ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA

INDENO(1,2,3-C,D)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 or summaries as being "what the original author said," the proposed interagency funding of a bigger project with more elaborate peer review and quality control steps never materialized.

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

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

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

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

> **Irwin, R.J., M. VanMouwerik, L. Stevens, M.D. Seese**, and **W. Basham.** 1997. Environmental Contaminants Encyclopedia. National Park Service, Water Resources Division, Fort Collins, Colorado. Distributed within the Federal Government as an Electronic Document (Projected public availability on the internet or NTIS: 1998).

Indeno(1,2,3-c,d)pyrene (CAS number 193-39-5)

Brief Introduction:

Br.Class: General Introduction and Classification Information:

Ideno(1,2,3-c,d)pyrene is a high molecular weight, 5-ring polycyclic aromatic hydrocarbon (PAH), and an EPA Priority Pollutant and EPA-classified carcinogen [446,680,634].

Ideno(1,2,3-c,d)pyrene is included on the expanded scan of PAHs and alkyl PAHs recommended by NOAA [828]; this list includes the PAHs recommended by the NOAA's National Status and Trends program [680].

Br.Haz: General Hazard/Toxicity Summary:

This compound often occurs together with other aromatics (sometimes including alkyl PAHs), and a typical complex mixture of aromatics may be more toxic or hazardous in general than this compound would be alone (see "PAHs as a group" entry).

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.

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

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

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].

This PAH has very stringent (low concentration) criteria related to drinking water and some other media (see details in sections below).

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

EPA 1996 IRIS database information [893]:

Classification as to human carcinogenicity weight-of-evidence classification: B2; probable human carcinogen

BASIS: Based on no human data and sufficient data from animal bioassays. Indeno(1,2,3-cd)pyrene produced tumors in mice following lung implants, subcutaneous injection and dermal exposure. Indeno(1,2,3-cd)pyrene tested positive in bacterial gene mutation assays.

HUMAN CARCINOGENICITY DATA: None

ANIMAL CARCINOGENICITY DATA: Sufficient.

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

This compound often occurs together with other PAHs, some possibly just as carcinogenic or more so (see "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 Survey/USGS, and Roy Irwin, National Park Service, personal communication, 1996).

The International Agency for Research on Cancer (IARC) has determined that indeno(1,2,3-c,d)pyrene is possibly carcinogenic to humans [788]. The Department of Health and Human Services (DHHS) has determined that indeno(1,2,3-c,d)pyrene may reasonably be anticipated to be a carcinogen [788]. EPA has determined that indeno(1,2,3-c,d)pyrene is a probable human carcinogen [788].

IARC Summary and Evaluation [366]: No data are available in humans. Sufficient evidence of carcinogenicity in animals. OVERALL EVALUATION: Group 2B: The agent is possibly carcinogenic to humans.

Relative (equivalency factor) oral carcinogenic potency value compared to Benzo(a)pyrene (BAP, which is ranked 1.0): The factor for indeno(1,2,3-cd)pyrene compared to BAP is 0.1 [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).

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

Indeno(1,2,3-cd)pyrene is known to be carcinogenic [881] but phototoxicity status is unknown.

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

The higher molecular weight PAHs benzo(a)pyrene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene, and compounds of molecular weight 302 amu were found to be mutagenic to the bacteria Salmonella typhimurium [816; Reprinted with permission from Environmental Toxicology and Chemistry, Volume 14, Marvin, C.H., J.A. Lundrigan, B.E. McCarry and D.W. Bryant, "Determination and genotoxicity of high molecular mass polycyclic aromatic hydrocarbons isolated from coal-tar-contaminated sediment". Copyright 1995 SETAC].

Indeno(1,2,3-cd)pyrene has growth-promoting effects on some higher plants as well as on planktonic algae [366].

Found to be one of the three principal mutagenic compounds in a coal-tar-contaminated sediment [816].

Indeno(1,2,3-cd)pyrene produced positive results in reverse mutation assays in Salmonella typhimurium strains TA100 and TA98 (2-3 ug/plate) [893].

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

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

[796].

