ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA
BENZO(E)PYRENE ENTRY

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

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

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

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

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

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

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

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

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

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

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

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

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

on the internet or NTIS: 1998).

Benzo(e)pyrene (CAS number 192-97-2)

Brief Introduction:

Br.Class: General Introduction and Classification Information:

Benzo(e)pyrene is a high molecular weight, 5-ring polycyclic aromatic hydrocarbon (PAH) [697].

Benzo(e)pyrene 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].

Benzo(e)pyrene occurs ubiquitously in products of incomplete combustion; it is also found in fossil fuels [847].

Br.Haz: General Hazard/Toxicity Summary:

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

An IARC search found no available data on the toxic effects of benzo(e)pyrene [847]. Much more information is available on BAP (see Benzo(a)pyrene entry).

PAHs in general tend to be associated with chronic impacts more often than acute. See also "PAHs as a group" entry.

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

EPA IRIS 1996: classification under review [893].

The International Agency for Research on Cancer (IARC) has determined that benzo(e)pyrene is not classifiable as to its carcinogenicity to humans [788].

No data are available in humans. Inadequate evidence of carcinogenicity in animals. Overall evaluation: Group 3 [366].

The 4- to 7-ring PAHs have been especially implicated in the carcinogenic effect of used oil [519; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 12, Upshall, C., J.F. Payne and J. Hellou. Induction of MFO enzymes and production of bile metabolites in rainbow trout (Oncorhynchus mykiss) exposed to waste crankcase oil. Copyright 1992 SETAC].

benzo(e)pyrene Inhibited 7,12-dimethylbenz(a)anthracene skin tumor-initiation in mice by 84%. [366, Slaga et al; Cancer Lett 7(1) 51-59 (1979)].

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

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

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

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

See also: PAHs (as a group) entry.

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

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

Synonyms/Substance Identification:

1,2-Benzopyrene [366]
1,2-Benzpyrene [366]
4,5-Benzopyrene [366]
4,5-Benzpyrene [366]
B(e)P [366]

Molecular Formula:
C20-H12 [366]

Associated Chemicals or Topics (Includes Transformation Products):

See also individual entry:

PAHs as a group

Metabolism/Metabolites [366]:

Qualitative & quantitative studies on metabolism of b(e)p...Showed that 3-hydroxy- & 4,5-dihydro-4,5-dihydroxy-benzo(e)pyrene were formed on incubation with rat liver homogenate. [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V3 146].
The major organic solvent-sol metabolite formed in extracellular medium after 24 hr of culture (hamster embryo cells) with b(e)p was k-region dihydrodiol 4,5-dihydro-4,5-dihydroxybenzo(e)pyrene & small amt monohydroxybenzo(e)pyrenes. [Macleod et al; cancer res 39(9) 3463-70 (1979)].

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(e)pyrene concentrations are 3.4-30.8 ng/L in surface water, 1.6-10.1 ng/L in rainwater, and 0.323-2.928 ng/L in waste water [847].

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 "PAHs as a group" entry). Therefore, any of the water (and other media) 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; A few words 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:

No information found. More information is available on BAP (see Benzo(a)pyrene entry).

W.Plants (Water Concentrations vs. Plants):

No information found.

W.Invertebrates (Water Concentrations vs. Invertebrates):

LT50 (mean survival time until the death of 50% of the test organisms) for Dapnia magna (water flea) was 15.36 hours at a concentration of 0.7 ug/L (ppb) [998].

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):

Drinking Water Health Advisories in IRIS: empty [893].

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):

Benzo(e)pyrene was detected in 100 % of urban-bay samples from the Puget Sound area. The mean concentration was 214.5 ug/kg dry weight (ppb), while the median concentration was 159.5 ug/kg (ppb) [852].

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

Sed.Typical (Sediment Concentrations Considered Typical):

Benzo(e)pyrene was detected in 57.1 % of non-urban-bay samples from the Puget Sound area. The mean concentration was 26 ug/kg dry weight (ppb), while the median concentration was 25 ug/kg (ppb) [852]. NOTE: these values based on only four samples where benzo(e)pyrene was detected.

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

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):

NOAA 1990: 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 there was too little data available to ascertain firm concern levels, but that effects in the two marine studies which were available were associated with the range of 194 mg/kg dry weight to 624 mg/kg dry weight [233] (see entry entitled ERL).

