ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA

BENZO(K)FLUORANTHENE ENTRY

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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 is also a major issue related to (lack of) data comparability from media other than water: soil, sediments, tissues, and air.

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

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

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

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

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

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

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

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

on the internet or NTIS: 1998).

Benzo(k)fluoranthene (CAS number 207-08-9)

Brief Introduction:

Br.Class: General Introduction and Classification Information:

Benzo(k)fluoranthene is a high-molecular-weight, 5-ring polycyclic aromatic hydrocarbon (PAH) and an EPA Priority Pollutant [680,634].

Benzo(k)fluoranthene is included on the expanded scan list used by the Geochemical and Environmental Research Group (GERG) Laboratory at Texas A&M [828]. This list includes most of the PAHs recommended by the NOAA's National Status and Trends program [680].

Br.Haz: General Hazard/Toxicity Summary:

Evidence of the potential hazards of this compound include the following:

> This PAH is phototoxic, and has very stringent (low concentration) criteria in water and other media (see details in sections below).

Human exposure to benzo(k)fluoranthene occurs primarily through smoking, inhalation of polluted air; food and water contaminated with products of combustion(1).[(1) IARC; Polynuclear Aromatic Compounds. Part I. Chemical environmental and experimental data. 32: 33-91, 164-7 (1983)] [366].

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

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

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

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

EPA 1996 IRIS database information [893]:

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

Classification: B2; probable human carcinogen

BASIS: Based on no human data and sufficient data from animal bioassays. Benzo(k)fluoranthene produced tumors after lung implantation in mice and when administered with a promoting agent in skin-painting studies. Equivocal results have been found in a lung adenoma assay in mice. Benzo(k)fluoranthene is mutagenic in bacteria. HUMAN CARCINOGENICITY DATA: None. Although there are no human data that specifically link exposure to benzo(k)fluoranthene to human cancers, benzo(k)fluoranthene is a component of mixtures that have been associated with human cancer. These include coal tar, soots, coke oven emissions and cigarette smoke (U.S. EPA, 1984, 1990; IARC, 1984).

ANIMAL CARCINOGENICITY DATA: Sufficient.

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

Relative (equivalency factor) oral carcinogenic potency value compared to Benzo(a)pyrene (BAP, which is ranked 1.0): The factor for benzo(k)fluoranthene compared to BAP is 0.01 [EPA, 1993, Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons]. Although the information is based on mouse skin painting studies, until better guidance is available, this relative oral carcinogenic potency value may be used in superfund site human risk assessments in conjunction with the oral carcinogenic slope factor for Benzo(a)pyrene found in EPA's IRIS database [893] (Stan Smucker, EPA Region 9, personal communication, 1996).

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

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

IARC Summary and Evaluation [366]:

> There is sufficient evidence of carcinogenicity in experimental animals. No data are available in humans. OVERALL EVALUATION: Group 2B: The agent is possibly carcinogenic to humans.

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

An IARC search found no available data on the effects of benzo(k)fluoranthene on reproduction, prenatal toxicity, or teratogenicity [847].

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

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

Environmental Fate/Exposure Summary [366]:

> Benzo(k)fluoranthene's (BkF) release into air and water is quite general since it is a ubiquitous product of incomplete combustion. Both in air and water it is largely associated with particulate matter. Although environmental concentrations are greatest near sources, BkFs presence in distant places indicates that it is reasonably stable in the atmosphere and capable of long-distant transport. Atmospheric losses are caused by gravitational settling and rainout. On land it is strongly adsorbed to soil and remains in the upper soil layers and should not leach into groundwater. Biodegradation may occur but will be very slow

(half-life ca 2 years with acclimated microorganisms). Benzo(k)fluoranthene will get into surface water from dust and precipitation in addition to runoff and effluents. In the water it will sorb to sediment and particulate matter in the water column. It would be expected to bioconcentrate in fish and seafood. Human exposure is from smoking, inhalation of polluted air and eating food contaminated with products of combustion or prepared in such a way (smoked, charcoal broiled) that polycyclic hydrocarbons are generated. Since water treatment such as filtration, chlorination and ozonolysis removes benzo(k)fluoranthene, exposure from drinking water should be minor. (SRC)

Synonyms/Substance Identification:

2,3,1',8'-Binaphthylene [366]
8,9-Benzofluoranthene [366]
8,9-Benzfluoranthene [366]
11,12-Benzo(k)fluoranthene [366]
11,12-Benzofluoranthene [366]
Dibenzo(b,jk)fluorene [366]
B(k)F [366].

