ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA

FLUORENE 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 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).

Fluorene (CAS number 86-73-7)

Brief Introduction:

Br.Class: General Introduction and Classification Information:

Fluorene is a low molecular weight, 3-ring polyaromatic hydrocarbon (PAH), and an EPA Priority Pollutant [697,634]. Although fluorene has not been treated as a carcinogen for modeling purposes [446,903], other more recent sources have determined that fluorene is not classifiable as to its carcinogenicity to humans [788,881,893].

Fluorene occurs ubiquitously in products of incomplete combustion; it also occurs in fossil fuels [847]. The most abundant aromatic hydrocarbon families in oil products have two and three fused rings with one to four carbon atom alkyl group substitutions [773]. Fluorene is called the parent compound, while fluorenes with alkyl group substitutions added to fluorene are called alkyl fluorenes.

Fluorene, and its alkyl homologs C1- through C3-, are included on the expanded scan list used by the Geochemical and Environmental Research Group (GERG) Laboratory at Texas A&M [828]. This list includes most of the PAHs recommended by the NOAA's National Status and Trends program [680].

Fluorene 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)].

Br.Haz: General Hazard/Toxicity Summary:

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

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.

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

Although there is less toxicity information available for most of the alkyl PAHs than for their parent compounds, most alkyl PAHs appear to be at least as toxic or hazardous as the parent compound. Within an aromatic series, acute toxicity increases with increasing alkyl substitution on the aromatic nucleus [851]. For example, there is an increase in toxicity of naphthalene 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].

Total fluorenes: Until more complete information on the effects of all the alkyl fluorenes is available, risk assessment experts suggest adding all alkyl fluorene concentrations plus the parent compound concentration and comparing the sum to known toxicological effects benchmarks and criteria for the respective parent compound (Bill Stubblefield, ENSR, personal communication, 1995). In this method, the concentration of total fluorenes is the sum of the following concentrations: total C1 fluorenes (including all methyl fluorenes) + total C2 fluorenes (including dimethylfluorenes) + total C3 fluorenes (including trimethyl fluorenes) + C0 (fluorene parent compound concentration). C0-C3 fluorenes are typically identified in expanded scans [828].

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

EPA 1996 IRIS database information [893]:

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.

Some glucuronides (metabolic conjugates) are less toxic than the parent compound, but one PAH glucuronide (N-hydroxyacetylaminofluorene glucuronide) is actually a stronger carcinogen than the parent compound N-hydroxyacetylaminofluorene [483].

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

IARC Summary and Evaluation [366,847]: No data are available for humans. Inadequate evidence of carcinogenicity in animals. OVERALL EVALUATION: Group 3: The agent is not classifiable as to its carcinogenicity to humans.

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).

EPA Historical (modeling purposes only) Classification: Carcinogen [302,446].

This is not a phototoxic PAH [887,888,891]. Although not definitive, as discussed above, phototoxicity represents one clue suggesting possible carcinogenicity.

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

Fluorene was not genotoxic in four different tests with bacteria [366].

A single topical application of fluorene at a dose of 1 mg/10 g to neonatal rats resulted in a significant induction of skin & liver aryl hydrocarbon hydroxylase (AHH) & 7-ethoxycoumarin o-deethylase activities [366].

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

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

Volatilization of acenaphthene, anthracene, fluorene, and phenanthrene (low molecular weight PAHs) from soil may be substantial. Lower molecular weight compounds may also volatilize from sediments; this process is not significant for the higher molecular weight compounds [788].

PAHs have been detected in groundwater either as a result of migration directly from contaminated surface waters or through the soil (for example, fluorene) [788].

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

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.

Synonyms/Substance Identification:

2,2'-methylenebiphenyl [366]
9h-fluorene [366,847]
Diphenylenemethane [366]
Methane, diphenylene- [366]
o-biphenylenemethane [366]
Alpha-diphenylenemethane [366]

Molecular Formula:
C13-H10 [366]

Associated Chemicals or Topics (Includes Transformation Products):

See also individual entries:

PAHs as a group
Fluorene, C1-
Fluorene, C2-
Fluorene, C3-
PAHs, Alkyl Homologs of

Metabolism/Metabolites:

... Fluorenyl-9-hydroperoxide has been implicated as an intermediate in the hydroxylation of fluorene to fluoren-9-ol. [The Chemical Society. Foreign Compound Metabolism in Mammals. Volume 1: A Review of the Literature Published Between 1960 and 1969. London: The Chemical Society, 1970, 366].