Environmental Fate/Exposure Summary [366]:

Indeno(1,2,3-cd)pyrene (IP) released to soil will sorb strongly (estimated Koc = 20,146) and hence is not expected to leach. No information was found about volatilization from, hydrolysis in, or biodegradation in soil. IP released to water will sorb strongly to suspended particulate matter, biota and sediments. Although there is a high potential for IP to bioconcentrate in most aquatic organisms, it may not in fish since fish contain microsomal oxidase, which allows polyaromatic hydrocarbons to be metabolized. No information was found about IP volatilization, photolysis, hydrolysis, or biodegradation in water. IP will probably be persistent in the aquatic environment and concentrate in sediments. Almost all IP released to the atmosphere will be sorbed to particulate matter; thus its atmospheric fate will primarily depend on physical processes such as dry and wet deposition. However, a computer-estimated half-life for IP in the vapor phase is about 20 hours due to reaction with photochemically produced hydroxyl radicals. IP has been found in rain, drinking water, groundwater, surface waters, treated industrial wastewaters, marine and freshwater sediments, suspended sediments, automobile exhaust, ambient air, foods (cereals, cooking oils, barley malt), powdered milk, infant formula, seafoods, and sewage sludge. The primary route of human exposure to IP will probably be through ingestion of contaminated food(SRC). Other exposure to IP may be from drinking water and breathing air that is contaminated with IP.

Synonyms/Substance Identification:

1,10-(1,2-Phenylene)pyrene [366]
1,10-(O-Phenylene)pyrene [366]
2,3-O-phenylenepyrene [366]
2,3-phenylenepyrene [366]
O-phenylenepyrene [366]
Indenopyrene [366]
Ideno(1,2,3-cd)pyrene [366]
IP [366].

Molecular Formula [366]:
C22-H12 [366]

Associated Chemicals or Topics (Includes Transformation Products):

See also individual entries:

PAHs as a group
Petroleum, General

Metabolism/Metabolites [366]:

Most of the polynuclear aromatic hydrocarbons taken in by mammals are oxidized and the metabolites excreted.

The metabolism of indeno(1,2,3-cd)pyrene was investigated. A total of 400 micrograms of radioactive Indeno(1,2,3-cd)pyrene was added to 4 milliliters of supernatant from rat liver homogenates. Incubation was stopped every 5 minutes over a 70 minute period. The metabolites were separated ... The mutagenic potency of the metabolites was evaluated by the Ames assay. Some metabolites identified included the 1,2-dihydrodiol form, the 8-hydroxy form, the 1,2-dihydrodiol form, the 9-hydroxy form and the 1,2-quinone form of IP. No oxygenated metabolites of IP were detected. The 8 and 9 hydroxy forms were strongly mutagenic in the presence of the supernate. The 1,2-oxide was a potent mutagen in the absence of metabolic activation. ... /Results indicate/ that the epoxide precursors to the phenolic dihydrodiols contribute to the overall mutagenic activity of indeno(1,2,3-cd)pyrene.

Water **Da**ta 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):

As much as 15,000 ug/cu m have been found in sewage water [366].

W.Typical (Water Concentrations Considered Typical):

Indeno(1,2,3-c,d)pyrene concentration ranges in water have been found to be: 0.2-0.5 ng/L in surface water, 0.3-4.8 ng/L in tap water, 0.2-8.7 ng/L in rainfall, 0.2-5.0 ng/L in subterranean water [847].

The indeno(1,2,3-c,d)pyrene concentrations in surface waters of the Atlantic region of Canada range from <0.003 to 0.006 ug/L (based on 58 samples taken 1980-81) [754].

In surface water, concentrations ranged from 1.4-123 Ug/cu m [366].

GROUNDWATER [366]: Indeno(1,2,3-cd)pyrene (IP) was detected in groundwater from a contaminated aquifer in St. Louis Park, MN(1). IP concentrations in groundwaters from Germany ranged from 0.4-12.6 ng/l(2) and in the Netherlands up to 1 ug/l(3). [(1) Rostad CE et al; Chemosphere 14: 1023-36 (1985) (2) Sorrell RK et al; Environ Inter 4: 245-54 (1980) (3) Zoeteman BCJ et al; Sci Total Environ 21: 187-202 (1981).