NOTE: This compound is often misspelled as "benzo(k)fluoranthrene". The misspelling has been common enough to make it into some government contracts and reports.

Molecular Formula:
$C20-H12$ [366]

Associated Chemicals or Topics (Includes Transformation Products):

See also individual entry:

PAHs as a group

Metabolism/Metabolites [366]:

Benzo(k)fluoranthene is metabolized to 8,9-dihydro-8,9-dihydroxybenzo(k)fluoranthene in mice. [Lavoie EJ et al; tumor initiating activity of dihydrodiols of benzo(b)fluoranthene, benzo(j)fluoranthene, and benzo(k)fluoranthene; carcinogenesis (london) 3 (1): 49-52 (1982)].

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):

No information found.

W.Typical (Water Concentrations Considered Typical):

Benzo(k)fluoranthene concentrations are 0.2-0.8 ng/L in surface water, 1.6-10.1 ng/L in rainwater, 1-3.5 ng/L in subterranean water, and 0.07 and 1-3.4 ng/L in tap water [847].

Water Concentrations [366]:

DRINKING WATER: Tapwater < .1 to < 2 ng/l(2,5,6). Benzo(k)fluoranthene may be picked up in distribution systems lined with coal tar or asphalt (e.g. Columbus OH finished water < 0.1 ng/l, distributed water 3 ng/l)(2). Tapwater 0.07-8.0 ng/l(3). GROUND WATER: Contaminated groundwater in the Netherlands 3 ug/l max(1). Groundwater in Germany 0.5-10.0 ng/l(2), 0.2-3.5 ng/l(3). SURFACE WATER: 0.8-265 ng/l mostly associated with particulate matter(2), 0-400 ng/l(3). RAINWATER & SNOW: Rain 1.6-450 ng/l(3). Southern Norway rain and snow 50-300 ng/l including benzo(b)fluoranthene(4). SEAWATER: Tamar Estuary, England 4.2 ng/l avg, 382 ng/g avg in suspended solids(7). Benzo(k)fluoranthene concentration in estuary correlates with total suspended solids in areas away from Plymouth; high concn in vicinity of Plymouth is due to urban discharges including sewage(7). [(1) Zoetman BCJ et al; Sci Total Environ 21: 187-202 (1981) (2) Sorrell RK et al; Environ Inter 4: 245-54 (1980) (3) IARC; Polynuclear Aromatic Compounds. Part I. Chemical environmental and experimental data; 32: 33-91, 164-7 (1983) (4) Lunde G et al; Organic Micropollutants in Precipitation in Norway; pp.17 SNSF Project FR-9/76 (5) Kveseth K et al; Chemosphere 11: 623-39 (1982) (6) Konasewich D et al; Status Report on Organic and Heavy Metal Contaminants in the Lakes Erie, Michigan, Huron and Superior Basins. Great Lakes Quality Review Board (1978) (7) Readman JW et al; Est Coastal Shelf Sci 14: 369-89 (1982)].

Effluent Concentrations [366]:

Industries in which the mean levels of benzo(k)fluoranthene in raw or treated wastewater exceeds 10 ppb include nonferrous metals manufacturing, organic chemical manufacturing/plastics and timber products processing(1). Maximum levels which exceed 10 ppb include: coal mining 11 ppb, coil coating 10 ppb, foundries 10 ppb, nonferrous metal manufacturing 210 ppb, and timber products processing 3900 ppb(1). Norwegian sewage treatment plant < 3 ng/l(2). National Urban Runoff Program (86 samples from 19 cities), frequency of detection 2%, 4-10 ppb in runoff at Lake Quinsigamond, MA and Bellevue, WA(3). Effluent discharge 0.01-8 ppb and sludge 150-1270 ppb(4). Emissions from burning coal 0.05-17.2 ppm(4). Emissions from oil-fired stoves 0.03-405 ppb(4). [(1) USEPA; Treatability Manual; pp.10.4-1 to 10.4-4 USEPA-600/282-001a (1982) (2) Kveseth K et al; Chemosphere 11: 623-39 (1982) (3) Cole RH et al; J Water Pollut Control Fed 56: 898-90 (1984) (4) IARC; Polynuclear Aromatic Compounds. Part I. Chemical environmental and experimental data. 32: 33-91, 164-7 (1983)].