1-Hydroxy, 9-hydroxy and 9-ketofluorene have been detected as matabolites of fluorene following incubation of this compound with rat-liver preparations [847].

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):

In wood preservative sludge: 6.61 g/l of raw sludge [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 674] [366].

W.Typical (Water Concentrations Considered Typical):

In Eastern Ontario drinking waters (June - Oct 1978): 0.04 - 1.8 ng/l (n= 12); In Eastern Ontario raw waters (June - Oct 1978): 0.4 - 0.9 ng/l (n= 2). [366, Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 675] [366].

Concentrations ranging from 4.1 to 102.2 ng/L fluorene have been detected in surface waters, and 4 to 16 ng/L in tap water [847].

Effluent Concentrations [366]:

In leachate from test panels freshly coated with coal tar: Influent: 0.001 ug/l; Effluent: 0.021 ug/l. [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 674].

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):

EPA 1996 IRIS database information [893]:

Freshwater Acute Criteria: None Published.

Freshwater Chronic Criteria: None Published

Marine Acute Criteria: 3.0E+2 ug/L LEC

Marine Chronic Criteria: None Published

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

Discussion: The values that are indicated as "LEC" are not criteria, but are the lowest effect levels found in the literature. LEC's are given when the minimum data required to

derive water quality criteria are not available. The values given represent polynuclear aromatic hydrocarbons as a class.

W.Plants (Water Concentrations vs. Plants):

No information found.

W.Invertebrates (Water Concentrations vs. Invertebrates):

Static toxicity tests were conducted with fluorene on daphnids (Daphnia magna), larval midges (Chironomus riparius), amphipods (Gammarus pseudolimnaeus), snails (Mudalia potosensis), mayflies (Hexagenia bilineata), bluegill (Lepomis macrochirus), rainbow trout (Salmo gairdneri), fathead minnows (Pimephales promelas), aquatic macrophytes (Chara sp), and green algae (Selanastrum capricornutum). Daphnia magna was the most sensitive organism tested with a 48 hr median effective concn of 0.43 mg/l. Fathead minnows were the least sensitive species, with no mortality at fluorene concentrations as high as 100 mg/l. In a 14-day test, fluorene exposure inhibited algal production at a threshold level of approximately 3.0 mg/l. Complete life cycle chronic toxicity tests were conducted with fluorene on daphnids and larval midges. Daphnid reproduction was significantly reduced at fluorene levels of 0.125 mg/l after 14 days. Emergence of larval midges was delayed at a concentration of 0.6 mg/l. In a 30 day partial life cycle study that was conducted to determined the impact of fluorene on growth, survival, and behavior of fingerling bluegill, survival was reduced at exposures of 0.5 and 1.0 mg/l and growth was inhibited at exposures of 0.25, 0.5, and 1.0 mg/l. Measurements of several behavioral characteristics indicated impairment of swimming and feeding activities at fluorene concentrations as low as 0.12 mg/l. [366, Finger SE et al; ASTM Spec Tech Publ 865: 120-33 (1985)] [366].

LC50 Values [851]:

Neanthes arenaceodentata
(marine polychaete) - 1.0 ppm, 96-hour test
Palaemonetes pugio
(grass shrimp) - 0.32 ppm, 96-hour test

LC50 for Hexagenia bilineata (mayfly) was 5.8 mg/L (ppm) for a 5-day exposure [998].

W.Fish (Water Concentrations vs. Fish):

See also [366] information in W.Invertebrates above.

LC50 Values [851]:

Cyprinodon variegatus
(sheep's-head minnow) - 3.18, 96-hour test

LC50 for Oncorhynchus mykiss (rainbow trout, donaldson trout) was 0.82 mg/L for a 96-hr exposure [998].

LC50 for Lepomis macrochirus (bluegill) was 0.91 mg/L for a 96-hr exposure [998].

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

No information found.

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

EPA Region IX tap water Preliminary remediation goal (PRG), 1995 [868]: 2.4E+02 ug/L.

