# ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA

# CHRYSENE ENTRY

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

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

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

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

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

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

For some categories, the editors found no information and inserted the phrase "no information found." This does not necessarily mean that no information exists; it

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

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

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

The following is one 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).

Chrysene (CAS number 218-01-9)

**Br**ief Introduction:

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

Chrysene is a high molecular weight, 5-ring PAH and an EPA Priority Pollutant [697,634].

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. Chrysene is also found in creosote [871].

Of all estimated environmental releases of chrysene, 93% are to air. Of the remaining 7%, approximately equal amounts of chrysene are released to water and land [869].

At this time (1990), chrysene has been found at 62 out of 1177 sites on the National Priorities List (NPL) of hazardous waste sites in the United States [871].

Chrysene is included on the expanded scan of PAHs and alkyl PAHs recommended by NOAA [828]; this list includes the PAHs recommended by the NOAA's National Status and Trends program [680].

Chrysene was one of the PAHs found by NASA in 1996 on a rock alleged to be a meteorite from mars (see Uses/Sources section below for details).

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

This compound often occurs together with other aromatics (sometimes including alkyl PAHs), and a typical complex mixture of aromatics may be more toxic or hazardous in general than this compound would be alone (see "PAHs as a group" entry). This PAH is phototoxic, and has very stringent (low concentration) criteria in water and other media (see details in sections below).

The heavier (4-, 5-, and 6-ring) PAHs, like this one, 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 chrysene 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 chrysene alone, but to a mixture of similar chemicals [871].

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

According to one source, no information has been found about specific levels of chrysene that have caused harmful effects in people after breathing, swallowing, or touching the substance [871].

According to one source, pertinent data regarding lethality and decreased longevity in humans or experimental animals following inhalation, oral, or dermal exposure to chrysene could not be located in the available literature [871].

Also according to the same source, no information is available on the systemic effects of chrysene in humans or experimental animals following inhalation, oral, and dermal exposures [871].

Additional human health issues related to this topic have been summarized by ATSDR [871].

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

EPA 1996 IRIS Human carcinogenicity weight-of-evidence classification:

Classification: B2; probable human carcinogen

BASIS: No human data and sufficient data from animal bioassays. Chrysene produced carcinomas and malignant lymphoma in mice after

intraperitoneal injection and skin carcinomas in mice following dermal exposure. Chrysene produced chromosomal abnormalities in hamsters and mouse germ cells after gavage exposure, positive responses in bacterial gene mutation assays and transformed mammalian cells exposed in culture.

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

The debates on exactly how to perform both ecological and human risk assessments on the complex mixtures of PAHs typically found at contaminated sites, are likely to continue. There are some clearly wrong ways to go about it, but defining clearly right ways is more difficult. PAHs such as this one usually occur in complex mixtures rather than alone. Perhaps the most unambiguous thing that can be said about complex PAH mixtures is that such mixtures are often hazardous in many ways, including carcinogenicity and phototoxicity. (James Huckins, National Biological Survey/USGS, and Roy Irwin, National Park Service, personal communication, 1996).

The International Agency for Research on Cancer (IARC) has determined that chrysene is not classifiable as to its carcinogenicity to humans [788]. Recent (1994) EPA weight-of-evidence evaluations have determined that chrysene is a probable human carcinogen [881].

IARC Summary and Evaluation [366,847]:

> No data are available in humans. Limited evidence of carcinogenicity in animals. Overall evaluation: Group 3.

This is a phototoxic PAH [887; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 6, Newstead, J.L. and J.P. Geisy. Predictive models for photoinduced acute toxicity of polycyclic aromatic hydrocarbons to Daphnia magna. Copyright 1987 SETAC]. Although not definitive, phototoxicity represents one clue suggesting possible carcinogenicity.

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

According to ATSDR, pertinent data regarding the reproductive and developmental toxicity of chrysene in humans or experimental animals following inhalation, oral, or dermal exposure could not be located in the available literature [871].

The genotoxicity of chrysene is supported by positive results in both reverse and forward bacterial mutation studies, one human epithelial mutation study, one SHE cell transformation study, and two in vivo cytogenetic studies. Chrysene is not genotoxic in all test systems. Generally, the results with chrysene have been either weakly positive or negative [871].

However, one the reasons that chrysene is classified as a probable carcinogen is that it produced chromosomal abnormalities in hamsters and mouse germ cells after gavage exposure and positive responses in bacterial gene mutation assays [893].

Genotoxic Effects [366]:

> Positive results for chrysene were only found in the salmonella typhimurium assay. The chemical was positive in the ames test with aroclor-induced rat liver S-9 mix using strains TA100 and TA98. [BROWN MM ET AL; J NATL CANCER INST 62 (4): 841 (1979)].
>
> The major deoxyribonucleoside-hydrocarbon adducts present in hydrolysates of DNA isolated from hamster embryo cells treated with chrysene were examined by chromatography on sephadex LH20 and by HPLC on zorbax ods. Both major adducts have chromatographic properties identical to those of adducts formed when r-1,t-2-dihydroxy-tert-3,4-oxy-1,2,3,4-tetrahydrochrysene reacts with DNA and provide evidence that metabolic activation of chrysene occurs via the formation of this bay-region diol-epoxide. ... [Hodgson RM et al; Carcinogenesis 3 (9): 1051 (1982)].

Additional human health issues related to this topic have been summarized by ATSDR [871]. Due to lack of time, important highlights from this ATSDR document have not yet been completely incorporated into this entry.

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

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

Chrysene was found in the groundwater at a coal and oil gasification plant some 30 years after the plant shut down [788].

One study showed how biodegradation of PAHs was related

to molecular weight. The 2- and 3-ring PAHs degraded rapidly. The 4-ring PAHs like chrysene generally biodegraded 50% in a few months. The 5-ring PAHs decreased slowly over a period of years [815].

For several PAH families (naphthalenes, fluorenes, phenanthrenes, dibenzothiophenes, and chrysenes) if the unsubstituted parent PAH is less abundant than the sum of its counterpart alkyl homologues, the source is more likely petrogenic (from crude oil or other petroleum sources) rather than pyrogenic (from high temperature sources) [942].

Since alkyl versions of this compound are often found in even greater concentrations than the parent compound, the following generalizations concerning alkyl vs. parent compound PAHs should be kept in mind:

Some alkyl PAHs tend to be less volatile than parent compound PAHs [867]. Alkyl substitution usually also decreases water solubility [754].

Introduction or extension of an alkyl group increases not only persistence but also lipophilicity; increased lipophilicity is often associated with increased absorption [856]. Alkyl PAHs tend to bioaccumulate to a greater degree than parent compound PAHs [347,885].

Alkylated PAHs are often more abundant than parent compounds [468], at least those alkyl PAHs originating from petrogenic sources [942].

Alkyl PAHs also tend to persist for a longer time than the parent PAHs [468, 856]. PAH persistence tends to increase with increasing alkyl substitution; for example, methyl naphthalene is more persistent than naphthalene (the parent compound) and dimethyl naphthalene is still more persistent than methyl naphthalene in sediments and amphipod tissues [885].