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

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

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

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

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

Water Quality Criteria in ug/L:

Freshwater Acute Criteria: None Published [689].

Freshwater Chronic Criteria: None Published [689].

Marine Acute Criteria: Ambient Water Quality Criteria for Aquatic Organisms from EPA 1996 [893]:

3.0E+2 ug/L LEC. 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 [893].

Marine Chronic Criteria: None Published [689].

Criteria Federal Register Notice Number: 45 FR 79318 (11/28/80)

NOTE: Before citing a concentration as EPA's water quality criteria, it is prudent to make sure you have the latest one. Work on the replacement for the Gold Book [302] was underway in March of 1996 and IRIS [893] is updated monthly.

W.Plants (Water Concentrations vs. Plants):

No information found.

W.Invertebrates (Water Concentrations vs. Invertebrates):

No information found.

W.Fish (Water Concentrations vs. Fish):

No information found.

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

No information found.

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

EPA National Water Quality Criteria [893]:

Human Health (10-6 or E-06) Risk Level for Carcinogens)

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

Same as previously published value: IRIS Recalculated (9/90) Criteria for Water and Organisms: 0.0028 ug/L [446,689,928].

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

Same as previously published IRIS Recalculated criteria: Published Criteria for Organisms Only: 0.0311 ug/l [446,689,928].

Maximum Contaminant Level (MCL) from IRIS 1996 EPA: 0.0002 mg/L Proposed 1990 Reference: 55 FR 30370 (07/25/90) [893].

Maximum Contaminant Level Goal, IRIS 1996 EPA: 0 mg/L (Proposed 1990): 55 FR 30370 (07/25/90). The proposed MCLG is zero. This value is based on carcinogenic PAH's as a class [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 [893].

EPA Region 9 Preliminary Remedial Goal for Tap water: 9.2E-01 ug/L [868].

Misc. Criteria or Standards:

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

Numeric Water Quality Criteria in Arizona [881]:

Domestic water source: 0.003 ug/L
Fish consumption: 0.00001 ug/L
Full body contact: 0.12 ug/L

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

This is a phototoxic PAH [891,887].

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):

Benzo(k)fluoranthene was detected in 93.6 % of urban-bay samples from the Puget Sound area. The mean concentration was 2030 ug/kg dry weight (ppb), while the median concentration was 600 ug/kg (ppb) [852].

NOTE: The above values are not normalized for total organic carbon (TOC) content.

Sed.Typical (Sediment Concentrations Considered Typical):

Benzo(k)fluoranthene was detected in 81.3 % of non-urban-bay samples from the Puget Sound area. The mean concentration was 1381 ug/kg dry weight (ppb), while the median concentration was 230 ug/kg (ppb) [852].

NOTE: The above values are not normalized for total organic carbon (TOC) content.

Sediment/Soil Concentrations [366]:

Sediment profiles in 2 remote Adirondack lakes: Sagamore Lake 0-4 cm 120 ppb, 4-8 cm 110 ppb, 8-12 cm 57 ppb, > 12 cm < 2 ppb; Woods Lake 0-4 cm 560 ppb, 4-8 cm 180 ppb, > 8 cm < 11 ppb(1). Benzo(k)fluoranthene was detected in sediment in Dohkai Bay, a heavily industrialized area in Japan; it is suggested that the major origin of sedimentary PAH was airborne dust(2). Forest soil in Germany 10-15 ppb(3). Tamar Estuary, England surface sediment 336 ppb dry wt avg(4). [(1) Tan YL, Heit M; Geochem Cosmochim Acta 45: 2267-79 (1981) (2) Shinohara R et al; Environ Int 4: 163-74 (1980) (3) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (4) Readman JW et al; Est Coastal Shelf Sci 14: 369-89 (1982)].

