ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA

PYRENE ENTRY

July 1, 1997

COMPILERS/EDITORS:

ROY J. IRWIN, NATIONAL PARK SERVICE

WITH ASSISTANCE FROM COLORADO STATE UNIVERSITY
STUDENT ASSISTANT CONTAMINANTS SPECIALISTS:

MARK VAN MOUWERIK
LYNETTE STEVENS
MARION DUBLER SEESE
WENDY BASHAM

NATIONAL PARK SERVICE
WATER RESOURCES DIVISIONS, WATER OPERATIONS BRANCH
1201 Oakridge Drive, Suite 250
FORT COLLINS, COLORADO 80525

WARNING/DISCLAIMERS:

Where specific products, books, or laboratories are mentioned, no official U.S. government endorsement is implied.

Digital format users: No software was independently developed for this project. Technical questions related to software should be directed to the manufacturer of whatever software is being used to read the files. Adobe Acrobat PDF files are supplied to allow use of this product with a wide variety of software and hardware (DOS, Windows, MAC, and UNIX).

This document was put together by human beings, mostly by compiling or summarizing what other human beings have written. Therefore, it most likely contains some mistakes and/or potential misinterpretations and should be used primarily as a way to search quickly for basic information and information sources. It should not be viewed as an exhaustive, "last-word" source for critical applications (such as those requiring legally defensible information). For critical applications (such as litigation applications), it is best to use this document to find sources, and then to obtain the original documents and/or talk to the authors before depending too heavily on a particular piece of information.

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 or summaries 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).

Pyrene (CAS number 129-00-0)

Brief Introduction:

Br.Class: General Introduction and Classification Information:

Pyrene is a high-molecular-weight, 4-ring polycyclic aromatic hydrocarbon (PAH), and an EPA Priority Pollutant [697,634]. Many sources have determined that pyrene is not classifiable as to its carcinogenicity to humans [788,847] (see Br.Car section below).

Pyrene is included on the NOAA expanded scan list [828]. This list includes most of the PAHs recommended by the NOAA's National Status and Trends program [680].

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

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).

Although considered "pyrogenic" by some, pyrene is also somewhat petrogenic in that it is found in many petroleum products (see Chem.detail section below).

Br.Haz: General Hazard/Toxicity Summary:

Pyrene is present as a major component of the total content of polynuclear aromatic compounds in the environment. Human exposure to pyrene occurs primarily through the smoking of tobacco, inhalation of polluted air and by ingestion of food and water contaminated by combustion effluents [847].

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

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

This 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).

Pyrene is phototoxic to both Daphnia magna and guinea pigs [366,887]. Phototoxicity has been seen in a wide variety of aquatic organisms, including aquatic plants [911].

The degree of hazard presented by pyrene is partly reflected in its very stringent (low concentration) criteria for drinking water (see details in W.Human section below) and some other media.

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

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

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

EPA 1996 IRIS database information [893]:

Classification as to human carcinogenicity; weight-of-evidence classification:

Classification: D; not classifiable as to human carcinogenicity

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

HUMAN CARCINOGENICITY DATA: None.

ANIMAL CARCINOGENICITY DATA: Inadequate.

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

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

This is a phototoxic PAH [891,911,887]. The phototoxic effects to mosquito larvae were similar to phototoxic effects of BAP [911]. Although not definitive, as discussed above, phototoxicity represents one clue suggesting possible carcinogenicity.

Some co-carcinogenic activity was noted when combined with mixtures of other PAHs in dermal treatments of mice [40].

The debates on which PAHs and alkyl PAHs to classify as carcinogens, and the details of 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. PAH compounds usually occur in the presence of other PAH compounds, and one of the few things that is relatively clear is that PAH mixtures in water, sediments, and organism internal tissues often tend to be both carcinogenic and phototoxic (Roy Irwin, National Park Service, personal communication, 1996; see also "PAHs as a group" entry and Arfsten et al [911]).

One way to approach site specific risk assessments is to collect the complex mixture of PAHs and other lipophilic organic contaminants in a semipermeable membrane device (SPMD, also known as a fat bag) [894,895,896], retrieve the organic contaminant mixture from the SPMD, then test the mixture for carcinogenicity, toxicity, and phototoxicity (James Huckins, National Biological Service, and Roy Irwin, National Park Service, personal communication, 1996).

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

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

There is limited evidence that pyrene is active in short-term (genotoxicity) tests [847].

Pyrene resulted in no increase of sister chromatid exchange frequency in chinese hamster cells. (Sirianni SR, Huang CC; Proc Soc Exp Biol Med 158 2: 269, 1978)

[366].

Information from IRIS [893]:

> In DNA damage assays in Escherichia coli and Bacillus subtilis pyrene was not mutagenic (Ashby and Kilbey, 1981) [893]. In bacterial gene mutation tests both positive and negative results have been reported. The consensus conclusion on the international collaborative study (which involved 20 bacterial test sets) was that protocol or evaluation criteria were critical factors in individual test verdicts. Pyrene induced increased incidence of mitotic gene conversion but not other genetic endpoints in yeast. Pyrene did not induce an increase in sex-linked recessive lethals in Drosophila. Mixed results have also been observed in mammalian assays in vitro, again with protocol and evaluation criteria being a factor in at least some of the cases. Pyrene did not induce chromosome aberrations (as detected by micronuclei) or SCE in bone marrow of several mouse strains receiving i.p. injections of pyrene [893].

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

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

Environmental Fate/Exposure Summary [366]:

> Pyrene's release to the environment is ubiquitous since it is a ubiquitous product of incomplete combustion. It is largely associated with particulate matter, soils and sediments. Although environmental concentrations are highest near sources, its presence in places distant from primary sources indicates that it is reasonably stable in the atmosphere and capable of long distance transport [366].
>
> When released to air it may be subject to direct photolysis, although adsorption to particulates apparently can retard this process. Half-lives for reaction of vapor phase pyrene with atmospheric pollutants are: O_3, 0.67 days, NO_2, 14 days; estimated half-life for reaction with photochemically produced hydroxyl radicals is 1.12 days [366].

If released to water, it will adsorb very strongly to sediments and particulate matter, bioconcentrate in aquatic organisms slightly to moderately, but will not hydrolyze. It may be subject to significant biodegradation, and direct photolysis may be important near the surface of waters. Evaporation may be important with a half-life of 4.8 to 39.2 days predicted for evaporation from a river 1 m deep, flowing at 1 m/sec with a wind velocity of 3 m/sec; half-life for evaporation from a model pond was 1176 days. Adsorption to sediments and particulates will limit evaporation [366].

If released to soil it will be expected to adsorb very strongly to the soil and will not be expected to appreciably leach to the groundwater, although its presence in groundwater illustrates that it can be transported there. It will not be expected to hydrolyze or significantly evaporate from soils and surfaces. It may be subject to appreciable biodegradation in soils. Human exposure will be from inhalation of contaminated air and consumption of contaminated food and water. Especially high exposure will occur through the smoking of cigarettes and the ingestion of certain foods (eg, smoked and charcoal-broiled meats and fish) [366].