Comparing PAHs and alkyl PAHs, the parent compound is typically the first to degrade. Thus, as mixed composition petroleum products age, the percentage of alkyl PAHs vs. PAHs increases, yet most standard EPA scans (even 8270) do not pick up alkyl PAHs [796]. This, coupled with the need for lower detection limits and the general hazards presented by alkyl PAHs, is one reason the NOAA protocol expanded scan [828] or other rigorous scans using Selected Ion Monitoring (SIM) [942] are often recommended rather than the older standard EPA scans.

Environmental Fate/Exposure Summary [366]:

Chrysene's release to the environment is quite wide spread since it is a ubiquitous product of incomplete combustion. It is largely associated with particulate matter, soils, and sediments. If released to soil it will be expected to adsorb very strongly to the soil and will not be expected to leach appreciably to groundwater. It will not hydrolyze or appreciably evaporate from soils or surfaces, and it may be subject to biodegradation in soils. If released to water, it will adsorb very strongly to sediments and particulate matter, but will not hydrolyze or appreciably evaporate. It will bioconcentrate in species which lack microsomal oxidase. It will be subject to near-surface, direct photolysis with a half-life of 4.4 hrs computed for exposure to sunlight at mid-day in midsummer at latitude 40 deg N. The small amount of information available suggests that chrysene may be subject to biodegradation in water systems. Adsorption to various materials may affect the rate of these processes. If released to air, chrysene will be subject to direct photolysis, although adsorption to particulates may affect the rate of this process. The estimated half-life of any gas phase chrysene in the atmosphere is 1.25 hrs as a result of reaction with photochemically produced hydroxyl radicals. Human exposure will be from inhalation of contaminated air and consumption of contaminated food and water. Especially high exposure will occur through the smoking of cigarettes and ingestion of certain foods ( smoked and charcoal broiled meats and fish). (SRC).

**Syn**onyms/Substance Identification:

1,2,5,6-Dibenzonaphthalene [366]
1,2-Benzophenanthrene [366]
1,2-Benzphenanthrene [366]
Benz(a)phenanthrene [366]
Benzo(a)phenanthrene [366]

Molecular Formula:
C18-H12 [366]

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

See also individual entries:

PAHs as a group
Chrysene, C1-
Chrysene, C2-

Chrysene, C3-
Chrysene, C4-
PAHs, Alkyl Homologs of

Metabolism/Metabolites [366]:

Four phenols were formed by rat liver homogenates: the main phenol is probably 1-hydroxy-chrysene, & two of the dihydro-dihydroxy compounds are probably 1,2-dihydro-1,2-dihydroxychrysene & 3,4-dihydro-3,4-dihydroxychrysene. [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 168 (1973)].

Microsomal oxidation of chrysene in rat liver occurs at various positions (1,2-; 3,4-; 5,6-). After various rat pretreatments with inducers of the monooxygenase system, the oxidation at the 3,4-position predominated in isolated microsomes. 1,2,3-Trihydroxy-1,2,3, 4-tetrahydrochrysene-trimethylsilyl-ether was formed under workup and derivatization conditions after pretreating rats with phenobarbital, PCB, 5,6-benzoflavone, or other polycyclic aromatic hydrocarbons. PCB and benzoflavone were the most potent inducers for the formation of this metabolite. [Jacob J et al; Arch Toxicol 51 (3): 255 1982)].

The major deoxyribonucleoside-hydrocarbon adducts present in hydrolysates of DNA isolated from hamster embryo cells treated with chrysene were examined by chromatography on sephadex LH20 and by HPLC on zorbax ods. Both major adducts have chromatographic properties identical to those of adducts formed when r-1,t-2-dihydroxy-tert-3,4-oxy-1,2,3,4-tetrahydrochrysene reacts with DNA and provide evidence that metabolic activation of chrysene occurs via the formation of this bay-region diol-epoxide. (This study may be applicable to carcinogenesis). [Hodgson RM et al; Carcinogenesis 3 (9): 1051 (1982)].

The fluorescence spectral properties of the major hydrocarbon-deoxyribonucleoside adduct that is formed in hamster embryo cells treated with chrysene are phenanthrene-like. This is consistent with metabolic activation occurring in this system through a vicinal diol-epoxide of the bay-region type. The spectral results are also consistent with the idea that the metabolic activation of chrysene involves the 'bay region' 1,2-diol 3,4-oxide. [Vigny P et al; Carcinogenesis 3 (12): 1491 (1982)].

The hydroxyl groups of (+-)-chrysene-trans-3,4-dihydrodiol were metabolized by liver microsomes from 3-methylcholanthrene-pretreated rats to form 1,2,3,4-tetrahydrotetrols as major products. It appears that the dihydrodiol epoxides derived from dihydrodiols can be

hydrolyzed or hydrated enzymatically by the epoxide hydrolase to form the tetrahydrotetrol derivatives. Chrysene trans-3,4-dihydrodiol is a major metabolite of the parent compound. It remains to be established whether vicinal dihydrodiol epoxides that can be derived metabolically from dihydrodiols are involved in covalent binding to cellular macromolecules in cultured cells or in animals that had been exposed to the respective parent hydrocarbons. Axial hydroxyl groups of chrysene-trans-3,4-dihydrodiol do not shift metabolism away from their vicinal double bond. [Chou MW et al; Proc Natl Acad Sci USA 78 (7): 4270 (1981)].

**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):

Groundwater samples from the site of a Seattle coal and oil gasification plant which ceased operation in 1956 were found to contain acenaphthylene, acenaphthene, fluorene, phenanthrene, fluoranthene, pyrene, and chrysene at concentrations ranging from not detected (detection limit 0.005 mg/L) to 0.25, 0.18, 0.14, 0.13, 0.05, 0.08, and 0.01 mg/L, respectively [881].

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

Water Concentrations [366]:

DRINKING WATER: Nordic tap water (sum of chrysene and triphenylene), 4 samples, 0.47-6.7 ppt(1). Detected (not quantified) in large volume samples of finished drinking water(2). Finished drinking water, 21 ppt; distributed drinking water, 4-26 ppt (max from system with coal-tar lined pipes)(3). [(1) Kveseth K, Sortland B; Chemosphere 11: 623-39 (1982) (2) Lucas SV; GC/MS (Gas Chromatography-Mass Spectrometry) Analysis of Organics in Drinking Water Concentrates and Advanced Waste Treatment Concentrates Vol 2: Battelle Columbus Labs OH USEPA-600/1-84-020a (1984) (3) Sorrell RK et al; Environ Internat 4: 245-54 (1980)].

GROUNDWATER: St. Louis Park, contaminated aquifer, identified, not quantified(1). [(1) Rostad CE et al; Chemosphere 14: 1023-36 (1985)].

SURFACE WATER: 7.6-62.0 ppt(1). US STORET database, 852 samples, 4.0% pos, median < 10

ppb(3). Main River, W Germany, 1964, 38.2 ppt; Thames River, UK, Kew Bridge, 140 ppt, Albert Bridge, 270 ppt, Tower Bridge, 530 ppt(2). Tamer Estuary, May 1980, 3.5 ppt(4). [(1) IARC; Polynuclear Aromatic Compounds Part 1, Chemical, Environmental and Experimental Data 32: 35-48 (1983) (2) Sorrell RK et al; Environ Internat 4: 245-54 (1980) (3) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985) (4) Readman JW et al; Estuarine Coastal Shelf Sci 14: 369-89 (1982)].