A simple and rapid analysis of polynuclear aromatic hydrocarbons (PAH) in soil and sediment by high performance liquid chromatography (HPLC) was investigated. The following method was used for analysis; soil and dried sediment samples were sieved through a screen (32 mesh) for removing large particles. PAH in the soil and sediment samples were extracted with 4 ml of acetonitrile for 15 min by using an ultrasonic apparatus, and then PAH in the supernatant was separated and determined by HPLC ... (250 mmrosorb RP 18) ... with UV and fluorescence detectors. This method was applied to the analysis of PAH in soil and sediment and 11 PAH were identified. Recovery rates of PAH from soil and sediment were 101.0 and 99.1% for benzo(a)pyrene (BaP), 98.8 and 99.4% for perylene, and 102.5 and 98.2% for benzo(k)fluoranthene (BkF), respectively. An apparent correlation was found between particle size of soil and distribution rate of BaP and perylene. The BaP contents in soil decreased with increasing the depth from the surface. PAH contents in soils sampled at road sides of Kitakyushu, Japan highway in March 1983 were ranged from 13.9 to 175 ppb for BaP, 11.7 to 171 ppb for BkF, 3.5 to 76.4 ppb for perylene and 20.8 to 273 ppb for benzo(ghi)perylene. BaP contents in soils sampled from the road side in Orio area were 656 to 1630 ppb. PAH contents in sediment which were sampled in Onga River in October 1983 were ranged from 6.4 to 82.9 ppb for BaP, 2.8 to 38.3 for BkF, and 2.7 to 27.2 ppb for perylene. BaP contents in sediments obtained from the polluted areas of Wakamatsu harbor were 1150 ppb and 12,400 ppb. In this method several kinds of PAH in soil and sediment including carcinogenic BaP can be analyzed easily. [Arashidani K et al; Eisei Kagaku 31 (1): 24-31 (1985)].

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):

Ontario Ministry of Environment Freshwater Sediment Guidelines, 1993. Lowest effect level: 240 ug/kg dry weight. Severe effect level: 1,340 mg/kg for a max of 10% organic carbon [761].

AET: The apparent effects threshold (AET) concentrations for benzofluoranthenes (as a group) in sediments proposed for Puget Sound ranged from 3.2 mg/kg dry weight (microtox) to 9.9 mg/kg dry weight (benthic) [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).

St. Lawrence River Interim Freshwater Sediment Criteria for for benzofluoranthenes (as a group), 1992. No effect level: 300 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):

No information found.

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

Soil.Low (Soil Concentrations Considered Low):

No information found.

Soil.High (Soil Concentrations Considered High):

No information found.

Soil.Typical (Soil Concentrations Considered Typical):

Sediment/Soil Concentrations [366]:

A simple and rapid analysis of polynuclear aromatic hydrocarbons (PAH) in soil and sediment by high performance liquid chromatography (HPLC) was investigated. The following method was used for analysis; soil and dried sediment samples were sieved through a screen (32 mesh) for removing large particles. PAH in the soil and sediment samples were extracted with 4 ml of acetonitrile for 15 min by using an ultrasonic apparatus, and then PAH in the supernatant was separated and determined by HPLC ... (250 mmrosorb RP 18) ... with UV and fluorescence detectors. This method was applied to the analysis of PAH in soil and sediment and 11 PAH were identified. Recovery rates of PAH from soil and sediment were 101.0 and 99.1% for benzo(a)pyrene (BaP), 98.8 and 99.4% for perylene, and 102.5 and 98.2% for benzo(k)fluoranthene (BkF), respectively. An apparent correlation was found between particle size of soil and distribution rate of BaP and perylene. The BaP contents in soil decreased with increasing the depth from the surface. PAH contents in soils sampled at road sides of Kitakyushu, Japan highway in March 1983 were ranged from 13.9 to 175 ppb for BaP, 11.7 to 171 ppb for BkF, 3.5 to 76.4 ppb for perylene and 20.8 to 273 ppb for benzo(ghi)perylene. BaP contents in soils sampled from the road side in Orio area were 656 to 1630 ppb. PAH contents in sediment which were sampled in Onga River in October 1983 were ranged from 6.4 to 82.9 ppb for BaP, 2.8 to 38.3 for BkF, and 2.7 to 27.2 ppb for perylene. BaP contents in sediments obtained from the polluted areas of Wakamatsu harbor were 1150 ppb and 12,400 ppb. In this method several kinds of PAH in soil and sediment including carcinogenic BaP can be analyzed easily. [Arashidani K et al; Eisei Kagaku 31 (1): 24-1 (1985)].

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 benzo(k)fluoranthene in soil is 0.1 ug/g dry weight [656].

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

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

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

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

Soil.Plants (Soil Concentrations vs. Plants):

No information found.

Soil.Invertebrates (Soil Concentrations vs. Invertebrates):

No information found.

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

No information found.