Synonyms/Substance Identification:

Benzo(d,e,f)phenanthrene [366]
Benzo(def)phenanthrene [366]
Beta-pyrene [366]
Molecular Formula [366]:
C16-H10

Associated Chemicals or Topics (Includes Transformation Products):

See individual entries in this volume:

PAHs as a group
Fluoranthene/pyrene, C1-
PAHs, Alkyl Homologs of

Impurities [366]:

The usual contaminant which gives it a yellow color is tetracene. [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1149] [366].

Metabolism/Metabolites [366]:

Yields trans-4,5-dihydro-4,5-dihydroxypyrene, s-(4,5-dihydro-

4-hydroxypyren-5-yl)glutathione, 1,6-dihydroxypyrene, 1,8-dihydroxypyrene & 1-hydroxypyrene in rats & rabbits: Boyland E & Sims P, Biochem J 90: 391 (1964). [Goodwin, B.L. Handbook of Intermediary Metabolism of Aromatic Compounds. New York: Wiley, 1976.,p. P-44].

For k-region of pyrene (4,5 bond), no evidence of phenol formation is found, 4,5-dihydrodiol is detected in relatively small amt, & no 4,5-dihydroxypyrene derivatives are found. Major metabolite appears to be mercapturic acid, n-acetyl-s-(4,5-dihydro-4-hydroxy-5-pyrenyl)l-cysteine. [Searle, C. E. (ed.). Chemical carcinogens. Acs monograph 173. Washington, DC: American Chemical Society, 1976. 287].

Pyrene was metabolized by liver microsomes from untreated rats to 1-hydroxypyrene, 4,5-dihydroxy-4,5-dihydropyrene, 2 different diphenols, & a k-region triol, tentatively identified as 1,4,5-trihydroxy-4,5-dihydropyrene. Pretreatment with phenobarbital or polychlorinated biphenyls favored oxidn at k-region, whereas cytochrome p-448 inducers stimulated oxidn at non-k region of pyrene. Hydroxypyrene did not inhibit pyrene oxidn. Pyrene diphenols were formed by secondary oxidn of 1-hydroxypyrene. Triols were formed from dihydrodiols by secondary oxidn. [Jacob J et al; Xenobiotica 12 (1): 45-53 (1982)].

/SRP: 1,6-Pyrenequinone & 1,8-pyrenequinone were isolated & identified in the metabolites of pyrene by liver microsomal fraction from polychlorinated biphenyl-pretreated rats/. [Okamoto H, Yoshida D; Cancer Lett 11 (3): 215-20 (1981)].

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

W.Low (Water Concentrations Considered Low):

No information found.

W.High (Water Concentrations Considered High):

Information from ATSDR on PAHs in water (for information on embedded references, see ATSDR) [881]:

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.Typical (Water Concentrations Considered Typical):

Pyrene concentrations in waste water range from 0.00023 to 11.8 ug/L [847].

Information from ATSDR on PAHs in water (for information on embedded references, see ATSDR) [881]:

> During April and May 1990, Hall et al. (1993) analyzed 48-hour composite samples from three locations in the Potomac River and three locations in the upper Chesapeake Bay for eight PAHs: perylene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz[a]anthracene, and chrysene. Pyrene was the only PAH found (0.42 ug/L) in these samples; it was detected in only one of nine Chesapeake Bay samples and not detected in any of the Potomac River samples (detection limit, 0.04 ug/L) [881].
>
> In a more recent study by Pham et al. (1993), raw water samples from 5 areas in the St. Lawrence River and its tributaries were analyzed for 12 PAHs. The highest mean total PAH concentrations were observed in samples collected in the spring (27.3 ng/L) and autumn (21.03 ng/L), which was attributed to snow melt and increased runoff during these respective seasons. The lowest mean total PAH concentration was observed in summer (14.63 ng/L). High molecular weight PAHs were detected more frequently in the spring and autumn samples. Phenanthrene, benzo[b]fluoranthene, fluoranthene, and pyrene were predominant, comprising on average 33.8%, 17.4%, 17.1% and 12.8% of the total PAHs, respectively. With the exception of anthracene and benzo[b]fluoranthene, a general decrease in concentration with increasing molecular weight was observed [881].

Information from HSDB [366]:

> Pyrene was one of the polycyclic aromatic hydrocarbons (PAH) determined in samples from bekkelaget sewage treatment plant in Oslo receiving indust waste water & household sewage: during dry period in 1979 (189 ng/l); after rainfall 1979 (168 ng/l); dry period (spring) 1980 (248 ng/l); after rainfall (summer) 1980 (110 ng/l). Five samples of nordic tap water were analyzed for polycyclic aromatic hydrocarbons. Concentrations of pyrene found were 12 ng/l, 8.5 Ng/l, 0.31 Ng/l, less than 0.30 Ng/l, & less than 0.72 Ng/l, respectively. [Kveseth K et al; Chemosphere 11 (7): 623-39 (1982)].
>
> DRINKING WATER: Norway, 1.1 ppt(1). Eastern

Ontario, Canada, 5 municipal plants, June-October, 1978, 0.04-2.0 ppb, avg 0.6 ppb, raw water, avg 1.0 ppb(2). Great Lakes area, 12 systems, 1980, Jan, 1.3-72.0 ppt, July-Aug, not detected - 31.0 ppt(3). [(1) IARC; Monograph on the Evaluation of the Carcinogenic Risk of Chemicals to Humans 32: 432-45 (1983) (2) Santodonato J et al; Hazard Profiles on PAH p 53 TR-81-633 (1981) (3) Williams DT et al; Chemosphere 3: 263-76 (1982)].

GROUNDWATER: 1.6-2.5 ppt(1). [(1) IARC; Monograph on the Evaluation of the Carcinogenic Risk of Chemicals to Humans 32: 432-45 (1983)].

SURFACE WATER: Eastern Ontario, raw waters, June-Oct, 1978, 0.2-1.7 ppt(1). River water, < 0.001 ppm(1). Storet Database, 904 samples, 4.0% pos, avg < 10 ppb(2). [(1) Verschueren K; Handbook of Environmental Data on Organic Chemicals 2nd ed Von Nostrand Reinhold NY (1983) p 1033 (1983) (2) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985)].

RAINWATER: Rainwater, 5.8-27.8 ppt(1). [(1) IARC; Monograph on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. 32: 432-45 (1983)].

Effluents Concentrations [366]:

Data on emission levels of wastewaters & solid residuals from petroleum refining industry are summarized. Types of waste water & residual samples for which data are presented incl raw waste loadings from class A through E refineries, loading of various pollutants across several process units such as dissolved air flotation, activated sludge process, carbon columns (powdered & granular), & clarifiers, & oily solids (tank bottoms, crude oil, bunker c, & waxy product). Pyrene concn ranges found in refinery category B, C, E, & an undesignated category (biotreatment effluent < 0.1 To 30 ug/l, 3 ug/l, 0.7 To 16 ug/l, & 5.4 Ug/l: final effluent < 1 to 7 ug/l, < 0.5 Ug/l, < 1 ug/l, & < 0.1 Ug/l) respectively. [Snider EH, Manning FS; environ int 7 (4): 237-58 (1982)].