RAINWATER: Portland, OR, Feb-April, 1984, 7 sampling periods, 1-5 days each: 3.3-12 ppt, avg 7.9 ppt(1); Concn in rain contained in particulate matter, 1.3-11 ppt(2). [(1) Ligocki MP et al; Atmos Environ 19: 1609-17 (1985) (2) Ligocki MP et al; Atmos Environ 19: 1619-26 (1985)].

Effluent Concentrations [366]:

Chrysene was determined in effluent from bekkelaget sewage treatment plant in norway at up to 184 ng/l (1980); at up to 50 ng/g in transplanted mussels outside the bekkelaget sewage treatment plant; at up to 6.7 Ng/l in samples of nordic tap water. [Kveseth K et al; Chemosphere 11 (7): 623 (1982)].

24-Hour composite samples of wastewaters were analyzed from dissolved air floatation (DAF) and final clarifier (fc) units of class b refinery activated sludge treatment system. Chrysene was present in both samples. [Burke SL; Environ Int 7 (4): 271 (1982)].

US STORET database, 1,236 samples, 3.3% pos, median < 10 ppb(1). Estimated emissions from mobile sources, 1979, 150 metric tons(2). Wood smoke, chrysene/benz(a)anthracene, ppm, seasoned oak, fireplace, < 1, baffled stove 13, non-baffled stove 8(3). Mean raw wastewater concn, ppb, in those industries exceeding 100 ppb includes (max wastewater concn, ppb): iron and steel < 200 (800), foundries 2400 (13,000), photographic 180 (350), nonferrous metals 160 (10,000), organic chemicals/plastics 390(-)(4). [(1) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985) (2) National Research Council; Polycyclic Aromatic Hydrocarbons: Evaluation of Sources and Effects, National Acad Press Washington, DC (1983) (3) Santodonato J et al; Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons; Lee SD, Grant L eds; Pathotox Publ Park Forest South IL (1981) (4) USEPA; Treatability Manual; pp 1.10.12-2 to 1.10.12-3 USEPA-600/2-82-001A (1981)].

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

Water Quality Criteria in ug/L:

Freshwater Acute Criteria: None Published [893,928].

Freshwater Chronic Criteria: None Published [893,928].

Marine Acute Criteria: 300 ug/L LEC [893].

Marine Chronic Criteria: None Published [893,928].

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

No information found.

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

One study found a concentration of 1.0 ppm of chrysene to be "not acutely toxic" in 96 hours to Neanthes arenaceodentata, a marine polychaete [851].

NOTE: Results from (probably) the same study are also stated as follows: LC50 for Neanthes arenaceodentata (polychaete) was <1.0 mg/L (ppm) for a 96-hr exposure [998].

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

No information found.

**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 = E-06) Risk Level for Carcinogens), EPA National Water Quality Criteria Concentrations in ug/L:

EPA 1996: Ambient Water Quality Criteria for Human Health: Water & Fish: 2.8E-3 ug/liter [893]. Reference: 45 FR 79318 (11/28/80) [893]. Same concentration Previously published as Criteria for Water and Organisms: 0.0028 ug/L [689].

EPA 1996: Published Criteria for Fish Only: 3.11E-2 ug/liter [893]. Same concentration previously published as a Criteria for Organisms Only: 0.0311 ug/L [689].

Discussion: 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)] [366,871].

Drinking Water MCLs [893]:

Maximum Contaminant Level (MCL) Value: 0.0002 mg/L Status/Year: Proposed 1990 Reference: 55 FR 30370 (07/25/90).

Maximum Contaminant Level Goal [893]:

Value: 0 mg/L Status/Year: Proposed 1990 Reference: 55 FR 30370 (07/25/90) Contact: Health and Ecological Criteria Division / (202)260-7571 Safe Drinking Water Hotline / (800)426-4791

Discussion: The proposed MCLG is zero. This value is based on carcinogenic PAH's as a class.

Preliminary remediation goal (PRG) for Tapwater, EPA Region IX, 1995 [868]: 9.2 ug/L.

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

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

Numeric Water Quality Criteria in Arizona [881]:

Domestic water supply: 0.03 ug/L
Fish consumption: 0.0001 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

See also: [USEPA; Ambient Water Quality Criteria Doc: Polynuclear Aromatic Hydrocarbons (Draft) p.C-121 (1980)].

NOTE: Before citing a concentration as EPA's water quality criteria, it is prudent to make sure you have the latest one. Work on the

replacement for the Gold Book [302] was underway in March of 1996, and IRIS [893] is updated monthly.

NOTE: 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].

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

This is a phototoxic PAH [887; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 6, Newstead, J.L. and J.P. Geisy. Predictive models for photoinduced acute toxicity of polycyclic aromatic hydrocarbons to Daphnia magna. Copyright 1987 SETAC].

Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. /polynuclear aromatic hydrocarbons/ [40 CFR 401.15 (7/1/87)] [366].

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

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

No information found.

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

Analyses of sewage sludges form 50 publicly owned treatment works by the U.S. Environmental Protection Agency (1985): The mean concentration of chrysene was 8.3 ppm (dry weight) [347].

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

Chrysene was detected in 100 % of urban-bay samples from the Puget Sound area. The mean concentration was 2219 ug/kg dry weight (ppb), while the median concentration was 360 ug/kg (ppb) [852].

Chrysene was detected in 74.7 % of non-urban-bay samples from the Puget Sound area. The mean concentration was 2826 ug/kg dry weight (ppb), while the median concentration was 119 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.

Great Lakes Harbors: The control site in one Great Lakes study had a sediment concentration of <0.01 mg/kg dry weight [145].

Sediment Concentrations [366]:

> SEDIMENTS: US STORET database, 319 samples, 9.0% pos, median < 500 ppb(14). 40-240 ppb(1). Buzzards Bay, MA, estuarine sediment, ppb-dry weight (miles from shore), 240 (0.5), 40 (1.3)(2). Niagara River at Niagara-on-the-Lake 1975-82, suspended sediments (seds), chrysene and phenanthrene trace to 20 ppm(3). Lake Pontchartrain, LA, (dry weight (wt)) 3 sites, 54 ppb (8 samples), 7.3 ppb and not detected (1 sample each)(5). Eagle Harbor, Puget Sound, WA, 1983, 3 sites, 15 samples, site avgs 300-7800 ppb (dry wt), overall avg 5400 ppb; Presidents Point, 1 samples 140 ppb(6). Cayuga Lake, 16 km north to 8 km south of coal-fired power plant, chrysene and triphenylene (chr/tr), deepwater seds, 140-290 ppb, avg 180 ppb, littoral seds, 70-450 ppb, avg 180 ppb(7). Northwestern Atlantic, chr/tr (not sep) 0-1000 km from Boston, 4-21,000 ppb (dry wt) (max at 0 km)(8). Remote Adirondack lakes, NY, ppm dry wt (depth, cm): Sagamore Lake, 190 (0-8), 77 (8-12), 2-7 (12-85); Woods Lake, 890 (0-4), 220 (4-8), 4 (8-11), 2-17 (12-84) (9). Chesapeake Bay, 1979 (dry wt), spring, 7 stations, 58-330 ppb, avg 179 ppb, fall, 7 stations, 54-322 ppb, avg 157, 1 station, 68,000 ppb(12). 27 worldwide stations, 96% pos, not detected (nd)- 1500 ppb (dry wt), 1 station, 21,000 ppb (Charles River, Boston, MA) (13). Delaware River, north of Philadelphia, Aug, 1977, trace(15). Georges Bank Region, 1977-82, 22