Soil.Human (Soil Concentrations vs. Human):

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 = 9 mg/kg for ingestion pathway [952].

SSL = 2 to 49 mg/kg for protection from migration to groundwater at 1 to 20 Dilution-Attenuation Factor (DAF) [952].

See also [656] information in Soil.General section above.

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

Residential Soil: 6.1 mg/kg wet weight

California-modified PRG: 0.61 mg/kg wet wt

Industrial Soil: 26 mg/kg wet weight

NOTE:
1) Values are based on a one-in-one million cancer risk.
2) PRGs focus on the human exposure pathways of ingestion, inhalation of particulates and volatiles, and dermal absorption. Values do not consider impact to groundwater or ecological receptors.
3) PRGs for residential and industrial landuses are slightly lower concentrations than EPA Region III RBCs, which consider fewer aspects (more limited to ingestion pathway) [903].

EPA 1995 Region 3 risk-based concentration (RBC) to protect from transfers to groundwater:

4 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:

Norway: Algae trace - 66 ppb including benzo(j)fluoranthene(1). [(1) Knutzen J, Solland B; Water Res 16: 421 (1982)] [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:

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

Seafood Concentrations [366]:

Oysters taken in Texas waters: Galveston Bay 0.1 and 0.4 ppb in approved and closed waters resp, Aransas Bay not detected(1). Softshell clams from Coos Bay, Oregon 1.1-10.9 ppb(2). Mussels from Yaquina Bay, Oregon 0-4.2 ppb, 1.7 ppb avg at less industrialized site, 8.5-22.5 ppb, 17.4 ppb avg from more industrial site(3). Norway: mussel 6-69 ppb; limpet trace - 39 ppb including benzo(k)fluoranthene(4). [(1) Fazio T, Howard

JW; pp.461-505 in Handbook of Polycyclic Aromatic Hydrocarbons; Bjorseth J ed; Marcel Dekker New York NY (1983) (2) Mix MC, Schaffer RL; Mar Pollut Bull 14: 94-7 (1983) (3) Mix MC, Schaffer RL; Mar Environ Res 9: 193-210 (1983) (4) Knutzen J, Sortland B; Water Res 16: 421 (1982)].

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):

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 concentrations (carcinogenic), rounded to two significant figures [903]: 0.043 mg/Kg wet weight.

Oral Slope Factor: 7.3E-02 mg/kg-day [868].

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:

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

The benzo(k)fluoranthene concentration in mosquitofish with extremely elevated total PAH concentrations (60.79 mg/kg) was 3.2 mg/kg [201].

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.Invertebrates, C), above.

Food Survey Results [366]:

UK total diet sample (from 5 geographically diverse areas of the UK) 0.06 ug/person-day (cereals 29%, meat 3%, fish 2%, oils/fats 41%, fruit/sugar 5%, root vegetables 6%, other vegetables 13%, beverages 0%, milk 2%)(1). Daily intake of combined benzo(b)fluoranthene, benzo(j)fluorathene and benzo(k)fluoranthene estimated from duplicate cities .5 ug median 1.7 ug max(2). Benzo(k)fluoranthene in kale 2.8-9.5 ppb, 6.1 ppb avg (leafy vegetables are thought to be high because they have a large surface area which collects atmospheric particulates)(2). [(1) Dennis MJ et al; Food Chem Toxicol 21: 569-74 (1983) (2) Valssen HAMG et al; Toxicol Environ Chem 7: 297-324 (1984)].

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 concentrations (carcinogenic), rounded to two significant figures [903]: 0.043 mg/Kg wet weight.

Oral Slope Factor: 7.3E-02 mg/kg-day [868].

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

No information found.

Tis.Misc. (Other Tissue Information):

This is a phototoxic PAH [891,887].

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 [366]:

> No specific data could be found on the bioconcentration of benz(k)fluoranthene. Assuming a calculated log KOW of 6.84(1), one can calculate a log BCF of 4.97 for fish(2,SRC). It might be mentioned that although polynuclear aromatic hydrocarbons bioconcentrate in a variety of aquatic organisms, for benzo(a)pyrene, at least, there is no bioconcentration in fish due to the presence of a microsomal oxidase which enables it to be metabolized. Whether benzo(k)fluoranthene is also metabolized in fish has not been ascertained(3).[(1) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (2) Lyman WJ et al; Handbook of Chemical Property Estimation Methods. Environmental behavior of organic chemicals; McGraw Hill Book Co New York NY pp.5.1-5.30 (1982) (3) Santodonato J et al; pp.160-76 in Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons; Pathotox Publishers Inc Park Forest South Ill (1981)].

