-oxidn 10 fold, but 10,11-oxidn is completely suppressed. The above mentioned carcinogen is also formed. [Jacob J et al; Carcinogenesis 2 (5): 395-401 (1981)].

3,4- & 8,9-dihydrodiols are formed as metab of benz(a)anthracene (ba) by rat liver microsomes, by mouse skin & hamster embryo cells. In incubations with rat liver microsomal fractions, only small amt of 3,4-dihydrodiol of ba were detected relative to other dihydrodiol metab & only small amt of ba-deoxyribonucleoside adducts derived from the related diol-epoxide, t-3,r-4-dihydroxy-t-1,2-oxy-1,2,3, 4-tetrahydrobenz(a)anthracene, were detected relative to adducts derived from r-8,t-9-dihydroxy-t-10,11-oxy-8,9, 11-tetrahydrobenz(a)anthracene. In the 2 other systems larger amt of free 3,4-dihydrodiol were detected & larger prop of the hydrocarbon-deoxyribonucleoside adducts resulted from reaction of anti-ba-3,4-diol 1,2 oxide with dna. [Macnicoll AD et al; Cancer lett 11 (3): 243-50 (1981)].

... Metabolism of benz(a)anthracene by human mammary epithelial cell aggregates in culture ... using non-neoplastic tissues obtained from 8 patients undergoing reduction mammoplasty. ... Metabolized to water-soluble and organic solvent soluble products /including/ K- and non-K-region dihydrodiols. The major dihydrodiols detected were 8,9-dihydrodiols. ... Only very low levels of reaction with DNA were detected in tissue preparations treated with benz(a)anthracene. [Grover PL et al; Int J Cancer 26 (4): 467-76 (1980)].

Diol-epoxide derivative of polycyclic aromatic hydrocarbons are the ultimate carcinogenic forms of these compounds encountered in vivo. ... Diol epoxides of benzo(a)anthracene... bind to the DNA helix at an inclination of approximately 50 degrees. This ... may indicate a systematic behavior in the molecular associations precursive to carcinogenesis. [Ridler P, Jennings B; Cancer Lett 22 (1): 95-8 (1984)].

In case of benz(a)anthracene major metabolite at k-region is ... A mercapturic acid, n-acetyl-s-(5, 6-dihydro-6-hydroxy-5-benz(a)anthracenyl)cysteine ... 5,6-Dihydrodiol. [Searle, C. E. (ed.). Chemical Carcinogens. ACS Monograph 173. Washington, DC: American Chemical Society, 1976. 287].

Primary cultures of human and murine (strain C3H/Z) bronchial epithelial cells were pre-treated with benz(a)anthracene (10 muM). The formation of phenolic and dihydrodiol metabolites of benzo(a)pyrene was measured 16 hr later. Murine cultures /exhibited/ metabolism towards formation of both phenolic and dihydrodiol compounds ... human cultures only phenolic BP-metabolites were increased ...reflecting a difference in metabolism in the two test species. [Hukkelhoven MW et al; Toxicol Lett 12 (1): 41-6 (1982)].
7,12-Dimethylbenz(a)anthracene (DMBA) was biosynthesized in vitro from benz(a)anthracene, 7-methylbenz(a)anthracene, and 12-methylbenz(a)anthracene in rat liver cytosol preparations. ... Benz(a)anthracene was metabolized to DMBA. ... The /investigators/ conclude that benz(a)anthracene, 7-methylbenz(a)anthracene, and 12-methylbenz(a)anthracene are bioalkylated in the meso-anthracenic position to yield the potent carcinogen DMBA. [Flesher JW et al; Cancer Letters 24 (3): 335-43 (1984)].

The metabolism of benzo(a)anthracene was compared in fetal Syrian-hamster lung cells in culture, in liver microsomes obtained from untreated rats, dogs, mice, and humans, and in liver microsomes obtained from Wistar rats treated with common monooxygenase inducers, as well as with polycyclic aromatic hydrocarbons (PAHs) such as chrysene, benzo(b)fluoranthene, benzo(j)fluoranthene, and benzo(k)fluoranthene. The oxidation of benzo(a)anthracene by liver microsomes from untreated rats, dogs, mice, and humans resulted exclusively or predominantly in the production of such metabolites as 5,6-dihydrodiol, 8,9-dihydrodiol, and 10,11-dihydrodiol.

... The comparatively rapid conversion of primary benz(a)anthracene metabolites into secondary metabolites should be regarded as an additional factor in the biological activity of benz(a)anthracene. [Grimmer G et al; Polynuclear Aromatic Hydrocarbons: Mechanisms, Methods and Metabolism, Battelle Press p.521-32 (1985)].

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

**W.Lo**w (Water Concentrations Considered Low):

No information found.

**W.Hi**gh (Water Concentrations Considered High):

No information found.

**W.Typ**ical (Water Concentrations Considered Typical):

Water Concentrations [366]:

It has been identified in ... surface water, river water (0.4 to 30.6 ng/l); tap water (0.4 to 10.7 ng/l) rainfall (3.2 to 12.3 ng/l); subterranean water (0 to 1.3 ng/l); /&/ wastewater (0.5 to 4.9 ug/l) ... . [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V32 136 (1983)].

SURFACE WATER: Detected, not quantified in 1 of 204 water samples from 14 heavily industrialized US river basins(2). Surface water from an unspecified source contained 4.3 to 185 ppm(1). Major rivers in Germany 4.3 to 385 parts/trillion(3). [(1) IARC; Monographn Certain Polycyclic Aromatic Hydrocarbons and Heterocyclic Compounds 3: 45-68 (1973) (2) Ewing BB et al; Monitoring to Detect Previously Unrecognized Pollutants in Surface Water p. 75 USEPA 560/6-77-015, USEPA 560/6-77-015a (1977) (3) Verschueren K; Handbook of Environmental Data on Organic Chemicals p. 245 New York, NY Von Nostrand Reinhold Co (1983)].

SEAWATER: Dohkai Bay, Kitakyushu area Japan - detected, not quantified(1,2). [(1) Akiyama T et al; J UOEH 2: 285-300 (1980) (2) Shinohara R et al; Environ Int 4: 163-74 (1980)].
RAIN WATER: Great Lakes ecosystem sampling - range 2.6 to 3.1 parts/trillion, mean 3 parts/trillion(1). Norway - detected, not

quantified in 6 of 24 samples, however it was not separable from chrysene and triphenylene(2). [(1) Eisenreich SJ et al; Environ Sci Technol 15: 30-8 (1981) (2) Lunde G et al; Organic Micropollutants in Precipitation in Norway 17 p SNSF Project, FR-9/76 (1977)].

DRINKING WATER: Benz(a)anthracene has been detected in finished water from 5 water treatment plants in Ontario, Canada at a range of not detected to 2.6 parts/trillion, however, it was not separable from chrysene and triphenylene so these values are upper limits(5). A sample from Ottawa, Canada contained 3.3 parts/trillion benz(a)anthracene(2). 4 of 5 samples of Nordic tap water were pos at 0.12 to 1.5 parts/trillion(3). German drinking water samples ranged from 1 to 23.2 parts/trillion (4,5). In the heavily industrialized area of Kitakyushu, Japan, benz(a)anthracene was not detected in tap water(1). [(1) Akiyama T et al; J UOEH 2: 285-300 (1980) (2) Benoit FM et al; Int J Environ Anal Chem 6: 277-87 (1979) (3) Kveseth K et al; Chemosphere 11: 623-39 (1982) (4) IARC: Monograph Certain Polycyclic Aromatic Hydrocarbons and Heterocyclic Compounds 3: 45-68 (1973) (5) Santodonato J et al; Hazard Profiles on PAH 182 p Syracuse Res Corp, Syracuse NY TR-81-633 (1981)].