stations, 48 samples, 100% pos, <1-31 ppb(16). Washington coastal seds, 17 samples, 100% pos, 0.4-34. ug/g organic carbon(17). South Wales, site of old coal mine, river seds, 35.5 ppm(4). Wilderness Lake, Ontario, Canada, 23 ppb (dry wt)(19). Severn Estuary, UK, chr/tr, 8 sites, ppm dry wt (ppm wet wt), 1.1-5.0 (0.9-3.6), avg 2.9 (2.2)(10). Marine seds, ppb (dry wt), Baltic Sea, 61, Gulf of Finland, 115; Finnish Archepelago, 11-206, Saudafjord, Norway, 50, Hirakata Bay, Japan, 199-353(11). Great Barrier Reef Region, Australia, 1982, 7 stations, 35 samples, < 0.6-1500 ppb (dry wt) (max Townsville Harbor)(17). Tamar Estuary, UK, May 1980, suspended solids, 283 ppb, seds, 345 ppb(20). [(1) IARC; Polynuclear Aromatic Compounds; Part 1, Chemical, Environmental and Experimental Data 32: 248-9 (1983) (2) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (3) Kuntz KW; Toxic Contaminants in the Niagara River, 1975-82 Burlington Ontario Tech Bull No 134 (1984) (4) Carlson RM et al; Implications to the Aquatic Environment of Polynuclear Aromatic Hydrocarbons Liberated from Northern Great Plains Coal USEPA-600/3-79-093 (1979) (5) McFall JA et al; Chemosphere 14: 1561-9 (1985) (6) Malins DC et al; Carcinogenesis 6: 1463-9 (1985) (7) Heit M; Water, Air, Soil Pollut 24: 41-61 (1985) (8) Windsor JG, Hites RA; Geochim Cosmochim Acta 43: 27-33 (1979) (9) Tan YL, Heit M; Geochimica 45: 2267-79 (1981) (10) John ED et al; Bull Environ Contam Toxicol 22: 653-9 (1979) (11) Poutanen EL et al; Chemosphere 10: 347-54 (1981) (12) Bieri RH et al; Organic compounds in surface sediments and oyster tissue from the Chesapeake Bay p 187 USEPA-600/3-83-018A (1983) (13) Hites RA et al; Adv Chem Ser 185: 289-311 (1980) (14) Staples CA et al; Environ Toxicol Chem 4: 289-311 (1980) (15) Hites RA; Proc Nat Municipal Sludge Manage 8: 107-19 (1979) (16) Boehm PD, Farrington JW; Environ Sci Technol 18: 840-5 (1984) (17) Prahl FG, Carpenter R; Estuarine, Coastal, Shelf Sci 18: 703-20 (1984) (18) Smith JD et al; Marine Pollut Bull 16: 110-4 (1985) (19) Verschueren K; Handbook of Environmental Data on Organic Chemicals 2nd ed Von Nostrand Reinhold NY pp 392-4 (1983) (20) Readman JW et al; Estuarine, Coastal Shelf Sci 14: 369-89 (1982)].

**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):

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

AET 1988: The apparent effects threshold concentrations for chrysene in sediments proposed for Puget Sound ranged from 1.4 mg/kg dry weight (microtox) to 9.2 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 chrysene sorbed to marine sediments is 0.900 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 2800 ppb dry weight Effects Range-Median (ERM) concentration and was lowest in sediments where its concentration was less than the 384 ppb dry weight Effects Range-Low (ERL) concentration [664] (see sections 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 the entries entitled ERM and ERL):

| | |
|---|---|
| <ERL | 19.0 |
| ERL-ERM | 45.0 |

>ERM 88.5

Ontario Ministry of the Environment Freshwater Sediment Guidelines, 1993. Lowest effect level: 340 ug/kg dry weight. Severe effect level: 460 mg/kg to a max of 10% organic carbon [761].

St. Lawrence River Interim Freshwater Sediment Criteria, 1992. No effect: 100 ug/kg dry weight. Minimal effect: 600 ug/kg dry weight. Toxic effect: 80 mg/kg to a max of 10% organic carbon [761].

Environment Canada Interim Sediment Quality Assessment Values. Toxic effect level: 57.1 ug/kg dry weight. Probable effect level: 861.7 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):

Buffalo river sediment extracts contained polynuclear aromatic hydrocarbons (PAH) which caused skin darkening, hyperplasia, skin papillomas, mild coarsening and local pigmentations in the brown bullhead (Ictalurus nebulosus). Sixteen PAH were identified in the sediment extract: fluorene, phenanthrene, anthracene, fluoranthene, 2-methylphenanthrene, pyrene, 2-methylanthracene, benzanthracene, chrysene, perylene, benzo(f)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene, and indeno(1,2,3-c,d)pyrene. [Black JJ; Polynucl Aromat Hydrocarbons Int Symp 7th 99-11 (1983)] [366].

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

No information found.

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

No information found.

**Sed.Misc.** (Other Non-concentration Sediment Information):

No information found.

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

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

No information found.

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

Analyses of sewage sludges form 50 publicly owned treatment works by the U.S. Environmental Protection Agency (1985): The mean concentration of chrysene was 8.3 ppm (dry weight) [347].

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

| | |
|---|---|
| Chrysene | 1,586 |

In a 1988 study at a hazardous waste land treatment site for refinery process wastes, which had been operative since 1958, average PAH concentrations in surface soils (0-30 cm) ranged from not detected (detection limits 0.1-2.0 mg/kg dry weight) for acenaphthylene, acenaphthene, anthracene, benz[a]anthracene, and benzo[k]fluoranthene to 340 mg/kg dry weight for dibenz[a,h]anthracene (Loehr et al. 1993). In addition to dibenz[a,h]anthracene, the three most prevalent compounds at this depth were benzo[a]pyrene (204 mg/kg), benzo[b]fluoranthene (130 mg/kg), and chrysene (100 mg/kg). PAH concentrations decreased with increasing depth and the majority of PAHs were not detected at depths below 60 cm. At 90-135 cm, only phenanthrene (1.4 mg/kg), pyrene (4.0 mg/kg), chrysene (0.9 mg/kg), and dibenz[a,h]anthracene (0.8 mg/kg) were found [881].

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

Soil Concentrations [366]:

SOILS: Nova Scotia, chr/tr (not sep), 10 sites, 30 samples, 100% pos, not detected-62 ppb (dry wt), median 4 ppb(7). 19 worldwide stations, not detected-75 ppb (dry wt), 2 stations, 280 and 560 ppb(13). [(7) Heit M; Water, Air, Soil Pollut 24: 41-61 (1985) (13) Hites RA et al; Adv Chem Ser 185: 289-311 (1980)].