Interactions:

No information found.

Uses/Sources:

See also Chem.Detail section below for benzo(k)fluoranthene concentrations in petroleum products.

Column and thin-layer chromatography followed by spectrofluorometry indicated that commercial samples of 4 suntan oils based on mineral &/or vegetable oils contained benzo(k)fluoranthene. Total polycyclic aromatic hydrocarbon (pah) content ranged from 88.5 To 188.7 ng/g. Users of suntan oils may be exposed to low levels of potentially hazardous pah; however, in comparison with many other cosmetics that are presumably based on similar oils, suntan oils are only used intermittently & for relatively short periods. [monarca s et al; presence of benzo(a)pyrene and other polycyclic aromatic hydrocarbons in suntan oils; food chem toxicol 20 (2): 183-7 (1982)] [366].

Cigarettes 0.7-1.4 ug/1000 cigarettes(1), lubricating oils 0.04 ppm(1), used motor oil 1.5-36.8 ppm; crude oil 15.9 ppm(1). Exhaust from gasoline engine: air-cooled 27 ug/l fuel, water-cooled 11 ug/l fuel(1). Bitumen 0.34-1.41 ppm(2), Kuwait and South Louisiana crude oil < 1 ppm(2). [(1) IARC; Polynuclear Aromatic Compounds. Part I. Chemical environmental and experimental data; 32: 33-91, 164-7 (1983) (2) Verschuren K; Handbook of Environmental Data on Organic Chemicals; 2nd ed Van Nostrand Reinhold, New York, NY pp.252-4 (1983)] [366].

Natural Occurring Sources [366]:

Since benzo(k)fluoranthene is a product of incomplete combustion, there will be natural sources arising from volcanoes, forest fires, etc.(SRC). There is some evidence for biosynthesis of benzo(k)fluoranthene by algae(1). Fossil fuels(2). [(1) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (2) IARC; Polynuclear Aromatic Compounds. Part I. Chemical environmental and experimental data; 32: 33-91, 164-7 (1983)] Artificial Sources: 1. Gasoline 9 ug/l [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 252].

Ubiquitous product of incomplete combustion, occurring in exhaust from motor vehicles and other gasoline engines, emission from coal- and oil-burning stoves and furnaces, coal tar emissions, cigarette smoke; generally soot and smoke of industrial and domestic origin(1). Crude oil, gasoline, bitumen, sewage and sewage sludge(2). [(1) IARC, Polynuclear Aromatic Compounds 32: 163-70 (1983) (2) Verschueren K; Handbook of Environmental Data on Organic Chemicals; 2nd ed Van Nostrand Reinhold New York NY pp.252-4 (1983)].

Forms/Preparations/Formulations:

No information found.

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

Solubilities:

Water solubilities range from 0.0007 to 0.008 mg/L at 25 degrees C [848].

Insoluble (sic, actually relatively isoluble) in water

[366].

Soluble in alcohol, benzene, acetic acid [366].

Vapor Pressure [848]:

Values range from 1.28x10(-8) to 6.70x10(-5) Pa at 25 degrees C.

Henry's Law Constant [848]:

3.921, and 7.50 Pa m3/mol

Molecular Weight [366]:

252.32 [U.S. Department of Health and Human Services, Public Health Service, Center for Disease Control, National Institute for Occupational Safety Health. Registry of Toxic Effects of Chemical Substances (RTECS). National Library of Medicine's current MEDLARS file.,p. 86/8503].

Octanol/Water Partition Coefficient (log Kow) [848]:

Nine values from the literature range from 6.06 to 7.20, with an approximate average of 6.50.

Sorption Partition Coefficient (log Koc) [848]:

5.74, 5.99

Benzo(k)fluoranthene concentrations in South Louisiana crude and Kuwait crude were <1.3 and <1 mg/kg (ppm), respectively [177].

Benzo(k)fluoranthene 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: ND (not detected), ND, and 2 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 benzo(k)fluoranthene content (mg/kg or ppm) in one fresh sample of Exxon Valdez Crude Oil [971]: 0 mg/kg = ppm

Benzo(k)fluoranthene content in one fresh sample of NSFO (Fuel Oil 5, Chuck Rafkind, National Park Service, Personal Communication, 1996): 0.6 ng/mg (ppm)

Benzo(k)fluoranthene 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): 39.7 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).