SURFACE WATER [366]: Indeno(1,2,3-cd)pyrene (IP) concentration was <10 ug/l in 878 observations in the STORET data base(1). IP was detected in Lakes Ontario, Erie, Michigan and Superior(2). IP concentrations (ng/l) in a lake and in rivers in Europe were: 2.6 (Bodensee, 1964), 16.4 (Danube River, 1964), 32.0 (Main River), and 123.0 (Rhine River at Mainz, 1964)(3). Concentrations of IP in 9 rivers in the UK were: 95, 86, 25, 339, 10, 19, 10, 29, and 77 ng/l(4). [(1) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985) (2) Great Lakes Water Quality Board; An Inventory of Chemical Susbtances Identified in the Great Lakes Ecosystems Vol 1 - Summary Report to the Great Lakes Water Quality Board Windsor, Ontario Canada (1983) (3) Sorrell RK et al; Environ Inter 4: 245-54 (1980) (4) Crane RI et al; A Survey of Polycyclic Aromatic Hydrocarbon Levels in British Waters Medmenham UK: Water Research Centre TR-158 (1981).

DRINKING WATER: Indeno(1,2,3-cd)pyrene (IP) concentrations (parts per trillion) in drinking waters were: 1.2 (Pittsburgh), 1.2 (Huntington, WV), 0.7 (Endicott, NY), 0.9 (Hammondsport, NY), 1.7 (Philadelphia, PA), 2.2 (New York City), and 0.9 (Lake George, NY)(1). Maximum and average IP concentrations in Dutch drinking water were 0.075 and 0.008 ug/l, respectively(2). IP was generally below the detection limit in British groundwaters used as drinking water; however, concentrations of up to 51 ng/l were detected during repair work on the distribution systems(3). Raw surface waters in the UK used as drinking water sources typically contained IP (5-97 ng/l) before water treatment; however, after treatment, IP concentrations were always <3 ng/l(3). [(1) Saxena J et al; Method Development and Monitoring of Polynuclear Aromatic Hydrocarbons in Selected US Waters USEPA-600/11-77-052 (1977) (2) Kraybill HF; NY Acad Sci Annals 298: 80-9 (1977) (3) Crane RI et al; A Survey of Polycyclic Aromatic Hydrocarbon Levels in British Waters Medmenham UK: Water Research Centre TR-158 (1981).

Effluent Concentrations [366]:

Indeno(1,2,3-cd)pyrene (IP) was detected in vehicle emissions(1) and in an effluent channel from a coking plant(2). Sewage effluent in the UK contained 9.9 and

30.1 ng IP/l(3). IP concentrations (ug/l) in treated industrial wastewaters in the US (unspecified locations) were: 10-11 (11 avg) from coal mining, not detected - 8.0 (0.35 avg) from nonferrous metals manufacturing, and 10-110 (10 avg) from timber products processing(4). IP concentrations from 5-10 ug/l (0.06-0.12 ug/g) up to 160-240 ug/l (4.57-6.86 ug/g) were found in UK sewage sludge samples(5). [(1) Perry R; Inter Symp Ident Meas Environ Pollut pp 130-7 (1971) (2) Griest WH; in Hydrocarbon Halo Hydrocarbon Aquatic Environ Afghan BK, Mackay D eds Plenum Press NY (1980) (3) Crane RI et al; A Survey of Polycyclic Aromatic Hydrocarbon Levels in British Waters Medmenhham UK: Water Research Centre TR-158 (1981) (4) USEPA; Treatability Manual Vol 1 Treatability Data USEPA-600/2-82-001a (1981) (5) McIntyre AE et al; Anal Lett 14: 291-309 (1981).

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

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

EPA 1996 IRIS database information [893]:

Ambient Water Quality Criteria for Aquatic Organisms:

Marine Acute: 3.0E+2 ug/L

Other Water Quality Criteria in ug/L:

Freshwater Acute Criteria: None Published [446,893].

Freshwater Chronic Criteria: None Published [446,893].

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

Marine Chronic Criteria: None Published [446,893].

Canada's Interim Assessment Criterion for indeno(1,2,3-c,d)pyrene in water is 0.1 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.

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 1996 IRIS database information [893]:

Maximum Contaminant Level Goal:

Value: 0 mg/L Status/Year: Proposed 1990 Econ/Tech?: No, does not consider economic or technical feasibility Reference: 55 FR 30370 (07/25/90).