Background Soil Concentrations of Polycyclic Aromatic Hydrocarbons (PAH concentration in ug/kg) [881]:

(The below table is not indented to allow it to fit the margins):

| Compound | Rural soil | Agricultural Soil | Urban Soil |
|---|---|---|---|
| Chrysene | 38.3 | 78-120 | 251-640 |

**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 Protection of Soil-dwelling Biota in General; Includes Soil Concentrations Versus Mixed or General Soil-dwelling Biota):

Acceptable on-site soil concentrations for chrysene approved by the Ontario Ministry of the Environment for the Texaco and Shell refinery sites (1987): 470 ppm [347].

Quebec soil contamination indicators that differ from those of the Netherlands (1987): 0.1 ppm of chrysene indicates a background concentration. 5 ppm of chrysene indicates a moderate soil contamination. 50 ppm indicates a threshold concentrations 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 chrysene in the soil was 2.0 ppm, the range was 0.19-4.6 ppm (dry weight). The mean concentration of chrysene in the earthworms was 0.35 ppm, the range was 0.15-1.7 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 = 88 mg/kg for ingestion pathway [952].

SSL = 8 to 160 mg/kg for protection from migration to groundwater at 1 to 20 Dilution-Attenuation Factor (DAF) [952].

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

Residential Soil: 24 mg/kg wet wt.

California-modified PRG: 6.1 mg/kg

Industrial Soil: 24 mg/kg wet wt.

NOTE:

1) PRGs focus on the human exposure pathways of ingestion, inhalation of particulates and volatiles, and dermal absorption. Values do not consider impact to groundwater or ecological receptors.
2) These values are based on saturated concentrations of chrysene in soil.
3) For residential and commercial use, PRGs are slightly lower concentrations than EPA Region III RBCs, which consider fewer aspects (are more limited to ingestion pathway) [903].

EPA Region III RBC to protect from transfers to groundwater:

1 mg/Kg dry weight [903].

**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:

No information found.

**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:

Details of chrysene content (ug/kg or ppb) in whole body samples of mussels) 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 mussel tissues [971]. These values are wet weight (Jerry Neff, Battelle Ocean Sciences, Duxbury, MA, personal communication 1996):

| | |
|---|---|
| chrysene: | 411 ug/kg = ppb |
| C1-chrysene: | 658 ug/kg = ppb |
| C2-chrysene: | 521 ug/kg = ppb |
| C3-chrysene: | 239 ug/kg = ppb |
| C4-chrysene: | 43.9 ug/kg = ppb |

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 chrysene in the soil was 2.0 ppm, the range was 0.19-4.6 ppm (dry weight).

The mean concentration of chrysene in the earthworms was 0.35 ppm, the range was 0.15-1.7 ppm (ash-free dry weight) [347].

Fish/Seafood Concentrations [366]:

Lobsters which had been kept in a commercial tidal pond constructed of creosoted timber contained highly elevated levels of carcinogenic hydrocarbons including chrysene. Chrysene levels in the tail meat of lobsters before and after impoundment were 2.2 And 303 ng/g wet weight, respectively. [Dunn BP, Fee J; J Fish Res Board CAN 36 (12): 1469 (1979)].

Fish, 0.4-4.3(1). Shucked oysters, 20-40 ppb(2). Lake Pontchartrain, LA, oysters, 58 ppb (wet wt)(3). Mussel Watch: Naraganset Bay, homogenate of 50 mussels (Mytilus edulis), 3 different methods, chrysene/benz(a)anthracene (not separated), dry wt, method 1, 6 observations (obs), 29 ppb, method 2, 10 obs, 28 ppb, avg 31 ppb, method 3, 4 obs, 47 ppb(7). Coos Bay, OR, softshell clams (Mya arenaria), 1978-79, 2 sites, 6 sample periods, 20 clams/site/period, site 1 Remote area), 5.9-8.9 ppb, avg 7.6 ppb, site 2 (adjacent to industrial area), 21.5-38.9 ppb, avg 27.2 ppb(8). English sole, Puget Sound, WA, 1983, stomach: Eagle Harbor (EH), 6500 and 11,000 ppb (dry weight), Presidents Point (PP), 15 ppb; liver: EH, < 7.3 ppb, PP, < 25 ppb; muscle, EH, < 2.7 ppb(4). UK total diets, 1979, fish, not detected (nd)-1.84 ppb, avg 0.65 ppb(5). Smoked fish, 46 samples, chrysene/triphenylene nd-13.0 ppb(6). Great Barrier Reef, Australia, clams (Tridacna maxima), 13 sites, 21 samples, < 0.05-1.9 ppb (wet wt)(9). [(1) IARC; Polynuclear Aromatic Compounds, Part 1, Chemical, Environmental and Experimental Data 32: 35-48 (1983) (2) National Research Council; Polycyclic Aromatic Hydrocarbons: Evaluation of Sources and Effects, National Acad Press Washington DC (1983) (3) McFall JA et al; Chemosphere 14: 1561-9 (1985) (4) Malins DC et al; Carcinogenesis 6: 1463-9 (1985) (5) Dennis MJ et al; Food Chem Toxicol 21: 569-74 (1983) (6) Vaessen HAMG et al; Toxicol Environ Chem 7: 297-324 (1984) (7) Galloway WB et al; Environ Toxicol Chem 2: 395-410 (1983) (8) Mix MC, Schaffer RL; Marine Pollut Bull 3: 94-7 (1983) (9) Smith JD et al; Environ Sci Technol 18: 353-8 (1984)].

**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:

See also Tis.Invertebrates, C), above.

Details of chrysene 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):

| | |
|---|---|
| chrysene: | 2.5 ug/kg = ppb |
| C1-chrysene: | 0.71 ug/kg = ppb |
| C2-chrysene: | 0.48 ug/kg = ppb |
| C3-chrysene: | 0.16 ug/kg = ppb |
| C4-chrysene: | 0.56 ug/kg = ppb |

The chrysene concentration in mosquitofish with extremely elevated total PAH concentrations (60.79 mg/kg) was 4.9 mg/kg [201].