EPA 1996 IRIS database information [893]:

EPA IRIS 1996: Ambient Water Quality Criteria for Human Health for routes of exposure from both water & fish: 2.8E-3 ug/liter [893].

Older Published Criteria for Water and Organisms, Human Health (10-6 = E-06) Risk Level for Carcinogens): was the same, 0.0028 ug/L [689].

Previous Discussion: 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 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)] [366].

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 polynuclear aromatic hydrocarbons class is composed of numerous compounds having diverse biological effects and varying carcinogenic potential. A "representative" polynuclear aromatic hydrocarbons 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 polynuclear aromatic hydrocarbons may not be scientifically sound. (3) No chronic animal toxicity studies involving oral exposure to polynuclear aromatic hydrocarbons mixtures exist. (4) No direct human data concerning the effects of exposure to defined PAH mixtures exist. /Polynuclear aromatic hydrocarbons/ [USEPA; Ambient Water Quality Criteria Doc: Polynuclear Aromatic Hydrocarbons (Draft) p.C-118 (1980)] [366].

EPA IRIS 1996: Ambient Water Quality Criteria for Human Health for routes of exposure from Fish only: 3.11E-2 ug/liter [893].

Older Published Criteria for Organisms Only wass the same, 0.0311 ug/L [689].

MCL, MCLG: None given [893].

Drinking Water Discussion from IRIS 1996 EPA database [893]:

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.

Criteria Federal Register Notice Number: 45 FR 79318 (11/28/80) [893].

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

Numeric Water Quality Criteria in Arizona [881]:

Domestic water supply: 280 ug/L
Fish consumption: 580 ug/L
Full body contact: 5600 ug/L
Partial body contact: 5600 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):

No information found.

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):

No information found.

Sed.Typical (Sediment Concentrations Considered Typical):

Fluorene was detected in 69.3 percent of urban-bay samples from the Puget Sound area. The mean concentration was 1140 ug/kg dry weight (ppb), while the median concentration was 91 ug/kg (ppb) [852].

Fluorene was detected in 47.2 percent of non-urban-bay samples from the Puget Sound area. The mean

concentration was 1124 ug/kg dry weight (ppb), while the median concentration was 41.5 ug/kg (ppb) [852].

NOTE: The above values are not normalized for total organic carbon (TOC) content. Urban bay concentrations may be lower than or near 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.

Sediment Concentrations [366]:

Sediment of Wilderness Lake, Colin Scott, Ontario (1976): 38 ppb (dry weight) [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 675].

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):

AET, 1988: The apparent effects threshold concentrations for fluorene in sediments proposed for Puget Sound ranged from 0.54 mg/kg dry weight (microtox) to 3.6 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 fluorene sorbed to marine sediments is 0.350 mg/kg dry weight [864]. An AET is defined as the lowest concentration of a compound in sediment at which biological effects (usually changes in composition of benthic invertebrate communities) are observed to occur [864].

NOTE: Even lower concentrations of this PAH may be of concern related to its contribution to "total PAH" sums (see the "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 540 ppb dry weight Effects Range-Median (ERM) concentration and was lowest in sediments where its concentration was less than the 19 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	27.3
ERL-ERM	36.5
>ERM	86.7

Ontario Ministry of the Environment Freshwater Sediment Guidelines, 1993. Lowest effect level: 190 mg/kg dry weight. Severe effect level: 160 mg/kg organic carbon [761].

St. Lawrence River Interim Freshwater Sediment Criteria, 1992. No effect level: 10 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):

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 PAHs 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 [366].

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):

No information found.

Soil.Typical (Soil Concentrations Considered Typical):

No information found.

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):

No information found.

Soil.Plants (Soil Concentrations vs. Plants):

No information found.

Soil.Invertebrates (Soil Concentrations vs. Invertebrates):

LC50's of earthworms for fluorene (1985): 173 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 = 3100 mg/kg for ingestion pathway [952].

SSL = 28 to 560 mg/kg for protection from migration to groundwater at 1 to 20 Dilution-Attenuation Factors (DAF) [952].

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

Residential Soil: 300 mg/kg wet wt.

Industrial Soil: 300 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 fluorene in soil.
3) PRGs for residential and industrial land uses 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:

160 mg/Kg dry weight [903].