Contact: Health and Ecological Criteria Division / (202)260-7571 Safe Drinking Water Hotline / (800)426-4791.

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

Maximum Contaminant Level (MCL):

Value: 0.0002 mg/L Status/Year: Proposed 1990 Econ/Tech?: Yes, does consider economic or technical feasibility Reference: 55 FR 30370 (07/25/90).

Contact: Drinking Water Standards Division / OGWDW / (202)260-7575 Safe Drinking Water Hotline / (800)426-4791.

Discussion: The proposed MCL is equal to the PQL and is associated with a maximum lifetime individual risk of 1E-4.

Ambient Water Quality Criteria for Human Health:

Water & Fish Route of Exposure: 2.8E-3 ug/liter [893].

Earlier Citation: Published Criteria for Water and Organisms: 0.0028 ug/L [446,689].

Fish Only Route of exposure: 3.11E-2 ug/liter [893].

Earlier Citation: Published Criteria for Organisms Only: 0.0311 ug/L [446,689].

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

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

Discussion: For the maximum protection from the potential carcinogenic properties of this chemical, the ambient water concentration should be zero. However, zero may not be obtainable at this time, so the recommended criteria represents a E-6 estimated incremental increase of cancer over a lifetime. The values given represent polynuclear aromatic hydrocarbons as a class.

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 is updated monthly [893].

EPA Tap Water Preliminary remediation goal (PRG) [868] and RBC value [903]: 9.2E-02 ug/L.

The warm water- and cold water sport fish community human cancer criteria for indeno(1,2,3-c,d)pyrene in Wisconsin public water supplies are each 0.023 mg/L [881].

The warm water- and cold water sport fish community human cancer criteria for indeno(1,2,3-c,d)pyrene in Wisconsin non-public water supplies are each 0.1 mg/L [881].

Numeric Water Quality Criteria in Arizona [881]:

Domestic water supply: 0.003 ug/L
Fish consumption: 0.000003 ug/L
Full body contact: 0.12 ug/L

Criteria for human health protection in Missouri [881]:

Fish consumption: 0.03 ug/L
Drinking water supply: 0.003 ug/L
Groundwater: 0.003 ug/L

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

A review of groundwater monitoring data from 479 waste disposal sites (178 CERCLA or Superfund sites, 173 RCRA sites, and 128 sanitary/municipal landfill sites) located throughout the United States indicated that 14 of the PAHs included in this profile were detected at frequencies ranging from 2 detections at one site in one EPA Region for indeno[1,2,3-c,d]pyrene, to 85 detections at 16 sites in 4 EPA Regions for fluorene (Plumb 1991). Benzo[a]pyrene was detected 13 times at 6 sites in 6 EPA Regions. Concentrations were not reported [881].

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

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

Sed.Low (Sediment Concentrations Considered Low):

No information found.

Sed.High (Sediment Concentrations Considered High):

No information found.

Sed.Typical (Sediment Concentrations Considered Typical):

Indeno(1,2,3-c,d)pyrene was detected in 76.4 % of urban-bay samples from the Puget Sound area. The mean concentration was 771 ug/kg dry weight (ppb), while the median concentration was 160 ug/kg (ppb) [852].

Indeno(1,2,3-c,d)pyrene was detected in 48.8 % of non-urban-bay samples from the Puget Sound area. The mean concentration was 1799 ug/kg dry weight (ppb), while the median concentration was 77 ug/kg (ppb) [852].

> NOTE: The above values are not normalized for total organic carbon (TOC) content. Urban bay concentrations may be lower than non-urban bay concentrations due to more frequent dredging practices in urban bays, and also to the fact that most of the urban bays are at the mouths of rivers which are continually depositing "clean" sediment into these bays.

The indeno(1,2,3-c,d)pyrene concentration range in dried sediments from lakes was 1 to 2070 ug/kg [847].