**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]:

Heavily smoked ham, 21.2 ppb; spinach, 28 ppb; black tea, 4.6-6.3 ppb; tomatoes, 0.5 ppb; cereals, 0.8-14.5 ppb; broiled sausage, 0.5-2.6 ppb; roasted coffee, 0.6-19.1 ppb; charcoal-broiled steaks, 1.4 ppb(1). Lettuce, 5.7-26.5 ppb; meat and sausages, 0.5-25.4 ppb(2). Smoked foods: 0.5 ppb, 2.6 ppb; barbecued beef, 9.6 ppb; hot sausage, 1.0 ppb; barbecued ribs, 2.2 ppb(3). Smoked salami, 1.2 ppb; smoked motadella, 3.4 ppb(4). Bakers yeast, 4.2-14.0 ppb (French, German, Russian), 50 ppb (Scottish)(5). UK total diets, 1979, total dietary load 0.50 ug/person/day (based on total daily consumption of 1.46 kg food and beverages); food classes ug/kg, range (avg); cereals, not detected (nd)-2.30 (0.77), meat, nd-0.34 (0.15), oils and fats, nd-4.18 (1.18), fruit and sugar, nd-1.29 (0.23), root vegetables, nd-0.55 (0.23), other vegetables, 0.16-1.65 (0.93), beverages, nd(6). Spinach, 19 ppb, salad, 5.7-26.5 ppb, kale, 58-395 ppb, roast peanuts, 0.01-0.7 ppb, cereals, 0.8-14 ppb(7). [(1) National Research Council; Polycyclic Aromatic Hydrocarbons: Evaluation of Sources and Effects, National Acad Press Washington DC (1983) (2) IARC; Polynuclear Aromatic Compounds Part 1 Chemical, Environmental and Experimental Data 32: 35-48 (1983) (3) Fazio T, Howard JW; p 461-506 in

Handbook of Aromatic Hydrocarbons; Bjorseth A ed (1983) (4) Sanotodonato J et al; Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons; Lee SD, Grant L eds Pathotox Publ Park Forest South IL (1981) (5) Syracuse Research Corp; Hazard Assessment Report on Polycyclic Organic Matter Syracuse Research Corp Syracuse NY p 68 TR 69-115 (1980) (6) Dennis MJ et al; Food Chem Toxicol 21: 569-74 (1983) (7) Vaessen HAMG et al; Toxicol Environ Chem 7: 297-324 (1984)].

Occurrence reported in cooked meat and fish, vegetables, cereals, refined vegetable oils, coffee, peas and whiskey. [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 164 (1972)].

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

For risk to human adults eating fish, separate carcinogenic and non-carcinogenic risk-based fish tissue concentrations were calculated [903]. The following EPA Region III fish tissue risk-based concentration (RBC) benchmark utilizes the lower of the two (carcinogenic vs. non-carcinogenic) concentrations, rounded to two significant figures [903]:

RBC Benchmark = 0.43 mg/Kg wet weight.

Slope Factor: 7.3E-03 [868].

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

Milk Concentrations [366]:

UK total diets, 1979, milk, not detected(1). [(1) Dennis MJ et al; Fd Chem Toxicol 21: 569-74 (1983)].

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

This is a phototoxic PAH [887; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 6, Newstead, J.L. and J.P. Geisy. Predictive models for

photoinduced acute toxicity of polycyclic aromatic hydrocarbons to Daphnia magna. Copyright 1987 SETAC].

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

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

Some log bioconcentration factors (BCFs) are: 4.72 for microorganisms in water; 3.785 for Daphnia magna [848].

Bioconcentration [366]:

Macoma inquinata, a detritus feeding clam, was exposed for 60 days to coarse-grained, and abarenicola pacifica, a burrowing polychaete, to fine-grained sediment. Each sediment contained chrysene. Over 70% of the chrysene remained in the coarse sediment during the exposure. Essentially all remained in the fine sediment. The concentration of chrysene in the clams rose steadily, reaching levels 11.6 Times as high as those in sediment. The concentrations in abarenicola tissue increased for 2 weeks to 4-6 times the sediment levels. The tissue concentration of chrysene remained constant thereafter. [Augenfeld JM et al; Mar Environ Res 7 (1): 31 (1982)].

Mussels were taken from two sites, the first relatively isolated from human onshore activities and the second along the newport bayfront of yaquina bay, with possible contamination from creosoted pilings, marinas, fishing vessels, fish processing plants and other light industrial operations. The first site showed no chrysene in mussels, while the second showed an average of 86.2 Ug/kg, wet weight. [Mix MC, Schaffer RL; Mar Environ Res 9 (4): 193 (1983)].

Polycyclic aromatic hydrocarbons (PAH) were analyzed in surficial sediments and benthic organisms in southwestern Lake Erie near a large coal-fired power plant. Sediments from stations 5 and 10 km to the north contained several times the level of PAH as did those from stations directly offshore or to the south. Midges collected at 1 km offshore exhibited bioconcentration of chrysene. Further offshore, the apparent bioconcentration disappeared, with the midges at near equilibrium with the sediments. A similar result was reported for the marine

mollusk mytilus edulis. [Eadie BJ et al; Chemosphere 11 (2): 185 (1982)].

BCF: Daphnia magna, approx 2000 (after 70 hr; rapidly eliminated)(1). Clams (Macoma inquinata), BCF 694 (uptake from seawater), 0.04 (uptake from sediments)(2). Using a reported range of octanol/water partition coefficients of 5.61-5.91(3,4), an estimated range of BCF values of 10,700-18,200 was calculated(5,SRC). Based on these estimated values chrysene would be expected to bioconcentrate. However, polyaromatic hydrocarbons are not likely to appreciably bioconcentrate in organisms which have microsomal oxidase, such as fish, as this enzyme enables the organism to metabolize them(6). [(1) Eastmond DA et al; Arch Environ Contam Toxicol 13: 105-11 (1984) (2) Roesijadi G et al; J Fish Res Board Canada 35: 608-14 (1968) (3) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (4) Yalkowsky SH et al; Res Rev 85: 43-55 (1983) (5) Lyman WJ et al; Handbook of Chemical Property Estimation Methods Environmental Behavior of Organic Compounds McGraw-Hill NY p 5-4 (1982) (6) Santodonato J et al; Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons; Lee SD, Grant L eds; Pathotox Publ Park Forest South IL (1981)].

... Some marine organisms have no detectable aryl hydrocarbons hydroxylase enzyme systems, namely: phytoplankton, certain zooplankton, mussels (Mytilus edulis), scallops (Placopecten sp), and snails (Litternia littorea). ... Those organisms which lack a metabolic detoxification enzyme system, tend to accumulate polycyclic aromatic hydrocarbons. /Polycyclic aromatic hydrocarbons/ [Malins DC; Ann NY Acad Sci 298: 482-496 (1977) as cited in: Health and Welfare Canada; Polycyclic Aromatic Hydrocarbons p.37 (1979) Report No. 80-EHD-50].

**Int**eractions:

Information from HSDB [366]:

Ellagic acid is a highly potent inhibitor of the mutagenic activity of bay-region diol epoxides of some benzopyrenes, but higher concentrations of ellagic acid are needed to inhibit the mutagenic activity of the chemically less reactive bay-region diol epoxides of chrysene. [Wood AW et al; Proc Natl Acad Sci USA 79 (18): 5513 (1982)].

The addition of chrysene to a synthetic petroleum hydrocarbon mixture of known composition and relatively low embryotoxicity resulted in embryotoxicity that was enhanced or equal to that of crude oil when 10 ul was applied externally to mallard duck eggs at 72 hours of

development. Mass fragmentography showed the passage of aromatic hydrocarbons including chrysene through the shell and shell membranes to the developing embryos. [Hoffman DJ, Gay ML; J Toxicol Environ Health 7 (5): 775 (1981)].

The influence of some compounds belonging to the group of polycyclic aromatic hydrocarbons (eg, ... chrysene, ... on the pharmacokinetics of theophylline in rats is described. ... /Chrysene/ significantly accelerated the elimination of the drug. ... [Brandys J, Piekoszewski W; Pharmazie 40 Iss: 566-68 (1985)].