Effluent Concentrations [366]:

Several waste water samples contaminated with possible industrial or bituminous waste ranged from 25-10,360 ug/cu m(3). Industries with mean raw waste water concentrations >150 ppb: organic chemicals manufacturing/plastics (880 ppb), foundries and iron and steel manufacturing; industries <100 ppb: photographic equipment/supplies, timber products processing, electrical/electronic components, nonferrous metal manufacturing and coil coating(4). Oslo, Norway - Bikkelaget sewage treatment plant effluent- dry period - 27 and 40 parts/trillion, 1979 and 1980 resp, after rainfall - 58 and 184 parts/trillion, 1979 and 1980 resp(2). Industrial Kitakyushu area, Japan - sewage effluent - 53 ppb(1). Exhaust from 2-cycle diesel engine 2.3-15 ug/cu m(3). Emissions from representative European gasoline engine leaded and unleaded - 7.3 to 32.4 ppb; emissions from asphalt hot mixing plant 5 to 24 ng/cu m; coke oven emissions - 105 to 2740 ppm(5); cigarette smoke 0.3 ug/100 cigarettes(3,5). Domestic effluent - 0.191 to 0.319 ppb(5). Sewage influent from Kitahyushu area Japan - 200 pbb(1). Sewage water from household, trade, road, and industrial sources 31.4

ppb max(3). [(1) Akiyama T et al; J UOEH 2: 285-300 (1980) (2) Kveseth K et al; Chemosphere 11: 623-39 (1982) (3) IARC; Monograph Certain Polycyclic Aromatic Hydrocarbons and Heterocyclic Compounds 3: 45-68 (1973) (4) USEPA; Treatability Manual page I.10.2-1 to I.10.2-5 USEPA 600/2-82-001a (1981) (5) Verschueren K; Handbook of Environmental Data on Organic Chemicals p 245 New York, NY Van Nostrand Reinhold Co (1983)].

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

**W.Gen**eral (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: This is a phototoxic compound (see more detailed discussion in "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:

National 1996 EPA Water Quality Criteria in IRIS database in ug/L [893]:

Freshwater Acute Criteria: None Published [446,893].

Freshwater Chronic Criteria: None Published [446,893].

Marine Acute Criteria: None Published [446,893].

Marine Acute Criteria: 3.0E+2 ug/L is the lowest effect level concentration (LEC) found in the literature [893].

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 1995. IRIS is constantly updated.

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 entry 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."

Benzo(a)anthracene (micrograms per liter, ug/l):

0.49 = Secondary acute value
0.027 = Secondary chronic value
0.65 = Estimated lowest chronic value - daphnid

Canada's Interim Assessment Criterion for benzo(a)anthracene is 0.01 ug/L [656].

NOTE: a) For most of the organic chemical parameters in [656], criteria are based on analytical detection limits; b) criterion is considered "Interim" since complete supporting rationale do not exist.

**W.Pl**ants (Water Concentrations vs. Plants):

No information found.

**W.Inv**ertebrates (Water Concentrations vs. Invertebrates):

LC50 for Daphnia pulex (water flea) was 10 ug/L (ppb) for a 96-hr exposure [998].

Exposure of Daphnia pulex to 5 aromatic hydrocarbons in water determined an increasing toxicity in the order of benzene, naphthalene, phenanthrene, benzo(a)anthracene, to benzo(a)pyrene ... measured by 96-hr median lethal concn values /ranging/ ... from 15 mg/l for benzene to 5 mug/l for benzo(a)pyrene. [Trucco RG et al; Environ Pollut Ser A 31 (3): 191-202 (1983)] [366].

**W.Fi**sh (Water Concentrations vs. Fish):

1.0 ppm of benz(a)anthracene caused 87% mortality in 6 months in bluegill [851].

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

No information found.

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

EPA 1996 IRIS database information [893]:

Human Health [10-6 Risk (E-06) Level* for Carcinogens], concentrations in ug/L:

*IRIS Discussion: 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 [893].

EPA (IRIS) 1996 Ambient Water Quality Criteria for Human Health Considering Both Water & Fish Routes of Exposure: 2.8E-3 ug/liter [893].

Older Reference to Published Criteria for Water and Organisms: 0.0028 [689,928]. Historical (older) EPA value: IRIS Recalculated (7/93) Criteria for Water and Organisms: 0.0044 [689].

Additonal Detail: The levels of polynuclear aromatic hydrocarbons in ambient water which may result in an incremental cancer risk of 1X10-5, 1X10-6, and 1X10-7 over an individual lifetime are estimated to be 28.0 ng/l, 2.8 ng/l, and 0.28 ng/l, respectively (for ingestion of both contaminated water and contaminated aquatic organisms). On the basis of the consumption of aquatic organisms alone, the corresponding levels in ambient water are estimated to be 311.0 ng/l, 31.1 ng/l, and 3.11 ng/l, respectively, based on benzo(a)pyrene as the model PAH /Polynuclear aromatic hydrocarbons/ [USEPA; Ambient Water Quality Criteria Doc: Polynuclear Aromatic Hydrocarbons (Draft) p.C-121 (1980)] [366,869].

The attempt to develop a drinking water criterion for polynuclear aromatic hydrocarbons (PAH) as a class is hindered by several gaps in the scientific data base: (1) The PAH class is composed of numerous compounds having diverse biological effects and varying carcinogenic potential. A "representative" PAH mixture, has not been defined. (2) The common practice of using data derived from studies with benzo(a)pyrene to make generalizations concerning the effects of environmental PAH may not be scientifically sound. (3) No chronic animal toxicity studies involving oral exposure to PAH mixtures exist. (4) No direct human data concerning the effects of exposure to defined PAH mixtures exist. /Polynuclear aromatic hydrocarbons/ [USEPA; Ambient Water Quality Criteria Doc: Polynuclear Aromatic Hydrocarbons (Draft) p.C-118 (1980)] [366].

EPA (IRIS) 1996 Ambient Water Quality Criteria for Human Health Considering Only Fish Route of Exposure: 3.11E-2 ug/liter [893].

Older Reference to Published Criteria for Organisms Only: 0.0311 [689,928]. Older IRIS Recalculated (7/93) Criteria for Organisms Only: 0.049 [689].

Drinking Water MCL: None Published [893,928].

Maximum Contaminant Level Goal (MCLG): Value: 0 mg/L Status/Year: Proposed 1990 Reference: 55 FR 30370 (07/25/90) [893].

Drinking Water Health Advisories: empty [893].

Preliminary remediation goals (PRGs) for Tap Water Published by EPA Region 9 [868]: 9.2E-02 (0.092) ug/L [868].