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

No information found.

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

Tis.Plants:

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

No information found.

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

No information found.

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 fluorene 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):

Fluorene:	38.3 ug/kg = ppb
C1-Fluorene:	383 ug/kg = ppb
C2-Fluorene:	1317 ug/kg = ppb
C3-Fluorene:	1535 ug/kg = ppb

Measured fluorene concentrations were (in wet weight) 0.028 to 1.7 ug/g in oysters, and 0.130 ug/g in clams from Canadian and American creosote-contaminated sites [864].

Tis.Fish:

A) As Food: Concentrations or Doses of Concern To Living Things Which Eat Fish (Includes FDA Action Levels for

Fish and Similar Benchmark Levels from other Countries):

No information found.

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

No information found.

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

Details of fluorene 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):

Fluorene:	6.86 ug/kg = ppb
C1-Fluorene:	12.63 ug/kg = ppb
C2-Fluorene:	22.87 ug/kg = ppb
C3-Fluorene:	13.64 ug/kg = ppb

The fluorene concentration in mosquitofish with extremely elevated total PAH concentrations (60.79 mg/kg) was 0.50 mg/kg [201].

Measured fluorene concentrations were (in wet weight) 0.16 ug/g in guppies, and 20.7 ug/g in English sole from Canadian and American creosote-contaminated sites [864].

Fish/Seafood Concentrations [366]: Smoked eel: 9.0 ppb; smoked lumpfish: 5.0 ppb; smoked trout: 67.0 ppb; electric smoked mackerel: 2.6 ppb; gas smoked mackerel: 8.2 ppb. [USEPA; Ambient Water Quality Criteria Doc: Polynuclear Aromatic Hydrocarbons (Draft) p.C-14 (1980)].

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:

No information found.

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 = 54 mg/Kg wet weight.

Note: unlikely to occur. However, the reader should keep in mind that elevated concentrations of individual PAHs often occur in the presence of complex mixtures of PAHs, and that complex mixtures of PAHs often display carcinogenic and phototoxic properties (see "PAHs as a group" entry).

RfD: 4E-2 mg/kg-day Confidence: Low [868,893,903].

Crit. Dose: 125 mg/kg-day [893].

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

EPA has suggested that taking 0.04 mg fluorene into your body each day is not likely to cause any significant (noncancer) harmful health effects [788].

Tis.Misc. (Other Tissue Information):

No information found.

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).

Alkyl PAHs tend to bioaccumulate to a greater degree than parent compound PAHs [347,885]. Introduction or extension of an alkyl group increases lipophilicity, which often appears as increased absorption [856].

Bioconcentration Factor, log BCF [848]:

2.62 to 3.67 (most report 3.11)

Bioconcentration [366]:

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: 482-96 (1977) as cited in: Health and Welfare Canada; Polycyclic Aromatic Hydrocarbons p.37 (1979) Report No. 80-EHD-50].

Polycyclic aromatic hydrocarbons (PAH) were analyzed in surfacial sediments & benthic organisms in southeastern Lake Rrie, 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. /Polynuclear aromatic

hydrocarbons/ [Eadie BJ et al; Chemosphere 11 (2): 185-92 (1982)].

Interactions:

No information found.

Uses/Sources:

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

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

Fluorene is a common PAH component of used motor oil [75]. Levels of up to 1.6% have been found in coal tar. It has been detected in main stream cigarette smoke and exhaust from gasoline engines [847].

To study water soluble leachates from out-of-service railway ties, one gram of wood was shaved from the surface of the railroad ties and agitated in water for 24 hours. Up to 120 ug/L of fluorene was found in the water [864].

Major Uses [366]:

> Chem int in numerous misc applications & in formation of polyradicals for resins [SRI].
>
> In resinous products; dyestuffs [Hawley, G.G. The Condensed Chemical Dictionary. 10th ed. New York: Van Nostrand Reinhold Co., 1981. 468].

Natural Sources [366]:

> Occurs in fossil fuels [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V32 366 (1983)].
>
> Fluorene is found in high temp process coal tars in 0.51-2.02 avg wt% and from low temp process coal tars in 0.13-0.62 avg wt% /From table/ [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. V35 86 (1985)].
>
> Fluorene occurs ubiquitously in products of incomplete combustion ... [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V32 366

(1983)].