STORET database, 1,271 samples, 5.2% positive, < 10 ppb(1). US National Urban Runoff Program, 15 cities, 40% positive, 86 samples, 11% positive, 0.3-10 ppb(2). Estimated emissions from mobile sources, 1979, 950 metric tons(3). Domestic effluent, 1.8 ppb; sewage: high percentage industry, 2.56-3.12 ppb, dry weather, 0.25 ppb, heavy rain, 16.1 ppb(4). 1964: automobile, 47.5

ug/km travelled, truck 275.0 ug/km; petroleum cracking, 245 ug/cu m; municipal incineration, 17.6 ug/km open burning of municipal refuse, 1762 ug/kg(5). Tire manufacturing plant wastewater, 10 ppb(6). [(1) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985) (2) Cole RH et al; J Water Pollut Control Fed 56: 898-908 (1984) (3) National Research Council; Polycyclic Aromatic Hydrocarbons: Evaluation of Sources and Effects, National Acad Press Washington DC (1983) (4) Verschueren K; Handbook of Environmental Data on Organic Chemicals 2nd ed Von Nostrand Reinhold NY p 272 (1983) (5) Santodonato J et al; J Environ Pathol Toxicol 5: 1-364 (1981) (6) Jungclaus GA et al; Anal Chem 48: 1894-6 (1976)].

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

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

Cautionary note: This is a phototoxic compound (see more detailed discussion in the "PAHs as a group entry" in this volume). 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]. 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:

Canada's Interim Assessment Criterion for pyrene is 0.2 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.

EPA 1996 Natioinal Ambient Water Quality Criteria for Aquatic Organisims (IRIS):

Freshwater Acute Criteria: None Published [893].

Freshwater Chronic Criteria: None Published [893].

Marine Acute Criteria: 3.0E+2 ug/L LEC [893].

Marine Chronic Criteria: None Published [893].

Reference: 45 FR 79318 (11/28/80)

W.Plants (Water Concentrations vs. Plants):

No information found.

W.Invertebrates (Water Concentrations vs. Invertebrates):

LC50s for Aedes aegypti (mosquito) were 20 and 35 ug/L (ppb) for 1-hr and 24-hr exposures, respectively [998].

LC50 for Aedes taeniorhynchus (mosquito) was 60 ug/L for a 24-hr exposure [998].

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

LC50 for Artemia salina (brine shrimp) was 8 ug/L (ppb) for a 1-hr exposure [998].

LC50 for Daphnia magna (water flea) was 4 ug/L for a 1-hr exposure [998].

W.Fish (Water Concentrations vs. Fish):

TLm (Median threshold limit) Mosquito fish 0.0026 mg/l/96 hr at 24-27 deg C in a static bioassay [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 1034] [366].

LC50 for Pimephales promelas (fathead minnow) was 220 ug/L (0.220 mg/L, ppm) for a 30-minute exposure [998].

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

No information found.

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

EPA 1996 IRIS database information [893]:

Ambient Water Quality Criteria for Human Health:

Water & Fish: 2.8E-3 ug/liter

Earlier Documentation of same concentration for Human Health (10-6) Risk Level for Carcinogens: Published Criteria for Water and Organisms: 0.0028 ug/L [689].

Fish Only: 3.11E-2 ug/liter

Earlier Documentation of same concentration as Human Health (10-6) Risk Level for Carcinogens: Published Criteria for Organisms Only: 0.0311 ug/L [689].

Reference: 45 FR 79318 (11/28/80)

Contact: Criteria and Standards Division / OWRS / (202)260-1315

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. The values given represent polynuclear aromatic hydrocarbons as a class.

Additional discussion [366]:

For the maximum protection of human health from the potential carcinogenic effects due to exposure of polynuclear aromatic hydrocarbons through ingestion of contaminated water and contaminated aquatic organisms, ... therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 1x10-5, 1x10-6, and 1x10-7. The corresponding ambient water criteria are 28.0 ng/l, 2.8 ng/l, and 0.28 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 311.0 ng/l, 31.1 ng/l, and 3.11 ng/l respectively. /Polynuclear aromatic hydrocarbons based on benzo(a)pyrene as the model PAH [USEPA; Ambient Water Quality Criteria Doc: Polynuclear Aromatic Hydrocarbons (Draft) p.C-121 (1980)].

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].

Drinking Water MCL: None Published [446,893,928].

NOTE: For critical applications, 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 and IRIS is updated monthly [893].

EPA Region 9 Preliminary remediation goal (PRG) for Tap Water, 1995 [868]: 1.1E+03 ug/L.

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

Numeric Water Quality Criteria in Arizona [881]:

Domestic water supply: 210 ug/L
Fish consumption: 1100 ug/L
Full body contact: 4200 ug/L
Partial body contact: 4200 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].

PAHs have been detected in surface waters of the United States. In an assessment of STORET data covering the period 1980-82, Staples et al. (1985) reported median concentrations in ambient water of less than 10 ug/L for 15 PAHs (acenaphthene, acenaphthylene, anthracene, benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[g,h,i]perylene, benzo[a]pyrene, chrysene, fluoranthene, fluorene, indeno[1,2,3-c,d]pyrene, naphthalene, phenanthrene, and pyrene). The percentage of samples in which these PAHs were detected ranged from 1.0 (benzo[g,h,i]perylene) to 5.0 (phenanthrene) and 7.0 (naphthalene) [881].

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

Sed.Low (Sediment Concentrations Considered Low):

No information found.

Sed.High (Sediment Concentrations Considered High):

Analyses of sewage sludges from 50 publicly owned treatment works by the U.S. Environmental Protection Agency (1985): The mean concentration of pyrene was 6.8 ppm (dry weight) [347].

Sed.Typical (Sediment Concentrations Considered Typical):

Pyrene concentrations in dried sediment from lakes ranged from 7 to 3940 ug/kg [847].

Pyrene was detected in 100 % of urban-bay samples from the Puget Sound area. The mean concentration was 3775 ug/kg dry weight (ppb), while the median concentration was 523 ug/kg (ppb) [852].

Pyrene was detected in 81.3 % of non-urban-bay samples from the Puget Sound area. The mean concentration was 3920 ug/kg dry weight (ppb), while the median concentration was 135 ug/kg (ppb) [852].

> NOTE: The above values from [852] 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 [145].