The warm water- and cold water sport fish community human cancer criteria for B(a)A in Wisconsin public water supplies are each 0.023 mg/L [881].

NOTE: These criteria are applicable to any combination of 10 specific PAHs.

The warm water- and cold water sport fish community human cancer criteria for B(a)A in Wisconsin non-public water supplies are each 0.1 mg/L [881].

NOTE: These criteria are applicable to any combination of 9 specific PAHs.

Numeric Water Quality Criteria in Arizona [881]:

Domestic water source: 0.03 ug/L
Fish consumption: 0.00008 ug/L
Full body contact: 0.12 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

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

This is a phototoxic PAH [891,911,887; 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]. See cautionary note under W.General section above.

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

**Sed.Lo**w (Sediment Concentrations Considered Low):

Freshwater Sediment Concentrations (Dry Weight) not Considered Elevated: Great Lakes Harbors: The control site in one Great Lakes study had a sediment concentration of <0.01 mg/kg [145].

**Sed.Hi**gh (Sediment Concentrations Considered High):

Analyses of sewage sludges from 50 publicly owned treatment works by the U.S. Environmental Protection Agency (1985): The mean concentration of benzo(a)anthracene was 9.1 ppm (dry weight) [347].

**Sed.Typ**ical (Sediment Concentrations Considered Typical):

Benz(a)anthracene was detected in 99.6 % of urban-bay samples from the Puget Sound area. The mean concentration was 1768 ug/kg dry weight (ppb), while the median concentration was 260 ug/kg (ppb) [852].

Benz(a)anthracene was detected in 74 % of non-urban-bay samples from the Puget Sound area. The mean concentration was 2184 ug/kg dry weight (ppb), while the median concentration was 64 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.

Information from HSDB [366]:

> New England area sites - Atlantic Ocean shelf 3.6 to 6.1 ppb, Buzzards Bay, MA - 330 ppb (0.15 mi from shore) and 41 ppb (1.3 mi from shore)(1,2). Duwamish River, Seattle, MA intertidal harbor sediment - 19 to 1800 ppb mean range, subtidal midchannel sediment - 500 to 1,600 ppb mean range(3). Fidalogo IS, March Pt beach, Alaska, near 2 major oil refineries, large wood pulp factory, and a population center of 8,000, 6 samples - 2.2 to 42 ppb, 8.3 ppb median(4). Kitakyshu area, Japan - detected not quantified(5,6). [(1) Santodonato J et al; Health and Ecological Assessment of Polynuclear Aromatic

Hydrocarbons Lee SD, Grant L, eds Park Forest South, IL: Pathotox Pub Inc. p. 364 (1981) (2) Sims RC, Overcash Mr; Res Rev 88: 1-68 (1973) (3) Macleod WD Jr et al; Anal Chem 54: 386-92 (1982) (4) Brown DW et al; Investigation of Petroleum in the Marine Environs of the Straight of Juan de Fuca and Northern Puget Sound 107 p USEPA 600/7-79-164 (1979) (5) Akiyama T et al; UOEH 2: 285-300 (1980) (6) Shinohara R et al; Environ Int 4: 163-74 (1980)].

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

**Sed.Gen**eral (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]:

0.108 mg/kg dry wt. is the estimated equivalent sediment quality criterion at 1% Organic Carbon.

Various Other Concern Levels for Sediment Concentrations (Dry Weight):

EPA 1988: The interim sediment criteria value proposed by EPA was 13.0 mg/kg [145].

AET, EPA 1988: The apparent effects threshold (AET) concentrations for benz(a)anthracene in sediments proposed for Puget Sound ranged from 1.3 mg/kg dry weight (microtox) to 5.1 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 benzo(a)anthracene sorbed to marine sediments is 0.550 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 or total carcinogenic PAH" sums (see "PAHs as a group" entry).

NOAA 1995: 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 1600 ppb dry weight Effects Range-Median (ERM) concentration and was lowest in sediments where its concentration was less than the 261 ppb dry weight Effects Range-Low (ERL) concentration [664] (see entries ERM and ERL). 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 | 21.1 |
| ERL-ERM | 43.8 |
| >ERM | 92.6 |

Ontario Ministry of Environment Freshwater Sediment Guidelines, 1993. Lowest effect level: 320 ug/kg dry weight. Severe effect level: 1,480 mg/kg organic carbon [761].

St. Lawrence River Interim Freshwater Sediment Criteria, 1992. No effect level: 50-100 ug/kg dry weight. Minimal effect level: 400 ug/kg dry weight. Toxic effect level: 50 mg/kg organic carbon [761].

Environment Canada Interim Sediment Quality Assessment Values. Toxic effect level: 31.7 ug/kg dry weight. Probable effect level: 384.7 ug/kg dry weight [761].

**Sed.Pl**ants (Sediment Concentrations vs. Plants):

No information found.

**Sed.Inv**ertebrates (Sediment Concentrations vs. Invertebrates):

No information found.

**Sed.Fi**sh (Sediment Concentrations vs. Fish):

No information found.

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

No information found.

**Sed.Hum**an (Sediment Concentrations vs. Human):

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.Lo**w (Soil Concentrations Considered Low):

Quebec soil contamination indicators that differ from those of the Netherlands (1987): 0.1 ppm of benzo(a)anthracene indicates a background concentration. 1 ppm indicates a moderate level of soil contamination. 10 ppm indicates a threshold value that requires immediate cleanup [347].

**Soil.Hi**gh (Soil Concentrations Considered High):

Quebec soil contamination indicators that differ from those of the Netherlands (1987): 0.1 ppm of benzo(a)anthracene indicates a background concentration. 1 ppm indicates a moderate level of soil contamination. 10 ppm indicates a threshold value that requires immediate cleanup [347].

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 soil concentration of benzo(a)anthracene was 2.0 ppm. The range was 0.22-4.5 ppm (dry weight). The mean concentration of benzo(a)anthracene in the earthworm was

0.25. The range was 0.093-1.7 ppm (ash-free dry weight) [347].

**Soil.Typ**ical (Soil Concentrations Considered Typical):

Information from HSDB [366]:

> Worldwide soil samples ranged from not detected to 560 ppb, while sediment samples (marine and freshwater) were from not detected to 21,000 ppb (benz (A) anthracene was not distinguished from chrysene and triphenylene)(1). It was observed that total concentrations of PAH from the Northeast US were much higher than in other areas(1). Hersey River near Read City, MI, spring fed contamination from the site of a former wood preservation facility where 2 known creosote spills had occurred (15,000 and 18,000 gals), sampling site upstream from entry point - not detected, 8 sampling sites downstream (up to 5 km) - 1,349 ppb (site 2) to 31 ppb (site 8)(2). 2 remote lakes in the Adirondack Park, NY - Woods lake, surface 360 ppb, 80-84 cm depth - 1 ppb, Sagamore Lake, surface 78 ppb, 4-8 cm depth - 89 ppb, 80-84 cm depth - 1 ppb, source primarily produced by anthropogenic combustion of fossil fuels(3). Vincent Landing, Calcasieu River, LA - detected not quantified(4). [(1) Hites RA et al; p. 298-31 in Advances in Chemistry Series 185 Pet Mar Environ (1980) (2) Black JJ; Arch Environ Contam Toxicol 11: 161 (1982) (3)Tan YL, Heit M; Geochim Cosmochim Acta 45: 2267-79 (1981) (4) Steinheimer TR et al; Anal Chim Acta 129: 57-67 (1981)] [366].
>
> Soil around industrial centers - 390 pb, near traffic highways - 1,500 ppb, soil polluted by coal-tar pitch 2,500 ppb, samples from forests, woodlands, and sand in Germany - 5 to 20 ppb(1). Saudafjord, Norway downshore from a ferro alloy smelter, 6 stations - 0-2 cm depth - 2158.9 ppb (site 1) tp 21 ppb (site 6); 6-8 cm depth - 1,516.2 ppb (site 1) to 3.0 ppb (site 6)(2). Wilderness lake - Collin Scott, Ontario - 7 ppb(3). [(1) IARC; Monograph Certain Polycyclic Aromatic Hydrocarbons and Heterocyclic Compounds 3: 45-68 (1973) (2) Bjorseth A et al; Sci Total Environ 13: 71-86 (1979) (3)Verschuern K; Handbook of Environmental Data on Organic Chemicals p. 245 New York, NY Von Nostrand Reinhold Co (1983)] [366].