Benzofluoranthenes concentration in Used Engine Oil [519; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 12, Upshall, C., J.F. Payne and J. Hellou. Induction of MFO enzymes and production of bile metabolites in rainbow trout (Oncorhynchus mykiss) exposed to waste crankcase oil. Copyright 1992 SETAC]: 46.0 ppm

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

Half-life in surface water is 3.8 to 499 hours, based on photolysis half-life in water [848].

Half-life in groundwater is 42,680 to 102,720 hours, based on estimated unacclimated aqueous aerobic biodegradation half-life [848].

Half-life in soil [848]: 21,840 to 51,360 hours, based on aerobic soil dieaway test data; > 50 days; mean half-life of 8.7 years for Luddington soil; anaerobic half-life of 87,360 to 205,440 hours, based on estimated unacclimated aqueous aerobic biodegradation half-life.

Environmental Fate [366]:

TERRESTRIAL FATE: When benzo(k)fluoranthene is spilled on soil, it will remain in the surface layers since it is strongly adsorbed. Benzo(k)fluoranthene as with other polynuclear aromatic hydrocarbons (PAHs) degrades slowly in soil. The half-life in soil with previous exposure to PAHs was about 2 years.

AQUATIC FATE: When benzo(k)fluoranthene is released into water it will rapidly sorb to sediment and particulate matter in the water column. There is a potential for reaction with alky peroxy radicals and hydroperoxy radicals which are photochemically produced in humic natural waters but no specific data could be found concerning this. There is also a potential for sorbed benzo(k)fluoranthene to be slowly desorbed and, therefore, low levels of benzo(k)fluoranthene in the water may last for long periods of time.

ATMOSPHERIC FATE: The presence of benzo(k)fluoranthene and other polyaromatic hydrocarbons in distant places far removed from sources, demonstrates not only their potential for long-ranged transport but also their stability to degradation in their predominant atmospheric state which is associated with submicron particles and aerosols. These particulates will be transported but are subject to gravitational settling and scavenging by rain and snow.

Biodegredation [366]:

Polynuclear aromatic hydrocarbons (PAHs) are degraded in soil, their persistence increasing with the number of condensed rings(1). Within a subclass in which the number of rings are constant, the more compact structures are more recalcitrant than the extended ones(1). When 7 applications of PAH-containing oil sludge was amended to soil over a two year period and then monitored for an additional year and a half, the benzo(k)fluoranthene residue in the soil at the end of the 2 year ammendation period was decreased by 57% in the following year and a half. Thirty percent of the total benzo(k)fluoranthene applied to the soil remained after 3 1/2 yrs(1). In a static biodegradability test employing a domestic wastewater inoculum, 50-70% of benzo(k)fluoranthene was degraded in four successive weekly subcultures(2).[(1) Bossert I et al; Appl Environ Microbiol 47: 763-7 (1984) (2) Tabak HH et al; 94th Ann Mtg Assoc Off Anal Chem: Test protocols for environmental fate and movement of toxicants; p.267 (1981)].

Abiotic Degradation [366]:

Solutions of benzo(k)fluoranthene in cyclohexane and dichloromethane are stable when exposed to sunlight or a fluorescent lamp filtered to provide wavelengths > 300 nm(1). However the relevance of solution photochemistry to the photolysis of benzo(k)fluoranthene in the free vapor state or adsorbed to particulate matter is unclear and probably remote(1). What is clear is that benzo(k)fluoranthene as well as other polynuclear aromatic hydrocarbons are transported to distant places far from sources and therefore demonstrate considerable atmospheric stability(2). In a laboratory study under simulated atmospheric conditions, benzo(k)fluoranthene had a half-life of 14.1 hr in sunlight without ozone present, 3.9 hr in sunlight with ozone (0.2 ppm) and 34.9 hr with ozone in the dark(2). No atmospheric studies employing benzo(k)fluoranthene in the adsorbed state could be found but its reactivity with ozone suggests that it may degrade faster under photochemical smog situations. Polynuclear aromatic hydrocarbons are very reactive with chlorine and ozone in solution, two agents used in disinfecting drinking water, which suggests that these chemicals will be lowered considerably in treated drinking water(3,5). Polynuclear aromatic hydrocarbons display a great range of reactivities with the alkyperoxy and hydroperoxy radicals which are found in natural waters, especially those with humic substances. However no data could be found on the reactivity of benzo(k)fluoranthene with these radicals(3). Polynuclear aromatic hydrocarbons are generally resistant to hydrolysis(4). [(1) Santodonato J et al; pp.77-176 in Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons; Pathotox Publishers Inc Park Forst South Ill (1981) (2) Bjorseth A, Olufsen BS; pp.507-24 in Handbook of Polycyclic Aromatic Hydrocarbons; Bjorseth A ed; Marcel Dekker Inc New York (1983) (3) Radding SB et al; The Environmental Fate of Selected Polynuclear Aromatic Hydrocarbons; p.131 USEPA-560/5-75-009 (1976) (4) Lyman WJ et al; Handbook of Chemical Property Estimation Methods. Environmental behavior of organic chemicals; McGraw-Hill New York, NY pp.7.1-7.41 (1982) (5) Sorrell RK et al; Environ Inter 4: 245-54 (1980)].