Information from HSDB [366]:

> SEDIMENTS: Wilderness Lake, Ontario, Canada, 1976, 23 ppb (dry wt); Lake Constance, rapid sand filter solids, 0.2 ppm(1). Lake sediments, 0.38 ppm; rivers, 0.33 ppm; river particulates, 6.0 ppm(2). Buzzards Bay, MA, 0.12-0.96 ppm(2). Niagara River, Niagara-on-the-lake, 1975-82, suspended sediments (susp sed), trace-4,000 ppb(3). Columbia River, WA, 1979, 11 monthly samples, 24-410 ppb (dry wt)(max January, min June), avg 56 ppb(4). Woods Lake, remote Adirondack lake, NY, March, 1978, 16-930 ppb (max 0-4 cm depth)(5). Northwestern Atlantic, 13 samples, 2-12,000 ppb (dry wt)(6). 21 samples, not detected (nd)-13,000 (dry wt) (max Charles River. Boston, MA(7). W Germany, 4 rivers, water solids, 1.1-8.0 ppm(1). Severn Estuary, UK 0.5-3.5 ppm (dry wt)(1). [(1) Verschueren K; Handbook of Environmental Data on Organic Chemicals 2nd ed Von Nostrand Reinhold NY p 1033 (1983) (2) Santodonato J et al; J Environ Pathol Toxicol 5: 1-

364 (1981) (3) Kuntz KW; Toxic Contaminants in the Niagara River, 1975-1982 Burlington, Ontario Tech Bull No.134 (1984) (4) Prahl FG et al; Environ Sci Technol 18: 687-93 (1984) (5) Tan YL, Heit M; Geochim Cosmochim Acta 45: 2267-79 (1981) (6) Windsor JG, Hites RA; Geochim Cosmochim Acta 43: 27-33 (1979) (7) Hites RA et al; Adv Chem Ser 185: 189-311 (1980)].

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

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

Various Concern Levels for Sediment Concentrations (Dry Weight):

EPA, 1988: The interim sediment criteria value proposed by EPA was 19.0 mg/kg [145].

AET, EPA 1988: The apparent effects threshold concentrations for pyrene in sediments proposed for Puget Sound ranged from 2.6 mg/kg dry weight (microtox) to 16 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.

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 in this volume).

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 2600 ppb dry weight Effects Range-Median (ERM) concentration and was lowest in sediments where its concentration was less than the 665 ppb dry weight Effects Range-Low (ERL) concentration [664]. To improve the original 1990 guidelines [233], the 1995 report included percent (ratios) incidence of effects for ranges below, above, and between the ERL and ERM values. These numbers represent the number of data entries within each concentration range in which biological effects were observed divided by the total number of entries within each range [664]:

<ERL	17.2
ERL-ERM	53.1
>ERM	87.5

Oak Ridge National Lab, 1994: Risk Assessment Screening Benchmarks for Sediment Concentrations. To be considered unlikely to represent an ecological risk, field pyrene concentrations should be below the following benchmark [652]:

> 13.1 mg/kg (ppm) dry weight is the interim (1988) sediment quality criterion - 1% Organic Carbon.

Ontario Ministry of the Environment Freshwater Sediment Guidelines, 1993. Lowest effect level: 490 ug/kg dry weight. Severe effect level: 850 mg/kg organic carbon [761].

St. Lawrence Interim Freshwater Sediment Criteria, 1992. No effect: 20-100 ug/kg dry weight. Minimal effect: 700 ug/kg dry weight. Toxic effect: 100 mg/kg organic carbon [761].

Environment Canada Interim Sediment Quality Assessment Values. Toxic effect level: 53.0 ug/kg dry weight. Probable effect level: 875.0 ug/kg dry weight [761].

Sed.Plants (Sediment Concentrations vs. Plants):

No information found.

Sed.Invertebrates (Sediment Concentrations vs. Invertebrates):

No information found.

Sed.Fish (Sediment Concentrations vs. Fish):

No information found.

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

No information found.

Sed.Human (Sediment Concentrations vs. Human):

No information found.

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

In a study of the effects of motor boat activity on the water and sediment quality of a drinking water reservoir near Washington, D.C., only a few PAHs (like phenanthrene, pyrene, and fluoranthene) were commonly found in the sediments, unlike the water samples in which all 11 of the PAHs monitored were frequently found [653].

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. /Concentration data not specified/ [Black JJ; Polynucl Aromat Hydrocarbons Int Symp 7th 99-11 (1983)] [366].

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

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

Soil.Low (Soil Concentrations Considered Low):

Soil criteria for evaluating the severity of contamination under the Dutch Soil Cleanup (Interim) Act (1982): 0.1 ppm indicates a background concentration of pyrene [347].

Soil.High (Soil 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 pyrene was 6.8 ppm (dry weight) [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 concentration of pyrene in the soil was 2.5 ppm (dry weight) and the range was <0.15-6.1 ppm. [347].

The following information is for representative individual PAHs: Soil samples collected from the site of a Seattle coal and oil gasification site, which ceased operation in 1956, contained pyrene levels up to 4,300 ug/kg. Soil samples collected from the Fountain Avenue Landfill in New York contained total PAH concentrations of 400-10,000 ug/kg [788]. A benzo(a)pyrene concentration of 650,000 ug/kg was measured in soil 10 meters from an industrial plant in Germany [788].

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]:

Pyrene	1,303

Soil.Typical (Soil Concentrations Considered Typical):

Information from ATSDR on PAHs in soil (for information on embedded references, see ATSDR) [881]:

> 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].

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
Pyrene	1-19.7	99-150	145-147,000

Information from HSDB [366]:

SOILS: Nova Scotia, Canada, 29 samples, 10 sites, < 0.1-64 ppb (dry wt), median, 5 ppb(6). 17 soil samples, nd-410 ppb (dry wt)(7). [(6) Windsor JG, Hites RA; Geochim Cosmochim Acta 43: 27-33 (1979) (7) Hites RA et al; Adv Chem Ser 185: 189-311 (1980)].

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

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

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

Canada's Interim Assessment Criterion for pyrene 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 pyrene in soil for three different land-uses (ug/g dry weight) [656]:

Agricultural = 0.1
Residential/Parkland = 10
Commercial/Industrial = 100

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].

The Canadian AET concentration (adapted from NOAA 1990) for pyrene sorbed to marine sediments is 1.000 mg/kg dry weight [864]. An AET (apparent effects threshold) 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].

Soil criteria for evaluating the severity of contamination under the Dutch Soil Cleanup (Interim) Act (1982): 100 ppm indicates a threshold value that requires immediate cleanup [347].

Soil.Plants (Soil Concentrations vs. Plants):

No information found.

Soil.Invertebrates (Soil Concentrations vs. Invertebrates):

Concentrations of PAH's in bioassay earthworms and bioassay soil from 15 sites at the Times Beach Confined Disposal Facility in Buffalo, N.Y. (1987): The mean concentration of pyrene in the soil was 2.5 ppm (dry weight) and the range was <0.15-6.1 ppm. The mean concentration of pyrene in earthworms was 0.23 ppm (ash-free dry weight) and the range was <0.015-4.5 ppm [347].

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

No information found.

Soil.Human (Soil Concentrations vs. Humans):

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

SSL = 2300 mg/kg for ingestion pathway [952].

SSL = 210 to 4200 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), 1995 [868]:

Residential Soil: 2.0E+3 mg/kg wet wt.
Industrial Soil: 2.0E+4 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) Values are based on a non-carcinogenic hazard quotient of one.
3) PRGs for residential and industrial landuses are slightly lower concentrations than EPA Region III RBCs, which consider fewer aspects [903].