The potencies of various xenobiotics for induction of monooxygenases and their influence on the rat liver microsomal metabolite profile of the environmentally relevant weak carcinogen, chrysene, was determined. ... [Jacob J et al; Cancer Letter 34 (1): 91-102 (1987)].

**Us**es/Sources:

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

Chrysene is present in some heavy crudes in significant amounts [468].

Chrysene was found in the groundwater at a coal and oil gasification plant some 30 years after the plant shut down [788].

During the summer of 1996, NASA announced that PAHs had been found on a martian meteorite. Three to 6 ring PAHs found included phenanthrene, pyrene, chrysene, perylene, and benzo(a)pyrene, with less than 10% of the mass being alkyl PAHs. It was said that the meteorite PAHs were typified by little alkylation and a lack a dibenzothiophene, making the PAH mixture different than typically found in the earth's atmosphere. However, another unidentified mass of alkyl PAH compounds were also found and NASA acknowledged that PAHs have been found in a wide range of extraterrestrial materials [McKay et.al. 1996, manuscript entitled "Search for Life on Mars: Possible Biogenic Activity in Martian Meteorite ALH84001," a NASA paper available at the time of the NASA press release].

Note from Roy Irwin: This represents and interesting and somewhat speculative attempt to link fingerprinting of PAH combinations to possible life on mars. NASA admits that the PAHs alone do not prove there was life on mars, and I may personally remain a bit skeptical until more comprehensive and convincing evidence is presented.

In a 1981-82 study that characterized air levels of 13 PAHs in Los Angeles, it was reported that mean ambient particle-phase PAH concentrations ranging from 0.32 ng/m3 for benzo[k]fluoranthene to 3.04 ng/m3 for combined benzo[g,h,i]perylene and indeno[1,2,3-c,d]pyrene. Mean concentrations of anthracene, fluoranthene,

pyrene, chrysene, benz[a]anthracene, combined perylene and benzo[e]pyrene, benzo[b]fluoranthene, and benzo[a]pyrene were 0.54; 0.94, 1.62, 0.97, 0.48, 0.43. 0.94, and 0.64 ng/m3, respectively [881].

Natural Sources [366]:

Since chrysene is a product of incomplete combustion, there will be natural sources arising from volcanoes, forest fires, etc(SRC). Also in crude oil, Louisiana, 17.5 ppm, Kuwait, 6.9 ppm; coal tar, detected (not quantified); bitumen, 1.64-5.14(1). [(1) Verschueren K; Handbook of Environmental Data on Organic Chemicals. 2nd ed Von Nostrand Reinhold NY pp 392-4 (1982)].

Artificial Sources [366]:

/It/ occurs in coal tar. Is formed during distillation of coal, in very small amt during distillation or pyrolysis of many fats & oils. [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 321].

Released to the environment as a ubiquitous product of incomplete combustion, occurring in exhaust from motor vehicles and other gasoline and diesel engines, emission from coal-, oil-, and wood-burning stoves and furnaces, cigarette smoke; generally in soot and smoke of industrial, municipal, and domestic origin, and cooked foods, especially charcoal-broiled(1). Also from refuse combustion(2). [(1) IARC; Polynuclear Aromatic Compounds, Part 1, Chemical, Environmental and Experimental Data 32: 247-61 (1983) (2) Graedel TE; Chemical Compounds in the Atmosphere Academic Press, NY p 153 (1978)].

**Fo**rms/Preparations/Formulations:

No information found.

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

Information from ATSDR [871]:

Solubility in water: 1.5 to 2.2 ug/L;

"Practically insoluble" in water [870].

Solubility in organic solvents: slightly soluble in acetone, carbon disulfide, diethyl ether, ethanol, glacial acetic acid, toluene, and hot xylene; soluble in benzene.

Solubility in biological fluids: unknown

Vapor pressure: 6.3x10(-9) mm Hg (20 C)

Partition coefficients:

Octanol-water (Kow): 4.1x10(5)
Log Kow: 5.61-5.91 [366,754].
Log Kow values for chrysenes [971]:

| | |
|---|---|
| chrysene: | 5.86 |
| C1-chrysene: | 6.42 |
| C2-chrysene: | 6.88 |
| C3-chrysene: | 7.44 |
| C4-chrysene: | 8 |

Soil-organic carbon-water (Koc): 2x10(5)

Henry's law constant: 1.05x10(-6)

Molecular weight: 228.3 g/mol

Color: colorless with red-blue fluorescence

Odor: unknown

Melting point: 255-256 C

Boiling point: 448 C; sublimes in vacuo

Density: 1.274

Concentrations of chrysene in South Louisiana crude, Kuwait crude, No. 2 fuel oil, and Bunker C residual were 17.56, 6.9, 2.2, and 196 mg/kg (ppm), respectively [177]. Another study showed concentrations of chrysene in South Louisiana crude and Kuwait crude were 23 and 6.9 10(-6)g/g oil (ppm), respectively [747].

Chrysene concentrations were determined for three different crude oil sample types taken from the Exxon Valdez oil spill. Concentrations in 1) unweathered oil from the tanker itself (March 1989), 2) oil skimmed from the water immediately after the spill and held in the skimmer barge for about 90 days (July 1989), and 3) weathered oil from Prince William Sound shorelines (May 1989) were: 41, ND (not detected), and 54 ug/g oil sampled, respectively [790; Reprinted with permission from Environmental Toxicology and Chemistry, Vol.14(11), W.A. Stubblefield, G.A. Hancock, W.H. Ford, and R.K. Ringer, "Acute and Subchronic Toxicity of Naturally Weathered Exxon Valdez Crude Oil in Mallards and Ferrets." Copyright 1995 SETAC].

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

| | |
|---|---|
| chrysene: | 46 mg/kg = ppm |
| C1-chrysene: | 89 mg/kg = ppm |
| C2-chrysene: | 138 mg/kg = ppm |
| C3-chrysene: | 115 mg/kg = ppm |

C4-chrysene: 0 mg/kg =ppm

Chrysene content in one fresh sample of NSFO (Fuel Oil 5, Chuck Rafkind, National Park Service, Personal Communication, 1996): 74.3 ng/mg (ppm).

Chrysene 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): 1817.1 ng/L (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).

Chrysene concentration in Used Engine Oil: 45.0 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].

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

Calculated half-lives of direct sunlight photolysis for 50% conversion at 40 degrees N latitude of midday in midsummer: 4.4 hours (near-surface water); 13 days (5-m deep inland water with no sediment-water partitioning); and 68 days (inland water with sediment partitioning) [848].

Half-life in soil is reported by one source to be 8904 to 24,000 hours [870]. Half-life in soil also reported to be: >5.5 days; 328 days for 5 mg/kg treatment; and 224 days for 50 mg/kg treatment [848].

Half-life in groundwater is reported by one source to be 17,808 to 48,000 hours [870].