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

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

Canada's Interim Assessment Criterion for benzo(a)anthracene in soil is 0.1 ug/g dry weight [656].

NOTE: a) "Interim" means complete supporting rationale do not exist; b) for most of the organic parameters in [656], criteria are based on analytical detection limits and are intended to provide general guidance only for the protection of both human and environmental health [656].

Canada's Interim Remediation Criteria for benzo(a)anthracene in soil for three different land-uses (ug/g dry weight) [656]:

Agricultural = 0.1
Residential/Parkland = 1
Commercial/Industrial = 10

NOTE: a) "Interim" means complete supporting rationale do not exist; b) if contaminant concentrations exceed the criterion for a current or anticipated land use at a site, then the need for further investigation and/or remediation exists; c) criteria are relevant to protection of both human and environmental health [656].

Quebec soil contamination indicators that differ from those of the Netherlands (1987): 0.1 ppm of benzo(a)anthracene indicates a background concentration. 1 ppm indicates a moderate level of soil contamination. 10 ppm indicates a threshold value that requires immediate cleanup [347].

**Soil.Pl**ants (Soil Concentrations vs. Plants):

No information found.

**Soil.Inv**ertebrates (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 benzo(a)anthracene was 2.0 ppm in the soil. The range was 0.22-4.5 ppm (dry weight) in the soil. The mean concentration of benzo(a)anthracene in the earthworm was 0.25. The range was 0.093-1.7 ppm (ash-free dry weight) [347].

**Soil.Wild**life (Soil Concentrations vs. Wildlife or Domestic Animals):

No information found.

**Soil.Hum**an (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 = 0.9 mg/kg for ingestion pathway [952].

SSL = 0.08 to 2 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: 0.61 mg/kg wet weight
Industrial Soil: 2.6 mg/kg wet weight

NOTE:

1) Values are based on a one-in-one million cancer risk.

2) 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.

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

EPA Region III RBC to protect from transfers to groundwater:

0.7 mg/Kg dry weight [903].

See also Canada's Interim Criteria in Soil.General section above.

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

No information found.

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

**Tis.Pl**ants:

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:

See Tis.Human, A), below.

**Tis.Inv**ertebrates:

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:

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 soil concentration of benzo(a)anthracene was 2.0 ppm. The range was 0.22-4.5 ppm (dry weight). The mean concentration of benzo(a)anthracene in the earthworm was 0.25. The range was 0.093-1.7 ppm (ash-free dry weight) [347].

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

Fish/Seafood Concentrations [366]:

Coos Bay, OR - 2 sites from a very heavily industrialized area, softshell clams - site 1 (less contaminated) - 2.9 ppb, site 2, 41.7 ppb(5). Yaquena Bay, OR - samples of mussels from near creosote coated piling - 30.9 ppb avg(6). Mussels near the Bekkelaget sewage treatment plant, Oslo Fjord, Norway contained 13.25 ppb avg(4). Mussels taken from a site adjacent to a smelter in the Saudafjord, Norway contained 25, 264 ppb, 10 km distance - 225 ppb, while a second species at this 10 km site contained 1398 ppb(1). 57 samples of mussels from the Thermaikos Gulf, Greece - 3 ppb(2). Mussels from 9 representative areas in Norway - 19 ppb min, and 159 ppb max, all samples pos; other representative marine invertebrates in this same study had a range of 1 to 229 ppb(3). [(1) Bjorseth A et al; Sci Total Environ 13: 71-86 (1979) (2) Iosifidou HG et al; Bull Environ Contam Toxicol 28: 535 (1982) (3) Knutzen J, Sortland B; Water Res 16: 421-8 (1982) (4) Kveseth K et al; Chemosphere 11: 623-39 (1982) (5) Mix MC, Schaffer RL; Marine Pollut Bull 14: 94-7 (1983) (6) Mix MC, Schaffer RL; Mar Environ Res 9: 193-210 (1983)].

**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:

Details of benzo(a)anthracene content (mg/kg or ppm) in salmon carcass (fatty viscera removed, so the concentrations may have been higher from whole body samples) from Snug Harbor, Alaska, an area heavily oiled by the Exxon Valdez Crude Oil, 4/15/89 [971]:

Note: Concurrent measurements of water quality, as well as equilibrium partitioning estimates of water quality based on concentrations in fish and mussels, both confirm that PAH concentrations did not exceed water quality criteria at the time these concentrations were measured in fish tissues [971]. These values are wet weight (Jerry Neff, Battelle Ocean Sciences, Duxbury, MA, personal communication 1996):

benzo(a)anthracene: 0.72 ug/kg = ppb

**Tis.Wild**life: 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):

No information found.

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

No information found.

**Tis.Hum**an:

A) Typical Concentrations in Human Food Survey Items:

See also Tis.Invertebrates, C), above:

Food Survey Results [366]:

UK total diet sample (from 5 geographically diverse areas of the UK) 0.22 ug/person-day (cereal 38%, meat 4%, fish 1%, oils/fats 34%, fruit/sugar 9%, root vegetables 4%, other vegetables 8%, beverages 0%, milk 2%)(5). Benz(a)anthracene has been detected in many foodstuffs, especially cooked or smoked meats and fish (0.4 ppb to 33 ppb)(1-4,6-12) and vegetable oils (including mayonnaise and margarine) (up to 29.5 ppb)(1-4). One study found charcoal broiled bacon to contain 189 ppb(2). On the average, charcoal broiled meats were more contaminated than smoked meats (50 and 20 ppb, respectively)(1). Roasted coffee contained up to 14.2 ppb(1,2), malt coffee 43 ppb(2), and coffee soots 16-150 ppb(1). Salads had a range of 4.6 to 15.4 ppb, and cereals - 0.4 to 6.8 ppb(1,2). Baker's yeast was found to contain up to 203 ppb(2,3). Roasted peanuts contained 0.95 ppb and whiskey ranged from 0.046 to 0.08 ppb(2). Canned unsmoked oysters - 15 to 30 ppb, smoked - 30 ppb(1). Various species of smoked fish may contain up to 2.8 ppb(1,2,4). At the high end of the spectrum, traditionally smoked Nigerian fish ranged from 8.28 to 58.4 ppb, while traditionally solar dried was much less, 0.04 to 1.52 ppb(13). [(1) Fazio T, Howard JW; p 461-505 in Handbook of Polycyclic Aromatic Hydrocarbons Bjorseth A ed New York NY Marcel Dekker Inc (1983) (2) IARC; Monograph Certain Polycyclic Aromatic Hydrocarbons and Heterocyclic Compounds 3: 45-68 (1973) (3) Santodonato J et al; Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons Lee SD, Grant L eds Park Forest South, IL: Pathotox Pub Inc p 364 (1981) (4) Santodonato J et al; Hazard Profiles on PAH p 19-27 Syracuse Res Corp Syracuse, NY TR-81-633 (1981) (5) Dennis MJ et al; Food Chem Toxic 21: 569-74 (1983) (6) Masuda Y, Kuratsune M; Katsuobuski Gann 62: 27 (1971) (7) Howard JW et al; J Assoc Off Anal Chem 49: 595 (1966) (8) Lijinsky W, Shubik P; Toxicol Appl Pharm 7: 337 (1965) (9) Malanoski AJ et al; J Assoc Off Anal Chem 51: 144 (1968) (10) Thorsteinsson T; Cancer 23: 455 (1969) (11) Frethein K; J Agric Food Chem 24: 976 (1976) (12) Lo M, Sandi E; Res Rev 69: 35-86 (1978) (13) Afolabi OA et al; J Agric Food Chem 31: 1083-90 (1983)].

Plant Concentrations [366]:

Spinach - 16 ppb, Kale - 43 to 230 ppb(1,2). Tomatoes - 0.3 ppb(2). Various species of marine algae from Norwegian waters - 0 to 73 ppb(3). Leaves of 5 plants 12-60 ppb(4). Leaves of plants which vary from 12-26 ppb when green increases to 44-166 ppb when yellow(4). Atmospheric deposition has been suggested as a source rather than uptake from polluted soils(4). [(1) Fazio T, Howard JW; p 461-505 in Handbook of Polycyclic Aromatic Hydrocarbons. Bjorseth A ed New York NY Marcel

Dekker Inc (1983) (2) IARC; Monograph Certain Polycyclic Aromatic Hydrocarbons and Heterocyclic Compounds 3: 45-68 (1973) (3) Knutzen J, Sortland B; Water Res 16: 421-8 (1982) (4) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983)].

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), rounded to two significant figures [903]: 0.0043 mg/Kg wet weight.

The oral cancer slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per mg/kg/day: slope factor for this compound is 0.73 mg/kd-d [868].

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

Benzo(a)anthracene was analyzed in blood serum & skin oil collected from roofing workers. Although range of 0.05 To 36 ng was observed in skin oil samples, none was detected in serum, at detection limits of 1.0 To 175 pg/ml. [WOLFF MS ET AL; CHEMOSPHERE 11 (6): 595-600 (1982)] [366].

Benzo(a)pyrene and benz(a)anthracene levels were 0.528 and 0.546 mug/l respectively in the urine in 451 and 437 samples collected in the northwest of the Ruhr area, whereas 35 and 34 urine samples collected in an uncontaminated area contained 0.395 and 0.416 mug/l of benzo(a)pyrene and benz(a)anthracene. Smoking did not affect the urinary ... levels. [Michels S, Einbrodt HJ; Wiss Umwelt 3: 107-12 (1979)] [366].

**Tis.Misc.** (Other Tissue Information):

This is a phototoxic PAH [891,911,887; 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]. See cautionary note under W.General section above.

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

Half-life for depuration by oysters: 9 days [848].

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 soil concentration of benzo(a)anthracene was 2.0 ppm. The range was 0.22-4.5 ppm (dry weight). The mean concentration of benzo(a)anthracene in the earthworm was 0.25. The range was 0.093-1.7 ppm (ash-free dry weight) [347].

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).

PAHs are degraded fairly quickly in many vertebrates, less quickly and in a different way in some other life forms; however, the breakdown products of many PAHs are more hazardous than the parent compound (see "PAHs as a group" entry).

Bioconcentration [366]:

> No data could be found concerning the bioconcentration of benz(a)anthracene in fish. However, the log of the bioconcentration factor is 4.0 in daphnia(1) and 3.03 in oysters(2). It is also strongly adsorbed by bacteria(3). Based on its octanol/water partition coefficient (log KOW= 5.61(3)), one calculates a log BCF of 4.04(4,SRC). [(1) Southworth GR et al; Water Res 12: 973-7 (1978) (2) Le RF; p 60-70 in Fate and Effects of Petroleum Hydrocarbons in Marine Organisms and Ecosystems Wolfe DA ed Vol 6 (1977) (3) Baughman GL, Paris DF; CRC Crit Rev Microbiol 8: 205-28 (1981) (4) Lyman WJ et al; Handbook of property estimation methods Environmental behavior of organic chemicals p 5-1 to 5-30 New York NY McGraw-Hill Co (1982)].

**Int**eractions:

Interactions [366]:

> Ip admin of 40 mg/kg BA to Wistar rats can reduce the potency of synthetic estrogen triphenylethylene, presumably as a result of BA hydroxylase induction. [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V32 137

(1983)].

... Benzanthracene causes incr in cytochrome content ... Incr is prevented by inhibitors of protein synthesis such as actinomycin D & puromycin. [Testa, B. and P. Jenner. Drug Metabolism: Chemical & Biochemical Aspects. New York: Marcel Dekker, Inc., 1976. 336].

Human mitogen-stimulated lymphocytes, cultured in the presence of amosite asbestos (AS), demonstrated a slight increase in aryl hydrocarbon hydroxylase activity compared with non- induced (control) cultures ($p = 0.005$). A much greater increase in enzyme activity occurred following addition of the inducers benzanthracene (BA) or cigarette tars (CT) (potential carcinogens) to cell cultures ($p < 0.001$ in both instances). Significant enzyme induction also occurred when AS fibers were first preincubated with CT or BA, washed with acetone, then added to lymphocyte cultures ($p < 0.003$ in all instances). This increased in AHH activity was not as great as the induction observed when BA or CT was added to cell cultures. No further increase in enzyme activity was noted when AS and CT or AS and BA were simultaneously added to cultured lymphocytes ($p > 0.070$ in all instances). Polycyclic aromatic hydrocarbons (PAH), such as BA and other components of CT, are apparently absorbed and transported by amosite AS particles. These AS-PAH, such as BA and other components of CT, are apparently adsorbed and transported by amosite AS particles. These AS-PAH complexes are capable of inducing AHH in cultured human lymphocytes. [McLemore TL et al; Cancer Lett 7 (2-3): 171-7 (1979)].

The affects of benz(a)anthracene (BA) on the metabolic activation of benzo(a)pyrene (BaP) were studied in-vitro. 12 or 13 day Syrian-hamster embryo (SHE) cultures were incubated for 24 hours with BaP, or BaP plus BA. In the combined exposures, the dose ratios of BA to BaP were 2 to 1 or 4 to 1. The cultures were assayed for cytotoxicity and induction of 6-thioguanine resistant mutants by V79 cells. BA reduced the toxicity of BaP and the number of BaP induced mutants. ... /Coadministration of/ BA with BaP decreases the metabolism and metabolic activation of BaP. Competition of BA with BaP for mixed function oxidases appears to be the major effect rather than induction of mixed function oxidase activity by BA. [Smolarek TA et al; Cancer Letters 30 (3): 243-49 (1986)].