EPA 1995 Region III Risk based concentration (RBC) to protect from transfers to groundwater:

1400 mg/kg dry weight [903].

See also Canada's Interim Criteria [656] in Soil.General section above.

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

No information found.

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

Tis.Plants:

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

No information found.

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

Natural background levels: poison oak (leaves), 40 ppb (dry wt), little bluestem (leaves), 30 ppb (dry wt)(1). [(1) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983)] [366].

Tis.Invertebrates:

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

No information found.

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

No information found.

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

Details of pyrene 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):

pyrene: 32.9 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 pyrene in the soil was 2.5 ppm (dry weight) and the range was <0.15-6.1 ppm. The mean concentration of pyrene in earthworms was 0.23 ppm (ash-free dry weight) and the range was <0.015-4.5 ppm [347].

Pyrene was one of the polycyclic aromatic hydrocarbons (PAH) determined in samples from Bekkelaget sewage treatment plant in Oslo receiving indust waste water & household sewage. Stationary mussels outside treatment plant contained 90 ng/g dec 8; 99 ng/g Dec 11; 82 ng/g Dec 15; 101 ng/g Dec 22; 132 ng/g Jan 6; & 80 ng/g April 28; transplanted mussels outside bekkelaget sewage treatment plant 16 ng/g dec 11; 51 ng/g dec 22; 40 ng/g Jan 6; 50 ng/g April 28. From the PAH-profiles observed in mussels near the discharge-point, it was concluded that the sewage treatment plant is major PAH-source in the area. [Kveseth K et al; Chemosphere 11 (7): 623-39 (1982)] [366].

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):

Fish don't tend to accumulate high concentrations of PAHs. See also Tis.Human section below.

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 = 41 mg/kg wet weight. However, the reader should keep in mind that PAHs seldom get this high in fish, that a bigger concern might be invertebrates, that elevated concentrations of individual PAHs often occur in the presence of complex mixtures of PAHs, and that complex mixtures of PAHs often display carcinogenic and phototoxic properties (see "PAHs as a group" entry in this volume).

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.Human, section A), below for more fish/seafood data.

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

Fish/Seafood Concentrations [366]:

> Samples of winter flounder, windowpane, red hake, rock crab, lobster, & sea scallops were collected from 25 sites in new york bight & long island sound region & analyzed by hplc for presence of 15 polycyclic aromatic hydrocarbons (PAH). Results show that the new york bight area is a site of measurable & significant pah contamination. [Humason AW, Gadbois DF; Bull Environ Contam Toxicol 29 (6): 645-50 (1982)].

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

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

No information found.

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

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.Human:

A) Typical Concentrations in Human Food Survey Items:

See also Tis.Fish, C) above.

Information from HSDB [366]:

> United Kingdom, 1979, total diets, 0.016 ug/kg/day; food groups, range (avg) ppb: cereals, 1.42-3.44 (1.85), meat, 0.25-0.94 (0.55), oils and fats, 0.45-4.04 (1.75), fruit and sugar, 0.34-1.22 (0.83), root vegetables, not detected (nd)- 0.74 (0.24), beverages, nd-0.16 (0.04)(3). Smoked foods (ppb): ham, 0.2-

11.2, pork roll, 2.5, frankfurters, 3.8, gouda cheese, 2.6 ppb, hot sausage, 1.5, barbecued beef, 3.2, chipped beef, 0.5(1), mutton, 8.0 ppb, salami, 5.2 ppb, mortadella, 15.0 ppb, heavily smoked bacon, 27.0 ppb, heavily smoked ham, 35.0-161.0 ppb(2). Charcoal broiled steaks, 35.0 ppb, charcoal broiled hamburger: fat-hot temp, 7.7 ppb, lean-hot temp, 1.6 ppb, lean-cool temp, 0.6, no drip pan, 0.1 ppb; bbq ribs, 42.0 ppb, bbq beef, 3.2 ppb(2). Vegetable oils, 6 types, range of avg 1.6-15 ppb(2). Bakers yeast, 11.6-327 ppb (max Scotland)(2). Milled wheat, 1.5-28 ppb (max, bran fraction); cereals, 2.2-21 ppb(4). [(1) Fazio T, Howard JW; p 461-506 in Handbook of Aromatic Hydrocarbons (1983) (2) Santodonato J et al; J Environ Pathol Toxicol 5: 1-364 (1981) (3) Dennis MJ et al; Food Chem Toxicol 21: 569-74 (1983) (4) Lawrence JF, Weber DF; J Agric Food Chem 32: 794-7 (1984)].

Smoked seafood: 6 species, < 0.5-4.0 ppb(1); 5 species, 1-6 ppb(2). Non-smoked fish: 3 species, 0.8-1.4 ppb(2). UK, 1979, total diets, fish, 0.36-2.11 ppb, avg 0.79 ppb(3). Mussels, Saudafjord, Norway, 1976, 105-8164 ppb (dry wt)(4). Oysters, 1983, not detected-50.1 ppb (wet wt)(5). [(1) Fazio T, Howard JW; pp 461-506 in Handbook of Aromatic Hydrocarbons (1983) (2) Santodonato J et al; J Environ Pathol Toxicol 5: 1-364 (1981) (3) Dennis MJ et al; Food Chem Toxicol 21: 569-74 (1983) (4) Bjorseth A et al; Sci Total Environ 13: 71-86 (1979) (5) Marcus JM, Stokes TP; Bull Environ Contam Toxicol 35: 835-44 (1985)].

Milk Concentrations [366]: Dried skim milk, 2.1 ppb(1). UK, 1979, total diets, milk products, not detected-0.23 ppb, avg 0.04 ppb(2). [(1) Lawrence JF, Weber DF; J Agric Fd Chem 32: 794-7 (1984) (2) Dennis MJ et al; Fd Chem Toxicol 21: 569-74 (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):

EPA 1996 IRIS database information [893]:

Crit. Dose: 75 mg/kg-day [Study 1 NOAEL].

RfD: 3E-2 mg/kg-day Confidence: Low

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 = 41 mg/kg wet weight. However, the reader should keep in mind that PAHs seldom get this high in fish, that a bigger concern might be invertebrates, that elevated concentrations of individual PAHs often occur in the presence of complex mixtures of PAHs, and that complex mixtures of PAHs often display carcinogenic and phototoxic properties (see "PAHs as a group" entry in this volume).

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

Information from HSDB [366]:

Human liver, 270-470 ppt (wet wt); fat, 49-2,700 ppt (wet wt)(1). [(1) National Research Council; Polycyclic Aromatic Hydrocarbons: Evaluation of Sources and Effects, National Acad Press Washington DC pp 6-36 to 6-37 (1983)].

The genotoxic effects of exposure to polycyclic aromatic hydrocarbons (PAH) in 38 topside coke oven workers was evaluated by the analysis of urine samples, workplace air samples and sera antibodies to an epitope on DNA adducts. Air analysis by means of capillary gas chromatography demonstrated that the levels recorded ranged from 212 to 315 mg/cu m air in the air outside the mask of the workers to 51 to 162 mg/cu m inside the mask. ... High pressure liquid chromatography revealed mean urinary PAH levels of 0.57 and 0.87 mg/mmole of creatinine for smokers and nonsmokers, respectively. [Haugen A et al; Cancer Res 46 (8): 4178-83 (1986)].