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):

Concentrations of PAH's in bioassay earthworms and bioassay soil from 15 sites at the Times Beach Confined Disposal Facility in Buffalo, N.Y. (1987): The mean concentration of BEP in the soil was 2.1 ppm (dry weight), the range was 0.22-4.0 ppm (dry weight). The mean concentration of BEP in the earthworm was 0.91 ppm (ash-free dry weight), the range was 0.099-4.2 ppm (ash-free dry weight) [347].

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. Much more information is available on BAP (see Benzo(a)pyrene entry).

Soil.Plants (Soil Concentrations vs. Plants):

No information found.

Soil.Invertebrates (Soil Concentrations vs. Invertebrates):

Concentrations of PAH's in bioassay earthworms and bioassay soil from 15 sites at the Times Beach Confined Disposal Facility in Buffalo, N.Y. (1987): The mean concentration of BEP in the soil was 2.1 ppm (dry weight), the range was 0.22-4.0 ppm (dry weight). The mean concentration of BEP in the earthworm was 0.91 ppm (ash-free dry weight), the range was 0.099-4.2 ppm (ash-free dry weight) [347].

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

No information found.

Soil.Human (Soil Concentrations vs. Human):

No information found.

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

No information found.

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

Note: Much more information is available on BAP (see Benzo(a)pyrene entry).

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:

Concentrations of PAH's in bioassay earthworms and bioassay soil from 15 sites at the Times Beach Confined Disposal Facility in Buffalo, N.Y. (1987): The mean concentration of BEP in the soil was 2.1 ppm (dry weight), the range was 0.22-4.0 ppm (dry weight). The mean concentration of BEP in the earthworm was 0.91 ppm (ash-free dry weight), the range was 0.099-4.2 ppm (ash-free dry weight) [347].

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:

The benzo(e)pyrene concentration in mosquitofish with extremely elevated total PAH concentrations (60.79 mg/kg) was 1.2 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:

benzo(e)pyrene concentrations in vegetable oils were found to be 0.0-32.7 ug/kg; and up to 74 ug/kg in smoked and cooked foods [847].

Food Survey Results [366]:

In meat or fish amt of b(e)p...Depends on method of cooking... In smoked fish...traces to 1.9 ug/kg... In gas-broiled fish, 1.2 ug/kg... charcoal-broiled or barbecued meat...1.7-7.5 ug/kg... In smoked ham, up to 5.2 ug/kg...heavy smoking...up to 17.9 ug/kg. [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V3 143].

...benzo(e)pyrene...Found/in/...Salad...Tomatoes...Spinach...Kale...Cereals... Vegetable oils...Roasted coffee...Black tea...Roasted peanuts...Yeast... [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V3 144].

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):

No information found. No RfD or slope information in IRIS [893].

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:

Concentrations of PAH's in bioassay earthworms and bioassay soil from 15 sites at the Times Beach Confined Disposal Facility in Buffalo, N.Y. (1987): The mean concentration of BEP in the soil was 2.1 ppm (dry weight), the range was 0.22-4.0 ppm (dry weight). The mean concentration of BEP in the earthworm was 0.91 ppm (ash-free dry weight), the range was 0.099-4.2 ppm (ash-free dry weight) [347].

Interactions:

benzo(e)pyrene Inhibited 7,12-dimethylbenz(a)anthracene skin tumor-initiation in mice by 84%. [Slaga et al; Cancer Lett 7(1) 51-59 (1979)] [366].

Uses/Sources:

Grimmer et al. reported concentrations of dibenz(a,c)-anthracene, 4-methylpyrene, fluoranthene, benz(a)anthracene, benzo(e)pyrene, benzo(g,h,i)perylene, and benzo(a)pyrene, respectively, 36, 49, 253, 720, 1,112, 4,770, and 7,226 times higher in "used" compared to "fresh" oil [519; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 12, Upshall, C., J.F. Payne and J. Hellou. Induction of MFO enzymes and production of bile metabolites in rainbow trout (Oncorhynchus mykiss) exposed to waste crankcase oil. Copyright 1992 SETAC].

See also Chem.Detail section below for benzo(e)pyrene concentrations in various petroleum products.

Natural Sources [366]:

Product of incomplete combustion (of carbon containing materials); component of fossil fuels.