The ability of polycyclic aromatic hydrocarbons and glucocorticoids to regulate monooxygenase activity of human fetal liver has been studied using hepatocytes prepared by collagenase digestion of liver samples from human abortuses of 13 to 19 weeks of gestational age, and maintained in primary monolayer culture for periods up to 5 days. Addition of 1,2-benzanthracene to the cells caused and increase in monooxygenase activity (3-hydroxylation of benzo(a)pyrene and O-deethylation of 7-ethoxycoumarin) in a time and concentration dependent fashion. ... Results are suggestive that glucocorticoids, which are produced by the fetal adrenal and have an important role in the regulation of fetal development, act synergistically with polycyclic aromatic hydrocarbons to induce the activity of liver monooxygenases in the human fetus. [Mathis JM et al; Arch Biochem Biophys 244 (2): 650-61 (1986)].

Phenobarbital was toxic to actively dividing rat liver fibroblasts within the concentration range of 0.1-10 mM but was toxic to nondividing rat hepatocytes only at > 2 mM. ... Cytotoxicity coincided with a decline in the phenobarbital-mediated inducibility of the microsomal monooxygenase system. Benz(a)anthracene induction of the microsomal monooxygenase system was not cytotoxic to either cell type at maximal inducing concentration. Exposure of the cells to a mixture of phenobarbital plus benz(a)anthracene at maximum inducing concentrations produced synergistic toxicity to the fibroblasts ... possibly /from/ phenobarbital-mediated induction of benz(a)anthracene reactive metabolite formation. [Fry JR, Bridges JW; Toxicol Lett 4 (4): 295-301 (1979)].

The percent of lymphoblasts was higher in benz(a)anthracene-treated cultures of peripheral blood mononuclear cells than in control cultures. In mitogen-treated cultures with higher levels of blast cells, benz(a)anthracene treatment decreased the number of blast cells. Aminophylline (0.7 muM)-treated cultures had lower numbers of blast cells and of total viable cells; benz(a)anthracene counteracted this effect. Aminophylline decreased the incorporation of thymidine into control and benz(a)anthracene (2mM)-treated cells. [Pawlak AL et al; Extrahepatic Drug Metb Chem Carcinog Proc Int Meet p. 615-16 (1983)].

Single injection of 5 mg BA in tricaprylin induced sarcomas in 8 of 50 c57bl mice. ... Simultaneous admin of 5 mg benz(a)anthracene & 20 mg dibenz(a,h)anthracene resulted in inhibition of tumor yield to about half the sum of individual tumor yields. [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V3 54 (1973)].

Benz(a)anthracene is a complete carcinogen for the mouse skin. The fact that the tumor yield was higher when using dodecane soln than with toluene is related to the co-carcinogenic effect of dodecane. [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V3 57 (1973)].

**Us**es/Sources:

Grimmer et al. reported concentrations of dibenz(a,c)-anthracene, 4-methylpyrene, fluoranthene, benz(a)anthracene, benzo(e)pyrene, benzo(g,h,i)perylene, and benzo(a)pyrene, respectively, 36, 49, 253, 720, 1,112, 4,770, and 7,226 times higher in "used" compared to "fresh" oil [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].

See Chem.Detail section below for benz(a)anthracene concentrations in various petroleum products.

Natural Occurring Sources [366]:

Occurs naturally in coal tar and is formed from incomplete combustion of organic material [SRI].

Since benz(a)anthracene is a product of combustion, there will be natural sources arising from volcanos, forest fires, etc.(SRC) .

Benz(a)anthracene occurs in crude oil & coal tar ... . [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. 3355].

Artificial Sources [366]:

Benz(a)anthracene (BA) is ubiquitous in the environment with typical sources being engine exhaust, cigarette smoke, coal-tar pitch, coke oven emissions, and soot and smoke of industrial and domestic origin(1,2). BA is a universal product of combustion of organic matter whose production is favored by oxygen-deficient flames, temperatures in the range of 650-900 deg C and fuels which are not highly oxidized(3). [(1) Smith JH et al; Environmental pathways of selected chemicals in freshwater systems Part II Laboratory studies. p 39 USEPA 600/7-78-074 (1978) (2) Verschueren K; Handbook of environmental data on organic chemicals. p 245-6 New York NY Van Nostrand Reinhold (1983) (3) Baum EJ; Occurrence and Surveillance of Polycyclic Aromatic Hydrocarbons. p 4581 in Polycyclic Hydrocarbons and Cancer Vol 1 Academic

Press (1978)].

Benz(a)anthracene occurs ubiquitously in products of incomplete combustion ... It has been identified in mainstream cigarette smoke (2.6 ug/100 cigarettes ... & 3.9 to 9.4 ug/1000 cigarettes); cigar smoke (2.5 to 3.9 ug/cigar); mainstream smoke of marijuana cigarettes (3.3 ug/100 cigarettes) ... exhaust emissions from gasoline engines (50-83 ug/l fuel); emissions from burnt coals (0.04 to 9.4 mg/kg); charcoal-broiled steaks (4.5 ug/kg); different broiled & smoked foods (up to 189 ug/kg); as well as fresh foods (up to 230 ug/kg); edible oils (0.1 to 98.3 ug/kg) ... rainfall (3.2 to 12.3 ng/l) ... waste water (0.5 to 4.9 ug/l); sludge 9230-1760 ug/kg); freeze dried sewage sludge (0.62 to 19 mg/kg); & crude oils (1 to 6.7 mg/kg). [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V32 136 (1983)].

... Pyrolysis product in tobacco smoke at 6.0-8.0 Ug/100 cigarettes, & in coal-derived products. It is generated in gasoline engine & emitted in exhaust gas at 17.3 Ug/min from gasoline & up to 56.3 Ug/min from other petroleum products. ... Common foods have analytically been determined to contain from 0.20-189 Ppb. [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. 3355].

Emissions from asphalt hot-mixing plant: 5 to 24 ng/cu m; (in high volume particulate matter): avg 11 ng/cu m. [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 245] Detected in soot from gasoline, diesel fuel and in the atmosphere(1). [(1) Syracuse Research Corp; Literature Review and Evaluation of the Health Effects Associated with Diesel Exhaust Emissions. Syracuse, NY p 39-56 Contract 68-02-2800 (1978)] [366].

**Fo**rms/Preparations/Formulations:

No information found.

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

Information from ATSDR [869]:

Solubility in water: virtually insoluble (9 to 14 ug/L at 25 C)

Solubility in organic solvents: slightly soluble in acetic acid and hot ethanol; soluble in acetone and diethyl ether; very soluble in benzene.

Solubility in biological fluids: unknown

Vapor pressure:

2.2x10(-8) mm Hg (20 C)
1.5x10(-8) kPa (25 C) [754].