Sediment Concentrations [366]:

> Indeno(1,2,3-cd)pyrene (IP) concentrations in sediments were: up to 176.9 ug/kg (South Carolina Coast)(1), 860 ng/g (wet wt, Duwamish River Delta, WA)(2), 9-228 ppb (dry wt, Penobscot Bay Stations ME)(3), 30-1200 ng/g (dry wt, Eagle Harbor and President Point, WA)(4), 0.10 and 1.80 mg/kg (near Darmstadt, W. Germany)(5), and 125 ng/g (Exe estuary, Devon, UK (6). An IP concentration (ng/g, dry wt) profile in an Adirondack Lake (NY) sediment was: 1300 (0-4 cm), 360 (4-8 cm), 20 (8-11 cm), 4 (12-17 cm), 3 (24-26 cm), 5 (34-38 cm), < 2 (42-44 cm), 8 (50-54 cm), and 2 (80-84 cm)(7). IP concns in a sediment sample from Saudafjord, Norway were from 7577.6 ppb (dry wt, 0-2 cm depth) to 3077.6 ppb (dry wt, 6-8 cm depth)(8). IP was detected in an effluent channel from a coking plant(9). IP concentration in suspended sediments from the Exe estuary, Devon, UK was 178 ng/g(6). [(1) Marcus JM, Stokes TP; Bull Environ Contam Toxicol 35: 835-44 (1985) (2) Varanasi U et al; Environ Sci Techol 19: 836-41 (1985) (3) Johnson AC et al; Marine Environ Res 15: 1-16 (1985) (4) Malins DC et al; Carcinogenesis 6: 1463-9 (1985) (5) Rump HH; Fresenius Z Anal Chem 319: 165-71 (1984) (6) Herrmann R, Huebner D; Neth J Sea Res 15: 362 (1982) (7) Tan YL, Heit M; Geochim Cosmochim Acta 45: 2267-79 (1981) (8) Bjoerseth A et al; Sci Total Environ 13: 71-86 (197) (9) Griest WH; in Hydrocarbon Halo Hydrocarbon Aquatic Environ Afghan BK, Mackay D eds Plenum Press NY (1980).

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

Sed.General (General Sediment Quality Standards, Criteria, and Benchmarks Related to Protection of Aquatic

Biota in General; Includes Sediment Concentrations Versus Mixed or General Aquatic Biota):

Concern levels for sediment concentrations:

AET: The Apparent Effects Threshold concentrations for indeno(1,2,3-c,d)pyrene in sediments proposed for Puget Sound ranged from 0.6 mg/kg dry weight (microtox) to 2.6 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).

Ontario Ministry of the Environment Freshwater Sediment Guidelines, 1993 [761]. Lowest level: 200 ug/kg dry weight. Severe effect level: 320 mg/kg organic carbon.

St. Lawrence River Interim Fresh Water Sediment Criteria, 1992 [761]. No effect level: 70 ug/kg dry weight.

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):

Combined field & lab studies were conducted to assess the possible role of contaminated bottom sediments to neoplastic disease in fish from eastern Lake Erie & upper Niagara River. Correlations between sediment polycyclic hydrocarbons, neoplasms in feral fish, & induction of neoplasms in bullheads (Ictalurus nebulosus) by dermal exposure to extracts of polluted sediment support the hypothesis that some fish neoplasms result from exposure to carcinogenic chemicals present in fish environment. O-phenylenepyrene was one of the polycyclic aromatic hydrocarbons identified by hplc in the samples taken from contaminated bottom sediments [366].

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

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

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

Soil.Low (Soil Concentrations Considered Low):

No information found.

Soil.High (Soil Concentrations Considered High):

Soil Concentrations (mg/kg dry weight) Polycyclic Aromatic Hydrocarbons (PAHs) at Contaminated Sites.

Highest values found at wood preserving, gas works, and coking site plants (mg/kg dry weight) [881]:

Indeno-(1,2,3-c,d)pyrene	316

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):

Canada's Interim Assessment Criterion for indeno(1,2,3-c,d)pyrene in soil is 0.1 ug/g dry weight [656].

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

Canada's Interim Remediation Criteria for indeno(1,2,3-c,d)pyrene 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):

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 indeno(1,2,3,c,d)pyrene in soil was 3.1 ppm; the range was 0.47-6.7 ppm [347].

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

No information found.

Soil.Human (Soil Concentrations vs. Humans):

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

SSL = 0.9 mg/kg for ingestion pathway [952].

SSL = 0.7 to 14 mg/kg for protection from migration to groundwater at 1 to 20 Dilution-Attenuation Factor (DAF) [952].