Tis.Misc. (Other Tissue Information):

This is a phototoxic PAH [891,911,887].

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

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

Bioconcentration Factor, log BCF [848]:

0.716 to 4.75 (most values 3.43). Specific values were: 3.43 for Daphnia pulex, 4.38 for mixed microbial population, 4.65 for p. hoyi, 4.08 for microorganisms in water, 2.66 for goldfish, 3.65 for mussel, 3.81 for clam, and 2.35 for shrimp.

HSDB Information [366]:

1. Reported BCF: rainbow trout, 72(1); goldfish, 457(2); fathead minnow, 600-970(3). Based on these values, minimal to moderate bioconcentration of pyrene in aquatic organisms would be expected(SRC). [(1) Spehar RL et al; J Water Pollut Control Fed 52: 1703-74 (1980) (2) Ogata M et al; Bull Environ Contam Toxicol 33: 561-7 (1984) (3) Carlson RM et al; Implications to the Aquatic Environment of Polynuclear Aromatic Hydrocarbons Liberated from Northern Great Plains Coal USEPA-600/2-79-093 (1979)].

2. Polycyclic aromatic hydrocarbons (PAH) were analyzed in surfacial sediments & benthic organisms in southeastern Lake Erie, near a large coal-fired power plant. Sediment concn (530-770 ppb PAH) were relatively homogenous throughout most of the 150 square km area, although river & nearshore concentrations reached 4 ppm. Oligochaete worms did not bioconcentrate (on wet wt basis) any of the PAH. Chironomide midges collected 1 km offshore exhibited bioconcentration of 5 PAH one of which was pyrene. Further offshore, these apparent bioconcentrations disappeared, with midges at near equilibrium with sediments. [Eadie BJ et al; Chemosphere 11 (2): 185-92 (1982)].

3. ... 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].

4. Bioaccumulation, especially in vertebrate organisms, is considered to be short-term, and is not considered an

important 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. 95-9].

Interactions:

Eight compounds present in crude coal tar were tested for phototoxicity on guinea pig skin. Four concentrations (5 millimicro molar to 5 millimolar) of each cmpd in ethanol were applied to dorsal surface of 6 animals. Each animal received 1.0E+5 j/square meter of UVA radiation. The erythematous (phototoxic) response was evaluated after 20 hr. Pyrene was strongly phototoxic. [Kochevar IE et al; Photochem Photobiol 36 (1): 65-9 (1982)] [366].

Co-carcinogenic studies on mouse skin (50 female icr/ha mice per group) were conducted. Simultaneous dermal application of 5 ug benzo(a)pyrene in same soln with pyrene (0.004 & 0.012 Mg) 3 times weekly in 0.1 Ml acetone per application resulted in 6/50 & 20/50 mice with squamous carcinomas, respectively. No neoplasms were observed in mice treated with pyrene alone. /From table/ [Searle, C. E. (ed.). Chemical Carcinogens. ACS Monograph 173. Washington, DC: American Chemical Society, 1976. 35] [366].

Uses/Sources:

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

Although considered "pyrogenic" by some, pyrene is also somewhat petrogenic in that it is found in many petroleum products (see Chem.Detail section below).

Pyrene occurs in crude oils at concentrations ranging from 3.5 to 41 ppm [177]. Used motor oil may contain 120 ppm pyrene [519].

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.

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]:

1. Since pyrene is a product of incomplete combustion, there will be natural sources arising from volcanoes, forest fires etc(SRC). There is some evidence for biosynthesis by plants and bacteria(2). Fossil fuels and coal-tar(3); crude oil, 3.5-4.5 ppm(1). [(1) Verschueren K; Handbook of Environmental Data on Organic Chemicals 2nd ed Von Nostrand Reinhold NY (1983) p 1031 (1983) (2) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (3) IARC; Monograph on the Evaluation of the Carcinogenic Risk of Chemicals to Humans 32: 432-45 (1983)].

2. /Found in the following natural sources:/ Kuwait Crude oil, 4.5 ppm; South Louisiana crude oil, 3.5 ppm [VERSCHUEREN. HDBK ENVIRON DATA ORG CHEM 1983 p.1031].

Artificial Sources [366]:

1. Ubiquitous product of incomplete combustion, occurring in exhaust from motor vehicles and other gasoline and diesel engines, emissions from coal-, oil-, and wood-burning stoves and furnaces, cigarette smoke; generally released from soot and smoke of industrial, municipal and domestic origin, and found in cooked foods, especially charcoal-broiled(1). Incinerators and coke ovens(2). [(1) IARC; Monograph on the Evaluation of the Carcinogenic Risk of Chemicals to Humans 32: 432-45 (1983) (2) Verschueren K; Handbook of Environmental Data on Organic Chemicals. 2nd ed Von Nostrand Reinhold NY (1983) p 1031-4 (1983)].

Other Environmental Concentrations [366]:

1. Mainstream cigarette smoke, 1.7-14 ug/100 cigarettes; one reported value of 27 ug/cigarette; sidestream cigarette smoke, 101-390 ug/cigarette; smoke-filled rooms, 8.0 ppt; cigar smoke, 17.6 ug/100 g tobacco consumed; pipe smoke, 75.5 ug/100 g tobacco; mainstream marijuana smoke, 6.6 ug/100 cigarettes(1). [(1) IARC; Monograph on the Evaluation of the Carcinogenic Risk of Chemicals to Humans 32: 432-45 (1983)].

2. /Found in the following man-made sources:/ gasoline -

1.55 mg/l; 4.7 mg/l, 17 mg/kg; bitumen - 0.17-0.80 ppm; Coal tar- 46.5 mg/g of sample, 19,000 ppm; wood preservative sludge - 24.2 g/l of raw sludge; fresh motor-oil - 0.29 mg/kg; used motor-oil, 10.7-743 mg/kg [VERSCHUEREN. HDBK ENVIRON DATA ORG CHEM 1983 p.1031].

Forms/Preparations/Formulations:

No information found.

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

Water Solubilities:

0.032 to 1.56 mg/L at 25 degrees C (most values near 0.134) [848].

Virtually insoluble in water (129 to 165 ug/L) [847].

Other Solubilities [366]:

Sol in carbon disulfide, & toluene [Weast, R.C. (ed.). Handbook of Chemistry and Physics. 60th ed. Boca Raton, Florida: CRC Press Inc., 1979.,p. C-471].

Sol in alc, ether, benzene, & petroleum ether [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 67th ed. Boca Raton, FL: CRC Press, Inc., 1986-87.,p. C-461].

Henry' Law Constant [848]:

0.125 to 694.1 Pa m3/mol (most values near 1.20).

Vapor Pressure [848]:

0.00017 to 0.014 Pa at 25 degrees C (most values 0.00033 to 0.00088).