Partition coefficients:

Octanol-water (Kow): 4.1x10(5)
Log Kow: 5.61
Log Kow: 5.91 [852].
Soil-organic carbon-water (Koc): 2x10(5)
Sorption partition coefficient (log Koc): 6.30 (sediments average) [848].

Henry's law constant:

1x10(-6)
0.1013 Pa m(3)/mol (20 C) [848].

Molecular weight: 228.29 g/mol

Color: colorless

Odor: unknown

Melting point: 162 C

Boiling point: 435 C; sublimes

Density: 1.274 (20 C)

Concentrations of Benz(a)anthracene in South Louisiana crude, Kuwait crude, No. 2 fuel oil, and Bunker C residual were 1.7, 2.3, 1.2, and 90 mg/kg (ppm), respectively [177]. Another study showed concentrations of benz(a)anthracene in South Louisiana crude and Kuwait crude were 3.1 and 2.3 10(-6)g/g oil (ppm), respectively [747].

Benz(a)anthracene content (mg/kg or ppm) in one fresh sample of Exxon Valdez Crude Oil [971]: 2 mg/kg = ppm

Benzo(a)anthracene content in one fresh sample of NSFO (Fuel Oil 5, Chuck Rafkind, National Park Service, Personal Communication, 1996): 41.1 ng/mg or ppm.

Benzo(a)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): 1053.5 ng/L or ppt

NOTE: the above two PAH concentrations 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).

Benz(a)anthracene concentration in Used Engine Oil: 38.0 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].

Benz(a)anthracene is found in gasoline at concentrations of 0.04 mg/L to 0.272 mg/L [870].

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

In general, volatilization half-lives from water surfaces are longer than 100 h for high-molecular-weight PAHs such as benz(a)anthracene. However, these numbers may vary depending upon surface wind velocity and turbulence [754,788].

Half-life in surface water is reported to be 1-3 hours, based on estimated photolysis half-life in water [848].

Half-life in groundwater is 4,896 to 32,640 hours [870].

Sorption of PAHs to soil and sediments increases with increasing organic carbon content and is also directly dependent on particle size. One researcher found about 2 times more benz(a)anthracene was retained by marsh sediment than by sand [788].

One study found a half-life for benz(a)anthracene of 290 days in sediment from an oil-contaminated stream but a half-life 10 to 400 times as long in an uncontaminated stream [849]. Another study reported a half-life of 9 days in stream sediment near the outfall of a coal-coking operation but no degradation in the stream water [849].

Half-lives in soil have been reported to be 4 to 2650 days; 240 days for 5 mg/kg treatment; and 130 days for 50 mg/kg treatment [848]. Another source reports half-life in soil to be 2448 to 16,320 hours [870].

One source reported that 90% of an application of B(a)A to a terrestrial environment remained after 11 months of incubation with bacteria. This would correspond to a half-life of approximately 2200 days for B(a)A based on first-order degradation. Another source estimated that the half-life of B(a)A in terrestrial environments is 430 days [866].

Environmental Fate [366]:

> TERRESTRIAL FATE: When benz(a)anthracene is spilled on soil it will remain in the surface layers since it is strongly adsorbed. Although benz(a)anthracene in the free state will photolyze when exposed to the sun, there

is no evidence that the adsorbed molecules photodegrade. Biodegradation will occur very slowly, having a half-life of close to a year in previous spill sites and much longer otherwise.(SRC) .

AQUATIC FATE: When benz(a)anthracene is released into water it will rapidly sorb to the sediment and particulate matter in the water column including phytoplankton and zooplankton. Therefore, high initial concentrations are rapidly reduced (few hours). However low concentrations caused by desorption can last almost indefinitely(1). The dissolved benz(a)anthracene will undergo photolysis (half-life hours to a few days) and in eutrophic bodies of water, oxidation by alkylperoxy radicals may be important. The relative contribution of sorption and photolysis to benz(a)anthracene removal will depend on the type of aquatic system(4). Biodegradation will be unimportant except in the sediment in which the half-life may be somewhat under a year if acclimated colonies of microorganisms exist from previous spills. In a microcosm experiment which simulated shallow coastal waters of the northeast US, 29% of the benzo(a)anthracene had respired to CO2 while 21% was unchanged(2). When a crude oil dispersion was placed on top of a water column in a controlled ecosystem enclosure in Saanich Inlet, Canada, the benz(a)anthracene concentration in the water column decreased exponentially, declining to half its initial concentration in 4-5 days(3). Benz(a)anthracene will bioconcentrate in aquatic organisms.(SRC) [(1) Smith JH et al; Environmental Pathways of Selected Chemicals in Freshwater Systems Part II Laboratory Studies p 39-63 USEPA 600/7-78-074 (1978) (2) Hinga KR et al; Environ Sci Technol 14: 1136-43 (1980) (3) Lee RF et al; Environ Sci Technol 12: 832-8 (1978) (4) Herbes SE et al; p 113-28 in The Scientific Basis of Toxicity Assessment Witschi H ed Elsevier/North Holland Biomed Press (1980)].

ATMOSPHERIC FATE: Benzo(a)anthracene (BA) is found in the atmosphere both as the free vapor and adsorbed to particulate matter. Polyaromatic hydrocarbons are found concentrated in submicron particles and aerosols. These particles will be transported but are subject to gravitational settling and scavenging by rain and snow. The estimated half-lives of these particles in the atmosphere has been estimated to be 5-30 days during which time they can be transported to remote regions(1,2). Although BA will be subject to photolysis and photooxidation, no studies could be found in the literature dealing with its photolysis or photooxidation in the free vapor phase or when adsorbed to small particles.(SRC) [(1) Baum EJ; Occurrence and Surveillance of Polycyclic Aromatic Hydrocarbons p 45-70 in Polycyclic Hydrocarbons and Cancer Vol 1 Geboin HV, Tsu POP eds Academic Press (1978) (2) Lunde G, Bjorseth A; Nature 268: 518-9 (1977)].

Biodegradation [366]:

There is evidence that bacteria and fungi exist in the environment that degrade benzo(a)anthracene (BA)(1-3,11). Several workers have studied the degradation in sediment which has been contaminated with petroleum products. In one such study 1.4-1.8% degradation was observed per week in a seawater-sediment slurry which indicates a half-life of 199-252 days(4,5). Another study found a half-life of 290 days in sediment from an oil-contaminated stream but a half-life 10 to 400 times as long in an uncontaminated stream(8). Microbial degradation is faster in the upper layers of sediment(4). Another investigator reported a much faster half-life, 9 days in stream sediment near the outfall of a coal-coking operation but no degradation in the stream water(6). Another study reported no degradation of BA in an estuarine stream(7). In some situations, degradation is limited by lack of nutrients in the water(9,10). [(1) Gibson DT et al; Science 189: 295-7 (1975) (2) Groenewegen D, Stolp H; Zentrabl Bakteriol Parasitenkd Infektionskr Hyg Abt 1: Orig Reihe B 162: 225-32 (1976) (3) Cerniglia CE et al; Bot Mar 23: 121-4 (1980) (4) Gardiner WS et al; Water Air Soil Poll 11: 339-47 (1979) (5) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (6) Herbes SE; Appl Environ Microbiol 41: 20-8 (1981) (7) Lee RF; 1977 Oil Spill Conf Proc Amer Petrol Inst p 611 (1977) (8) Herbes SE, Schwall LR; Appl Environ Microbiol 35: 306-16 (1978) (9) Roubal G, Atlas RM; Appl Environ Microbiol 35: 897-905 (1978) (10) Roubal GE, Allas RM; Dev Indust Microbiol 20: 497-502 (1979) (11) Walker JD, Colwell RR; Prog Water Technol 7: 783-91 (1975)].