Preliminary remediation goals (PRGs) [868]:

Residential Soil: 0.61 mg/kg wet weight
Industrial Soil: 2.6 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 [903].

EPA Region III Risk Based Criteria (RBC) to protect from transfers to groundwater:

35 mg/Kg dry weight [903].

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

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

No information found.

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

Tis.Plants:

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

No information found.

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

Present in the leaves of various kinds of trees (26-234 ug/kg) and in tobacco leaves (18-38 ug/kg) and it has been detected in algae (Chlorella vulgaris) [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].

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 indeno(1,2,3,c,d)pyrene in the earthworms was 1.3 ppm and the range was 0.21-5.0 ppm (ash-free dry weight) [347].

See also Tis.Fish, C), below.

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 (carcinogenic vs. non-carcinogenic) concentrations, rounded to two significant figures [903]:

RBC Benchmark = 0.0043 mg/Kg wet weight for carcinogenic risk.

See also: Tis.human below.

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].

Fish/Seafood Concentrations [366]:

Detected in African smoked fish. [Mossanda K et al; Food Cosmet Toxicol 17 (2): 141-4 (1979).

Indeno(1,2,3-cd)pyrene (IP) concentrations in seafoods were: up to 6218 ppb in mussels from a fjord in Norway(1), up to 8.7 ug/kg in soft shell clams from Coos Bay, Oregon(2), 1.7 ug/kg in oysters from a coastal marina in South Carolina(3), and up to 9.4 ug/kg (5.7 ug/kg avg) in mussels from Yaquina Bay, Oregon(4). Composites of stomach organisms from fish (English sole from the Oregon coast) contained 1600 and 1200 ng IP/g dry weight(5). [(1) Bjorseth A et al; Sci Total Environ 13: 71-86 (1979) (2) Mix MC, Schaffer RL; Marine Pollut Bull 14: 94-7 (1983) (3) Marcus JM, Stokes TP; Bull Environ Contam Toxicol 35: 835-44 (1985) (4) Mix MC, Schaffer RL; Mar Environ Res 9: 193-210 (1983) (5) Malins DC et al; Carcinogenesis 6: 1463-9 (1985).

Concentrations of 15 unsubstituted polynuclear aromatic hydrocarbons (PNAH) were determined in 2 subpopulations of softshell clams from

1978-9. For the 2 yr period, concn were highest in clams inhabiting areas adjacent to the industrialized bayfront and lowest in clams inhabiting more remote areas. During the study the average total PNAH concn in clams from the bayfront area was 555.1 mug/kg compared to 76.3 mug/kg for clams from a more remote environment. PNAH concn were lowest in the fall-winter and highest during the spring-summer. /Polynuclear aromatic hydrocarbons/ [Mix MC, Schaffer RL; Mar Pollut Bull 14 (3): 94-7 (1983).

Concn of 15 unsubstituted polynuclear aromatic hydrocarbons were measured in M edulis from 2 sites in Yaquina Bay, Oregon, USA, during 1979-1980. The average total concn in mussels inhabiting the more industrialized bayfront was 986.2 mug/kg compared with 273.9 mug/kg in mussels from a more remote site across the bay. The smaller, more water sol, cmpd were concn to 1 or 2 orders of magnitude above the large, less sol PNAH. /Polynuclear aromatic hydrocarbons/ [Mix MC, Schaffer RL; Mar Environ Res 9 (4): 193-210 (1983).

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

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

No information found.

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

No information found.

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

No information found.

Tis.Human:

A) Typical Concentrations in Human Food Survey Items:

See also Tis.Fish, C), above.

Food Survey Results [366]:

Fresh sausages contained 0.3 ug/kg, & charcoal broiling brought content up to 9 ug/kg. In coconut oil, olive oil, plant cooking fat & plant oil, 0.9-1.6 ug/kg have been found. ... Detected concn of 0.2-5.5 ug/kg in margarine, indenopyrene content being reduced considerably by treatment with activated charcoal & steam. The indeno(1,2,3-cd)pyrene (ip) content of oil decr slightly with frying, & that of fat with controlled lab heating. In normally roasted coffee no indenopyrene was found, but up to 0.8 ug/kg could be detected in extremely black coffee & up to 5.9 ug/kg in malt coffee, substitute coffee and sol coffee powder.