Density/Specific Gravity [366]:

1.271 AT 23 DEG C [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1149].

Octanol/Water Partition Coefficient, log Kow [848]:

4.45 to 6.70 (most values 4.88 to 5.18).

Sorption Partition Coefficient, log Koc [848]:

3.11 to 6.51 (most values near 4.82).

Molecular Weight [366]:

1. 202.26 [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 67th ed. Boca Raton, FL: CRC Press, Inc., 1986-87.,p. C-461].

Boiling Point [366]:

1. 393 deg C at 760 mm Hg; 260 deg C at 60 mm Hg [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 67th ed. Boca Raton, FL: CRC Press, Inc., 1986-87.,p. C-461].

Melting Point [366]:

1. 156 DEG C [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1149].

Color/Form [366]:

1. Monoclinic prismatic tablets from alcohol or by sublimation; pure pyrene is colorless [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1149].

2. Pale yellow plates (when recrystallized from toluene) [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 67th ed. Boca Raton, FL: CRC Press, Inc., 1986-87.,p. C-461].

3. Colorless solid (tetracene impurities give yellow color) [Sax, N.I. and R.J. Lewis, Sr. (eds.). Hawley's Condensed Chemical Dictionary. 11th ed. New York: Van Nostrand Reinhold Co., 1987. 981].

Pyrene concentrations in Used Engine Oil: 120 ppm [519]; 430 mg/kg [847].

Concentrations of pyrene in South Louisiana crude, Kuwait crude, No. 2 fuel oil, and Bunker C residual were 3.5, 4.5, 41, and 23 mg/kg (ppm), respectively [177]. Another study showed concentrations of pyrene in South Louisiana crude and Kuwait crude were 4.3 and 4.5 10(-6)g/g oil (ppm), respectively [747].

Pyrene concentrations in crude oil range from 1.6 to 10.7 mg/kg [847].

Pyrene 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: 9, 7, and 7 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].

Pyrene content (mg/kg or ppm) in one fresh sample of Exxon Valdez Crude Oil [971]: 10 mg/kg = ppm

Pyrene content in one fresh sample of NSFO (Fuel Oil 5, Chuck

Rafkind, National Park Service, Personal Communication, 1996): 177.9 ng/mg (ppm).

Pyrene 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): 5900.6 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).

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

Near-surface half-life for direct photochemical transformation was 0.58 hour at latitude 40 deg N, midday, midsummer; at 5 m deep with no sediment-water partitioning the half-life was 4.2 days, and with sediment-water partitioning it was 5.9 days [848]. Another source quotes 0.69 to 2.04 hours in surface water [848].

Half-lives in groundwater were 10,080 to 91,200 hours (based on the estimated unacclimated aqueous aerobic biodegradation half-life) [848].

Half-lives in soil [848]: 3 to 35 hours; 58 days for 5 mg/kg treatment, and 48 days for 50 mg/kg treatment; 5,040 to 45,600 hours (based on aerobic soil dieaway test data at 10-30 deg C); >50 days; 260 days for Kidman sandy loam soil, and 199 days for McLaurin sandy loam soil; 500 days; 0.4 to more than 90 weeks; and 8.5 years.

Environmental Fate [366]:

> TERRESTRIAL FATE: If pyrene is released to soil, it will be expected to adsorb very strongly to the soil and will not be expected to leach to the groundwater. Although no information concerning biodegradation in soil was located, pyrene has been shown to be metabolized in laboratory tests by microorganisms isolated from soils and natural waters. This suggests that it may also be degraded in the soil. It will not hydrolyze and evaporation from soils and surfaces will not be expected to be significant. (SRC)
>
> AQUATIC FATE: If released to water, pyrene will be expected to adsorb very strongly to sediments and particulate matter. It will not hydrolyze but may undergo slight to moderate bioconcentration. It may be subject to significant biodegradation in the water column. A near the surface half-life for direct photolysis in water of 0.68 hours suggests that photodegradation may be a significant removal process in the water column. Evaporation may be significant in certain waters with estimated half-lives ranging from 4.8 to 39.2 days

for evaporation of pyrene from a river 1 m deep, flowing at 1 m/sec with a wind velocity of 3 m/sec(1,SRC); the reported half-life for evaporation from a model pond is 1176 days(2), suggesting that evaporation from such bodies of water may not be significant. It is expected that adsorption to sediments and particulates will limit evaporation(SRC). [(1) Lyman WJ et al; Handbook of Chemical Property Estimation Methods NY: McGraw-Hill pp. 15-1 to 15-34 (1982) (2) Davis EM et al; Biodeterioration 5: 176-84 (1983)].

ATMOSPHERIC FATE: Pyrene released to the atmosphere will likely be associated with particulate matter and may be subject to long distance transport, depending mainly on the particle size distribution and climatic conditions which will determine the rates of wet and dry deposition. Its presence in areas remote from primary sources demonstrates the potential for this long range transport as well as pyrene's considerable stability in the air. It may be subject to direct photooxidation but evidence suggests that this process is retarded by the material being in the adsorbed state. In the vapor phase pyrene will be subject to reaction with various atmospheric pollutants with reported half-lives of 0.67 days for O3 and 14 days for NO2(1). The estimated half-life for reaction with photochemically produced hydroxyl radicals is 1.12 days(2,SRC). [(1) National Research Council; Polycyclic Aromatic Hydrocarbons: Evaluation of Sources and Effects, National Acad Press Washington DC (1983) (2) GEMS: Graphical Exposure Modeling System. FAP. Fate of Atmospheric Pollutants (1985)].

Biodegradation [366]:

Bacteria isolated from Colgate Creek, Chesapeake Bay, and cultured in Bay water degraded 19.6-22.4% pyrene present unspecified time; Eastern Bay bacteria similarly cultured affected 2.0-8.2% degradation(1). Pyrene at 5 ppm was 71% degraded with rapid adaptation after 7 days by microbes in settled domestic wastewater, 100% degraded 7 days after addition of the second subculture. At 10 ppm only 13% degradation was observed after 28 total days and the addition of three subcultures(2). Degradation in Center Hill Reservoir water, 4 weeks, 0-57.1%, avg 16.7%(3). In natural water from polluted steam, Urbana, IL, pyrene was cometabolized 63.3% (naphthalene as growth substrate) and 53.8% (phenanthrene growth substrate) in 4 weeks(4). Pyrene levels from sewage treatment plant: raw sewage, < 5 ppb, final effluent, < 5 ppb, waste activated sludge, < 5-423 ppb (wet weight), digester sludge, 50.5-563 ppb (wet weight)(5). Pyrene in contact with organics that are undergoing a high rate of composting was degraded 0 and 31% in 30-day duplicate tests; rate of degradation was higher over the last 23 days than it was the first 7 days(6). Pyrene has been shown to be bioconverted via oxidation by isolated soil bacteria without any growth substrate present(7). [(1) Walker JD, Colwell RR; p 783-90 in

International Conference on Water Pollution Research Vol 7 (1974) (2) Tabak HH et al; J Water Pollut Control Fed 53: 1503-18 (1981) (3) Sayler GS, Serrill TW; Bacterial Degradation of Coal Conversion By-products (Polycyclic Aromatic Hydrocarbons) in Aquatic Environments Office of Water Res and Technol NTIS PB 83-187161 (1981) (4) McKenna EJ; Biodegradation of Polynuclear Aromatic Hydrocarbon Pollutants by Soil and Water Microorganisms Water Resources Center 113: 1-25 (1976) (5) Lue-Hing C et al; AIChE Symp Ser 77: 144-50 (1981) (6) Snell Environmental Group Inc; Rate of Biodegradation of Toxic Compounds While in Contact with Organics which are Actively Composting Lansing, MI NTIS PB 84-193150 (1982) (7) Sims RC, Overcash MR; Res Rev 88: 1-68 (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].