Soil Adsorption/Mobility [366]:

No experimental data could be found on the adsorption of benzo(k)fluoranthene to soil. Using a calculated log Kow = 6.84(1) one would estimate a log Koc = 6.52 using a regression equation(1,SRC). In general polynuclear aromatic hydrocarbons are strongly adsorbed to soils and sediments with the adsorption increasing with the effective chain length of the molecule(1). [(1) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983)].

Volatilization from Water/Soil [366]:

No specific information could be found on the volatilization of benzo(k)fluoranthene from soil or water. Volatilization from soil would probably be low due to benzo(k)fluoranthene's low vapor pressure and strong adsorption to soil(SRC). However volatilization from water may be significant since some high molecular weight, sparingly soluble organics volatilize surprisingly rapid; however, volatilization does not appear to be an important process for polycyclic aromatic hydrocarbons(1). [(1) Callahan MA et al; Water Related Environmental Data of 129 Priority Pollutants vol; 2 pp.97-1 to 97-23 USEPA-440/4-79-029b (1979)].

Absorption, Distribution and Excretion [366]:

Short necked clam (Tapes japonica) were cultured in artificial seawater at 21 to 25 deg c for 10 days. Levels of polycyclic aromatic hydrocarbons (pah), incl benzo(k)fluoranthene, were markedly decr. Approx 20% decr was found on day 8. When clams were placed in basket & kept in water of Osaka Harbor, only small incr in pah levels were found within short period of time; after 1 month, a 2.5 To 9 fold incr was observed. [obana h et al; uptake of polycyclic aromatic hydrocarbons by short necked clam (tapes japonica); osaka-furitsu koshu eisei kenkyusho kenkyu hokoku, shokuhin eisei hen 12: 91-4 (1981)].

Benzo(k)fluoranthene was detected in skin /oil/ of 9 roofers at median concn of 0.2 Ng/mg (range: 0.02-2.2); Total ng in sample from 36 sq cm area of forehead, 0.8 Median (range: 0.5 To 4.3). [wolff ms et al; detection of polycylic aromatic hydrocarbons in skin oil obtained from roofing workers; chemosphere 11 (6): 595-600 (1982)].

Laboratory and/or Field Analyses:

Recommended detection limits:

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

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

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

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

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

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

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

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

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

In a similar vein, if the Park Service sediment investigation at Petersburg National Historical Battlefield (see Chem.Detail section in separate "PAHs as a group" entry; this study was performed in response to contamination by Diesel) had utilized EPA semi-volatile scan 8270 or any of the other typical EPA scans (625, etc.), all of which only include parent compounds and often utilize detection limits no lower than the 170-600 ppb range, the false conclusion reached would have been that only one PAH was present in significant (detection limit) amounts. This false negative conclusion would have been made because the parent compound PAHs present constituted only 2.4% of the PAHs detected in sediments, and the highest concentration found for any parent compound except pyrene was 85.5 ppb, far below the detection limits used on the older standard EPA scans. Pyrene was 185 ppb, which would have been non-detected on many of the EPA scans, but not all. However, utilizing the NOAA protocol expanded scan [828], it was determined that 97.6% of total quantity of PAHs detected in sediments were alkyl PAHs, and that all 39 PAHs and alkyl PAHs were present in these sediments.

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

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

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