Artificial Sources [366]:

Fluorene occurs ubiquitously in products of incomplete combustion, it has been detected in mainstream cigarette smoke, exhaust from gasoline engines, surface water, tap water, and sewage sludge [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V32 366 (1983)].

Fluorene is found in 0.01-1.0% concentration in coke-oven tars /from table/ [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. V35 87 (1985)].

Ground water: fluorene was identified in groundwater near a former creosote plant in Pensacola, Fl [Goerlitz DF et al; environ sci technol 19 (10): 955-61 (1985)].

Fluorene was detected in sediment at 3 Eagle Harbor, WA sites [Malius DC et al; Carcinogenesis 6 (10): 1463-9 (1985)].

.. Residues of chlorinated dibenzofuran, fluorene, biphenylene, phenanthrene, naphthalene, and 9H-carbazole were identified from the Buffalo River, NY sediments. [Kuehl DW et al; J Great Lakes Res 10 (2): 210-214 (1984)].

Fluorene is found in 0.01-1.0% Concentration in coke-oven tars /from table/ [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. V35 87 (1985)].

Fluorene is found in crude coal tar at 13,700 mg/kg /from table/ [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. V35 88 (1985)].

Fluorene was found in 4 samples of creosote in the range of 3.1-10% /From table/ [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. V35 92 (1985)].

High temp coal-tar pitches used as an electrode contained 800-4000 mg/kg fluorene /from table/ [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. V35 94 (1985)].

Fluorene was found in the following creosotes and coal at the following concentrations - commercial creosote: 51.9% +/- 8.5 mg/kg; hydrogenated creosote: 7.77 + or - 1.20 mg/kg; Solvent refined coal II materials: 14.4 + or - 0.4 mg/kg; Hydrogenated solvent refined coal ii materials: 6.78 + or - 1.13 mg/kg [Wright CW et al; J High Res Chrom & Chrom comm 8: 286 (1985)].

Forms/Preparations/Formulations:

No information found.

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

Water Solubility at 25 degrees C [848]:

1.50 to 4.65 mg/L (most values 1.68 to 1.90 mg/L)

Other Solubilities [366]:

Freely sol in glacial acetic acid; sol in carbon disulfide, ether, benzene, hot alc [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 594].

Insol (sic, they really mean "relatively" insoluble)" in water; sol in acetone, pyrimidine, carbon tetrachloride, toluene [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 67th ed. Boca Raton, FL: CRC Press, Inc., 1986-87.,p. C-276].

Boiling Point [366]:

295 DEG C [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 594].

Melting Point [366,848]:

116-117 degrees C

Density/Specific Gravity [366,848]:

1.203 at 20 degrees C

Vapor Pressure (at 25 degrees C) [848]:

0.079 to 1.66 Pa (most values 0.080 to 0.088 Pa)

Henry's Law Constant [848]:

5.06 to 33.4 Pa m3/mol (most values 7.74 to 10.57 Pa m3/mol)

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

3.91 to 4.47 (most values near 4.18)
Log Kow values for fluorenes [971]:

fluorene:	4.18
C1-fluorene:	4.97
C2-fluorene:	5.2
C3-fluorene:	5.5

Sorption Partition Coefficient, log Koc [848]:

4.15 to 5.47 (most values near 4.15)

Heat of Vaporization [366]:

13,682.8 gcal/gmol [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 67th ed. Boca Raton, FL: CRC Press, Inc., 1986-87.,p. C-675].

Molecular Weight [366]:

166.21 [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 594].

Color/Form [366]:

Dazzling white leaflets or flakes from alcohol [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 594].

Small, white, crystalline plates; fluorescent when impure [Hawley, G.G. The Condensed Chemical Dictionary. 10th ed. New York: Van Nostrand Reinhold Co., 1981. 468].

Concentrations of fluorene in South Louisiana crude, Kuwait crude, No. 2 fuel oil, and Bunker C residual were 200, <100, 3600, and 2400 mg/kg (ppm), respectively [177].