Abiotic Degradation [366]:

Polyaromatic hydrocarbons do not contain hydrolyzable groups and would therefore not be expected to hydrolyze(1). Photochemical studies of pyrene with sunlight and fluorescent lamps of wavelengths > 300 nm in cyclohexane and dichloromethane solution suggest that this compound is resistant to photochemical degradation(2). However, it has been reported that significant (90%) degradation occurred in cyclohexane solution irradiated with a sunlamp for only 7.7 hours(3). Exposure of a heptane solution of pyrene with 22 other polyaromatic hydrocarbons to sunlight for 1 month (Nov) resulted in a recovery of 0.9% of the original pyrene; recovery after 4 days of October exposure, 12%(4). The extent of photodegradation varies with whether the pyrene is pure or adsorbed, and the type of adsorbent(2,3,5-7). Pure unadsorbed pyrene under light in air degraded 42%, while pyrene adsorbed on soot under light in air only degraded 1%; pure material degraded 83% and soot adsorbed material 58% with light under smog conditions(5). Degradation of pyrene adsorbed on fly ash: sunlamp, 24 hours, 13.1%, sunlight, 5 hours, 6.2%, fluorescent light (> 290 nm), 87 hours, 6.6%, no illumination, 430 hours, 1.3%(3). Near surface half-life for direct photolysis of pyrene in water by sunlight, 0.68 hours(6). Pyrene adsorbed on a variety of solids (fly ash, silica gel, alumina) has been shown to react with NO2 and O3 to give nitropyrenes and quinones, respectively(7). The estimated vapor half-life in the atmosphere is 1.12 days as a result of reaction with photochemically produced hydroxyl radicals(8). [(1) Callahan MA et al; p 98-8 in Water-Related Environmental

Fate of 129 Priority Pollutants Vol 2 USEPA-440/4-79-029b (1979) (2) Santodonato J et al; Hazard Profiles on PAH Syracuse Res Corp Syracuse, NY p 53 TR 81-633 (1981) (3) Korfmacher WA et al; Environ Sci Technol 14: 1094-9 (1980) (4) Muel B, Saguem S; Intern J Environ Anal Chem 19: 111-31 (1985) (5) Santodonato J et al; J Environ Pathol Toxicol 5: 1-364 (1981) (6) Zepp RG, Schlotzhauer PF; p 141-58 in Polynuclear Aromatic Hydrocarbons Ann Arbor Science Ann Arbor MI (1979) (7) National Research Council; Polycyclic Aromatic Hydrocarbons: Evaluation of Sources and Effects, National Acad Press Washington DC (1983) (8) GEMS; Graphical Exposure Modeling System Fate of Atmospheric Pollutants (FAP) Data Base Office of Toxic Substances USEPA (1985)].

Soil Adsorption/Mobility [366]:

Koc for three soils, 57, 763-764, 706; Koc for three sediments, 48, 236-285, 256(1). Sediment from 2 ponds, 11,000 (sand) to 130,000 (medium silt); river sediment, 12,000 (sand) to 120,000 (medium silt)(2). Other reported Koc: 8,318(3) and 84,000(4). Based on these Koc values, pyrene would be expected to adsorb very strongly to soils and sediments(SRC). [(1) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (2) Karikoff SW et al; Water Res 13: 241-8 (1979) (3) Sabljic A, Protic M; Agric Food Chem 32: 243-6 (1984) (4) Kenaga EE; Ecotox Environ Safety 4: 26-38 (1980)].

Volatilization from Water/Soil [366]:

Percentage estimated maximum stripping removal in a simulated municipal wastewater treatment system was < 1%(1). Half-life for vaporization from model pond, 1176 days(4). Using reported Henry's Law constants of 1.09X10-4 to 5.42X10-5 atm-cu m/mol(1,2) a half-life ranging from 4.8 to 39.2 days was calculated for the evaporation of pyrene from a river 1 m deep, flowing at 1 m/sec with a wind velocity of 3 m/sec(3,SRC). [(1) Petrasek AC et al; J Water Pollut Control Fed 55: 1286-96 (1983) (2) Mackay D, Shiu WY; J Phys Chem Ref Data 10: 1175-99 (1981) (3) Lyman WJ et al; Handbook of Chemical Property Estimation Methods Environmental Behavior of Organic Compounds McGraw-Hill NY p 15-1 to 15-34 (1982) (4) Davis EM et al; Biodeterioration 5: 176-84 (1983)].

Absorption, Distribution and Excretion [366]:

1. The mechanism of transport by polynuclear aromatic hydrocarbons (PAH) into cells & between intracellular membranes is discussed. From the partitioning parameters, the rate limiting step involves solvation of transfer species in the interfacial water at phospholipid surface. Transfer of pyrene out of the phosphatidylcholine vesicles was examined. [Plant AL et al; Chem-Biol Interact 44 (3): 237-46 (1983)].

2. Twelve polycyclic aromatic hydrocarbons, one of which was

pyrene, were detected in skin oil of roofing workers./Srp: in 9 cases, median pyrene concn was 1.3 (Range, 0.2-10.6) ng/mg skin lipid. No pyrene was detected in serum/. [Wolff MS et al; Chemosphere 11 (6): 595-600 (1982)].

3. 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].

Laboratory and/or Field Analyses:

Many methods have been used to analyze for PAHs [861,1010,1013]. For risk assessment or drinking water purposes, low detection limits should be specified using Selective Ion Mode (SIM) methods [828] or other rigorous methods.

When potential biological effects are being considered, many of the methods historically used have been determined to be inferior to the NOAA protocol expanded scan [828] being recommended by some risk assessment experts in 1996. Most of the historically used methods, including EPA standard semi-volatile scan number 8270, do not cover important alkyl PAHs and do not utilize low-enough detection limits (10 ppt for water, 1 ppb for tissues, sediments, and soil) to use in ecological risk assessments. See also: PAHs as a group entry.

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, and these lower detection limits are far better for risk or hazard assessment, but in all cases detection limits for these media should not be above 10 ppb.

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].

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.

Contaminants data from different labs, different states, and different agencies, collected by different people, are often not very comparable (see also, discussion in the disclaimer section at the top of this entry).

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

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

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

Less rigorous scanning methods for various PAHs in drinking water have included High pressure liquid chromatography (EPA 550, 550.1); gas chromatographic/mass spectrometry (EPA 525): PQL= 0.0002 mg/L [893].