Artificial Sources:

benzo(e)pyrene is present in all kinds of soot & smoke...In industrial effluents...In exhaust of internal combustion engines [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V3

142].

benzo(e)pyrene is formed on pyrolysis of anthracene @ 950 deg C, of dicetyl @ 800 deg C...of carbohydrates, amino acids & fatty acids @ 700 deg C...& @ 500 Deg C...& of different tobacco constituents @ 650 deg C, 700 deg C & 800 deg C. [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V3 142].

In commercial waxes, up to 0.039 mg/kg & 12-48 ug/kg were found. ...0-0.23 mg/kg in petrolatum, 150-180 mg/kg in creosote & 1850-1880 mg/kg in coal-tar samples...Concn of 0.03-52 mg/kg in petroleum asphalts & 5400-7000 mg/kg in coal-tar pitches. benzo(e)pyrene has been found in rubber stoppers & in automobile tires...furnace blacks in quantities which do not diminish on processing, aging or wear. [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V3 143].

In smoke condensates of 100 cigarettes, concn ranging from 0.2-2 Ug have been found. ...Found 0.1 mg/kg &...1.09 mg/kg in cigarette smoke condensate. [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-1985. (Multivolume work).,p. V3 142].

Forms/Preparations/Formulations:

No information found.

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

Solubility:

Eight water solubility values from the literature range from 0.004 to 0.00732 mg/L at 25 degrees C [848].

Very slightly soluble in water [847].

Soluble in acetone [847].

Vapor Pressure [848]:

Five values from the literature range from 7.32x10(-7) to 2.25x10(-5) Pa at 25 degrees C, with the approximate average being 7.28x10(-6) Pa at 25 degrees C.

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

6.44, 7.40

Sorption Partition Coefficient (log Koc) [848]:

7.20 (specified particulate)
4.00 (predicted dissolved)

Concentrations of benzo(e)pyrene in South Louisiana crude, Kuwait crude, No. 2 fuel oil, and Bunker C residual were 2.5, 0.5, 0.1, and 10 mg/kg (ppm), respectively [177]. Another study showed concentrations of benzo(e)pyrene in South Louisiana crude and Kuwait crude were 3.3 and 0.5 10(-6)g/g oil (ppm), respectively [747].

Benzo(e)pyrene concentration is 0.030-0.402 in fresh motor oils, 0.23-48.9 mg/kg in used motor oils, 1.2-28.9 mg/kg oil in crude oils, and 0.18-1.82 mg/kg in gasolines [847].

Benzopyrene 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: 12, ND (not detected), and 1 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].

Benzo(e)pyrene content in one fresh sample of NSFO (Fuel Oil 5, Chuck Rafkind, National Park Service, Personal Communication, 1996): 29.8 ng/mg (ppm).

Benzo(e)pyrene content in one sample of groundwater subjected to long term contamination of NSFO (Fuel Oil 5), possibly mixed with some JP-4, motorgas, and JP-8, Colonial National Historical Park Groundwater Site MW-10 (Chuck Rafkind, National Park Service, Personal Communication, 1996): 1062.3 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).

Benzo(e)pyrene concentrations in Used Engine Oil: 32.0 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].

Benzo(e)pyrene, a heavy and persistent PAH, is found in unleaded, premium unleaded, and leaded gasolines at a (presumably typical) concentration of 0.3 mg/kg (ppm) [796].

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

Abiotic Degradation [366]:

Benzo(e)pyrene underwent photolysis much slower than pyrene or benzo(a)pyrene both in air & in presence of 03 under simulated sunlight conditions. [Katz et al; Polynucl Aromat Hydrocarbons; int symp chem biol-carcinog mutagen, 3rd, 1979, 171-189].

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 in the disclaimers section at the top of this entry, the interagency task force on water methods concluded that [1014]:

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

As of 1997, the problem of lack of data comparability (not only for water methods but also for soil, sediment, and tissue methods) between different "standard methods" recommended by different agencies seemed to be getting worse, if anything, rather than better. The trend in quality assurance seemed to be for various agencies, including the EPA and others, to insist on quality assurance plans for each project. In addition to quality control steps (blanks, duplicates, spikes, etc.), these quality assurance plans call for a step of insuring data comparability [1015,1017]. However, the data comparability step is often not given sufficient consideration. The tendency of agency guidance (such as EPA SW-846 methods and some other new EPA methods for bioconcentratable 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).