Prudhoe crude oil enriched with polycyclic aromatic hydrocarbons (pah) was added as dispersion to controlled ecosystem enclosures suspended in saanich inlet, canada. Concn of various pah were determined in water, zooplankton, oysters & bottom sediments. Initial concn of benz(a)anthracene, benzo(a)pyrene, & fluoranthene ranged from 1-6 mug/l. Concn decr at an exponential rate due to ... Microbial degradation & sedimentation. [Lee RF et al; Environ sci technol 12 (7): 832-8 (1978)].

Abiotic Degradation [366]:

Benz(a)anthracene (BA) absorbs light to beyond 480 nm and photolyzes in sunlight(1). The photolysis half-life in water measured in early March at 40 N latitude is 5 hours(1). Based on seasonal variations in solar irradiances, the half-life would be 2.9 and 7.8 hr in summer and winter, respectively(1,SRC). Another investigator estimates that midsummer photolysis rate to be 0.6 hr(2). The photolysis rate is reduced in humic waters due to light screening and quenching(1). Photolysis is also inhibited in anaerobic waters(1). 7,12-benzanthracene quinone and 2 unidentified products were observed in aerobic waters(1). When modeled for various environmental systems, the photolysis half-life was 10 hr for an oligotrophic lake, 20 hr for a stream and 50 hr for a eutrophic pond or lake(3). Although the rate of loss due to oxidation by peroxyl radicals is about four times slower than for photolysis, this process is dominant in a eutrophic lake or pond (half-life 38 hr)(1). In an experiment in which crude oil was added to a large salt-water tank with simulated natural conditions, 55% of the benz(a)anthracene photodecomposed in 5 hr and 100% photodecomposed in 10 hr(4). [(1) Mill T et al; Chemosphere 10: 1281-90 (1981) (2) Herbes SE et al; p 113-28 in Scientific Basis of Toxicity Assessment. Witschi H ed Elsevier/North Holland Biomed Press (1980) (3) Smith JH et al; Environmental pathways of selected chemicals in freshwater systems Part II Laboratory studies p 39-63 USEPA 600/7-78-074 (1978) (4) Nagata S, Kondo G; 1977 Oil Spill Conf Proc Amer Petrol Inst p 617 (1977)].

Prudhoe crude oil enriched with polycyclic aromatic hydrocarbons (pah) was added as dispersion to controlled ecosystem enclosures suspended in Saanich Inlet, Canada. Concn of various pah were determined in water, zooplankton, oysters & bottom sediments. Initial concn of benz(a)anthracene benzo(a)pyrene & fluoranthene ranged from 1-6 mug/l. Concn decr at an exponential rate due to evaporation, photochemical oxidn ... . [Lee RF et al; Environ sci technol 12 (7): 832-8 (1978)]

Soil Adsorption/Mobility [366]:

Benz(a)anthracene is strongly adsorbed to sediment with a KOC of .55 x 10+6 - 1.87 x 10+6 in 3 sediments(1). 19-60% of the chemical in water and wastewater samples was associated with particulate matter(2,5). 39% of the benz(a)anthracene added to the water column of a controlled ecosystem was recovered in the sediment a week later(4). In a modeling study, 55, 71 and 88% of the benz(a)anthracene was predicted to be sorbed in a lake, stream, and eutrophic pond respectively(1). Benz(a)anthracene which adsorbed to sediments in a microcosm was mostly (40-60%) found in surface sections to 4-5 cm below the surface(6). In atmospheric samples, benz(a)anthracene is found adsorbed to particulate matter and in the vapor phase(3). [(1) Smith JH et al; Environmental Pathways of Selected Chemicals in the Aquatic Environment. Part II Laboratory studies p 39-63 USEPA 600/7-78-074 (1978) (2) Herbes SE et al; p 113-28 in The Scientific Basis of Toxicity Assessment Witschi H ed Elsevier/North Holland Biodmed Press (1980) (3) Yamasaki H et al; Environ Sci Technol 16: 189-94 (1982) (4) Lee RF et al; Environ Sci Technol 12: 832-8 (1978) (5) Lee RF; 1977 Oil Spill Conf Proc Amer Petrol Inst p 611 (1977) (6) Hinga KR et al; Environ Sci Technol 14: 1136-43 (1980)].

Volatilization from Water/Soil:

The half-life for the volatilization of benz(a)anthracene from a body of water 1 m deep and with a 3 m/sec wind speed and 1 m/sec current is about 8 days with wind being the more important factor in volatilization than current(1). The loss by volatilization predicted from a modeling study was 41 days(2). [(1) Southworth GR; Bull Environ Contam Toxicol 21: 507-14 (1979) (2) Smith JH et al; Environmental Pathways of Selected Chemicals in Freshwater Systems. Part II Laboratory Studies p 39-63 USEPA 600/7-78-074 (1978)] [366].

The half-life for the volatilization of benz(a)anthracene from a river 1 m deep with a water velocity of 0.5 m/sec and a wind velocity of 1 m/sec was 500 hours [848].

Absorption, Distribution and Excretion [366]:

Premolt shrimp accumulated less benz(a)anthracene (ba) & benzo(a)pyrene (bp) than intermolt shrimp. Newly molted shrimp accumulated more ba than intermolt shrimp. Intermolt shrimp accumulated ba to a greater extent than bp at the amt admin. The accumulation of ba in tissues exam was in following order: digestive tract (stomach + intestine) greater than hepatopancreas greater than cephalothorax greater than abdomen. When exposed to media containing 2.5 Ppb bp or 2.8 Ppb ba, a rapid uptake by shrimp was noted during 1st 6 hr of exposure. However, at termination of 96-hr exposure, shrimp exhibited a trend of continual accumulation of ba & bp. When transferred to seawater, shrimp appeared to depurate ba & bp rapidly. Level of ba declined by 80% after a 7-day depuration. [Fox FR, Rao KR;USEPA, off res dev, (rep) epa; epa-600/9-82-013, symp: Carcinogen polynucl aromat hydrocarbons mar environ 336-49 (1982)].

Benz(a)anthracene undergoes intestinal transport by passive diffusion. [Rees EO et al; Biochem Biophys Acta 225: 96 (1971)].

... Benz(a)anthracene was not detected in /human/ liver, but was present in fatty tissues. [Obana H et al; Bull Environ Contam Toxicol 27 (1): 23-7 (1981)].

The time for uptake and metabolism of benz(a)anthracene is approximately 24 hours in Daphnia pulex. [Southworth GR et al; Water Res 12: 973 (1978)].

**Lab**oratory 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 (see Chem.Detail section in separate PAHs entry for more details).

In a similar vein, if the Park Service sediment investigation at Petersburg National Historical Battlefield (see Chem.Detail section in separate 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. In fact, as mentioned in the disclaimer (above) 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].

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).