Environmental Fate [366]:

TERRESTRIAL FATE: If chrysene is released to soil it will be expected to adsorb very strongly to the soil and will not be expected to leach to groundwater. It will not hydrolyze and evaporation from soils and surfaces will not be expected to be significant. The very little information concerning the biodegradability of chrysene in aqueous systems in the literature suggests that chrysene may be subject to degradation in soils, but the data are conflicting. (SRC)

AQUATIC FATE: If released to water, chrysene will be expected to adsorb very strongly to sediments and

particulate matter. It will not hydrolyze and will not be expected to appreciably evaporate. Chrysene may be subject to bioconcentration in organisms which lack microsomal oxidase (this enzyme enables the rapid metabolism of polyaromatic hydrocarbons). It will be subject to direct photodegradation near the surface of waters; a near-surface half-life of 4.4 hr was computed for sunlight at latitude 40 deg N. However, the photolysis rate may be affected if chrysene in adsorbed onto suspended particulate matter. The very little information concerning the biodegradability of chrysene in aqueous systems in the literature suggest that chrysene may be subject to degradation; however, the data are conflicting. (SRC)

ATMOSPHERIC FATE: Chrysene released to the atmosphere will likely be associated with particulate matter and may be subject to long distance transport, depending on the particle size distribution and climactic conditions which will determine the rates of wet and dry deposition. It may be subject to direct photodegradation, but evidence suggests that adsorption to various substrates may affect the rate of this process. (SRC)

Biodegredation [366]:

Chrysene at 5 ppm (values for 10 ppm) was 6% (0%) degraded with gradual adaptation after 7 days by microbes in settled domestic wastewater, 65%, 53%, 59%, (30%, 34%, 38%) degraded 7 days after addition of the 2nd, 3rd, 4th subculture, respectively(1). Chrysene was not degraded in 4 weeks in a suspension containing polluted water inoculum from a stream and either naphthalene or phenanthrene as a growth substrate(2). Observed loss due to biodegradation in wastewater treatment plant, was 9%(3). [(1) Tabak HH et al; Proc Symp AOAC 94: 267-328 (1981) (2) McKenna AJ; Water Resour Cent 113: 1025 (1976) (3) Petrasek AC et al; J Water Pollut Control Fed 55: 1286-96 (1983)].

Polycyclic aromatic hydrocarbons with 4 or less aromatic rings are degraded by microbes and are readily metabolized by multicellular organisms; biodegradation may be the ultimate fate process. /Polycyclic aromatic hydrocarbons/ [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume I. EPA-440/4 79-029a. Washington, DC: U.S.Environmental Protection Agency, December 1979.,p. 97-17].

Biodegradation is probably slower in the aquatic system than in the soil, and biodegradation may be much more important in those aquatic systems which are chronically affected by contamination. /Polycyclic aromatic

hydrocarbons/ [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume I. EPA-440/4 79-029a. Washington, DC: U.S.Environmental Protection Agency, December 1979.,p. 95-11].

Abiotic Degredation [366]:

Polyaromatic hydrocarbons do not contain hydrolyzable groups and would therefore not be expected to hydrolyze(1). Computed near-surface half-life for direct photochemical transformation for exposure to sunlight (latitude 40 deg N, midday midsummer) 4.4 hr; photosensitization was estimated to be negligible(2). Half-lives (substrate) for chrysene adsorbed on simulated atmospheric particulates and irradiated with light from a medium-pressure mercury lamp: 100 hr (silica gel), 78 hr (alumina), 38 hr (fly ash), 690 hr (carbon black)(3); this indicates that the nature of adsorption can affect photodegradation. Chrysene deposited on glass-fiber filters has been shown to be inert to nitrogen pentoxide(4). The estimated half-life of vapor phase chrysene in the atmosphere is 1.25 days as a result of reaction with photochemically produced hydroxyl radicals(5). [(1) Callahan MA et al; Water-Related Environmental Fate of 129 Priority Pollutants vol 2 pp 97-7 USEPA-440/4-79-029b (1979) (2) Zepp RG, Schlotzhauer PF; pp 141-58 in Polynuclear Aromatic Hydrocarbons Jones PW, Leber P eds Ann Arbor MI Ann Arbor Science Publishers (1979) (3) Behymer TD, Hites RA; Environ Sci Technol 19: 1004-6 (1985) (4) Pitts JN et al; Environ Sci Technol 19: 1115-21 (1985) (5) GEMS; Graphical Exposure Modeling System Fate of atmospheric pollutants (FAP) data base. Office of Toxic Substances USEPA (1986)].

Soil Adsorption/Mobility [366]:

Using a reported range of octanol/water partition coefficients of 5.61-5.91(1,2) an estimated range of Koc of 251,000-501,000 was calculated(3,SRC). Based on these estimated values, chrysene will be expected to adsorb very strongly to soils and sediments(SRC). [(1) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (2) Roesijadi G et al; J Fish Res Board Canada 35: 608-14 (1968) (3) Lyman WJ et al; Handbook of Chemical Property Estimation Methods Environmental Behavior of Organic Compounds McGraw-Hill NY p 4-8 (1982)].

Volatilization from Water/Soil [366]:

Percentage estimated maximum stripping removal in wastewater treatment plant, < 1%(1). Using reported water solubility of 0.002 ppm(2) and vapor pressure of 6.3X10-7(2), a Henry's Law constant of 9.4X10-8 was

calculated(3,SRC). Based on this calculated value volatilization from water should not be an important process(3). [(1) Petrasek AC et al; J Water Pollut Control Fed 55: 1286-96 (1983) (2) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (3) Lyman WJ et al; Handbook of Chemical Property Estimation Methods Environmental Behavior of Organic Compounds McGraw-Hill NY pp 15-1 to 15-34 (1982)].

Absorption, Distribution and Excretion [366]:

Polynuclear aromatic hydrocarbons are highly soluble in adipose tissue and lipids. /Polynuclear aromatic hydrocarbons/ [Sittig, M. Handbook of Toxic And Hazardous Chemicals. Park Ridge, NJ: Noyes Data Corporation, 1981. 564].

Polynuclear aromatic hydrocarbons (PAH), some of which are potent carcinogens, are common environmental pollutants. The transport processes for these hydrophobic compounds into cells and between intracellular membranes are diverse and are not well understood. A common mechanism of transport is by spontaneous desorption and transfer through the aqueous phase. From the partitioning parameters, ... the rate limiting step involves solvation of the transfer species in the interfacial water at the phospholipid surface. Transfer of 10 polynuclear aromatic hydrocarbons ... out of phosphatidylcholine vesicles has been examined. ... Results show that the molecular volume of the polynuclear aromatic hydrocarbons is a rate- determining factor. Moreover, high performance liquid chromatography (HPLC) data confirms the hypothesis that the rate of transfer is correlated with the size of the molecule and with the partitioning of the molecule between a polar and hydrocarbon phase. The kinetics and characteristics of the spontaneous transfer of carcinogens are likely to have a major impact on the competitive processes of polynuclear aromatic hydrocarbons metabolism within cell. [Plant AL et al; Chem-biol Interact 44 (3): 237-46 (1983)].

**Lab**oratory and/or Field Analyses:

Lab methods utilized should preferably be able to quantify alkyl chrysenes (C1, C2, C3, and C4), and most standard EPA scans [861,1010,1013] do not do that.

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 as a group" 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 as a group" 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 disclaimers section at the top of this entry, 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).