Fluorene 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: 80, 44, and 27 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 fluorene content (mg/kg or ppm) in one fresh sample of Exxon Valdez Crude Oil [971]:

fluorene: 93 mg/kg = ppm
C1-fluorene: 224 mg/kg = ppm
C2-fluorene: 366 mg/kg = ppm
C3-fluorene: 394 mg/kg = ppm

Fluorene content in one fresh sample of NSFO (Fuel Oil 5, Chuck Rafkind, National Park Service, Personal Communication, 1996): 216.0 ng/mg (ppm).

Fluorene 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): 1229.3 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).

Fluorene concentration in Used Engine Oil: 67.0 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:

One study showed how biodegradation of PAHs was related to molecular weight. The 2- and 3-ring PAHs (including fluorene) degraded rapidly. The 4-ring PAHs generally biodegraded 50% in a few months. The 5-ring PAHs decreased slowly over a period of years [815].

Environmental degradation of PAHs such as fluorene can be reduced by low dissolved oxygen and low algal productivity [92].

Biodegradation [366]:

> 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 Degradation [366]:

Aquatic reactions: Photo-oxidation by ultraviolet radiation in aqueous medium at 90-95 deg C: (time for formation of carbon dioxide (% of theoretical): 25%: 75.3 hr; 50%: 160.6 hr; 75%: 297.4 hr [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 675].

Absorption, Distribution and Excretion [366]:

There were species differences in excretion of an ip dose of (14)c-fluorene. Guinea pigs eliminated (14)c more rapidly than rats or rabbits & after 12 hr, had excreted 53% in urine whereas other species had excreted 12% & 20% respectively. In 48 hr, in urine & feces respectively, guinea pigs excreted 82% & 6%, rats excreted 57% & 16% & rabbits excreted 39% & 1%. 24 Hr after dose to rats, intestinal tract contained 14% of the (14)c & since this had not altered 24 hr later, entero-hepatic circulation of fluorene &/or its metabolites may have occurred to maintain those levels. However, slow release of 14(c) from injection site provides an alternative explanation. [The Chemical Society. Foreign Compound Metabolism in Mammals. Volume 1: A Review of the Literature Published Between 1960 and 1969. London: The Chemical Society, 1970. 94].

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, we have inferred that the rate limiting step involves solvation of the transfer species in the interfacial water at the phospholipid surface. Transfer of 10 PAH ... out of phosphatidylcholine vesicles has been examined. Our results show that the molecular volume of the PAH is a rate-determining factor. Morever, 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 PAH metabolism within cells. [Plant AL et al; Chem-biol Interact 44 (3): 237-46 (1983)].

Laboratory and/or Field Analyses:

Lab methods utilized must be able to quantify alkyl PAHs, and most standard EPA scans [861,1010,1013] do not do that. For risk assessment, 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 alkyl PAH analytes), are recommended.

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, semi-volatile 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 entry for more details).

In a similar vein, if the Park Service sediment investigation at Petersburg National Historical Battlefield (see Chem.Detail section in separate PAHs entry, this study was performed in response to contamination by Diesel) had utilized EPA semi-volatile scan 8270 or any of the other typical EPA scans (625, etc.), all of which only include parent compounds and often utilize detection limits no lower than the 170-600 ppb range, the false conclusion reached would have been that only one PAH was present in significant (detection limit) amounts. This false negative conclusion would have been made because the parent compound PAHs present constituted only 2.4% of the PAHs detected in sediments, and the highest concentration found for any parent compound except pyrene was 85.5 ppb, far below the detection limits used on the

older standard EPA scans. Pyrene was 185 ppb, which would have been non-detected on many of the EPA scans, but not all. However, utilizing the NOAA protocol expanded scan [828], it was determined that 97.6% of total quantity of PAHs detected in sediments were alkyl PAHs, and that all 39 PAHs and alkyl PAHs were present in these sediments.

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

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

Variation in concentrations of organic contaminants may sometimes be due to the typically great differences in how individual investigators treat samples in the field and in the lab rather than true differences in environmental concentrations. This is particularly true for volatiles and for the relatively lighter semi-volatiles such as the naphthalene PAHs, which are so easily lost at various steps along the way.

Contaminants data from different labs, different states, and different agencies, collected by different people, are often not very comparable. In fact, as mentioned earlier in the disclaimers section, 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).