Indeno(1,2,3-cd)pyrene (IP) concentrations (ug/kg) in breakfast cereals were 3.0 (puffed wheat), 1.4 (wheat bran), and 0.2 (corn bran), in cooking oils 0.5 (soy) and 0.5 (corn), and in barley malt 0.4 ug/kg(1). In a Dutch market basket survey (1976-1978), IP concn was < 0.4 ug/kg(2). [(1) Lawrence JF, Weber DF; J Agric Food Chem 32: 794-7 (1984) (2) Vaessen HAMG et al; Tox 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):

Oral Slope Factor: 7.3E-01 mg/kg/day [868].

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

RBC Benchmark = 0.0043 mg/Kg wet weight for carcinogenic risk.

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

Milk Concentrations:

Indeno(1,2,3-cd) pyrene (IP) concentrations in skim milk powder was 0.2 ug/kg and in powdered infant formula was 1.2 ug/kg(1). [(1)

Lawrence JF, Weber DF; J Agric Food Chem 32: 794-7 (1984).

Tis.Misc. (Other Tissue Information):

No information found.

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

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

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 indeno(1,2,3,c,d)pyrene was 3.1 ppm the range was 0.47-6.7 ppm. The mean concentration of indeno(1,2,3,c,d)pyrene in the earthworms was 1.3 ppm and the range was 0.21-5.0 ppm (ash-free dry weight) [347].

Bioconcentration [366]:

An estimated bioconcentration factor (BCF) for indeno(1,2,3-cd) pyrene (IP) using eqn 5-2(1) and an estimated log Kow of 6.584(2), is 59,407. This indicates a strong potential for bioconcentration(SRC); however, polyaromatic hydrocarbons (PAH) are not likely to appreciably bioconcentrate in organisms that have microsomal oxidase, such as fish, since this enzyme enables the organism to metabolize PAH(3).

... Some marine organisms have no detectable aryl hydrocarbons hydroxylase enzyme systems, namely: phytoplankton, certain zooplankton, mussels (Mytilus edulis), scallops (Placopecten sp), and snails (Litternia littorea). ... Those organisms which lack a metabolic detoxification enzyme system, tend to accumulate polycyclic aromatic hydrocarbons. /Polycyclic aromatic hydrocarbons.

Bioaccumulation, especially in vertebrate organisms, is considered to be short-term, and is not considered an important fate process. /Polycyclic aromatic hydrocarbons.

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

Interactions:

No information found.

Uses/Sources:

See also Chem.detail section below for indeno(1,2,3-cd)pyrene concentrations in various petroleum products.

Indeno(1,2,3-cd)pyrene (IP) is formed in most combustion or elevated temperature processes that involve compounds containing carbon and hydrogen. Known IP sources include coal, wood, and gasoline combustion, municipal waste incineration, coke ovens and cigarette smoke. IP has also been found in gasoline, fresh and used motor oil, and road runoff [366].

Geometric mean concentrations of ten PAHs (benzo[a]pyrene, benzo[k]fluoranthene, benzo[b]fluoranthene, benzo[k]fluoranthene, bins[a]enthrones, indeno[1,2,3-c,d]pyrene, benzo[g,h,i]perylene, pyrene, and chrysene) ranged from 0.03 to 0.62 ng/m3 in urban areas and from 0.01 to 0.12 ng/m3 in the rural area during the summer seasons [881].

A seasonal variation in particle-phase PAH concentrations in the Los Angeles atmosphere was seen in an earlier 1974-75 study [881]. Quarterly geometric mean concentrations of 11 PAHs (pyrene, fluoranthene, benz[a]anthracene, chrysene, benzo[a]pyrene, benzo[e]pyrene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, benzo[g,h,i]perylene, and indeno[1,2,3-c,d]pyrene) ranged from 0.06 to 2.71 ng/m3 (with an average of 0.45 ng/m3) during the May-October period, and from 0.26 to 8.25 ng/m3 (with an average of 1.46 ng/m3) during the November-April period. The highest and lowest concentrations were observed during the fourth (November-January) and second (May-July) quarters, respectively. Ratios of fourth quarterly and second quarterly geometric mean concentrations ranged from 3.9 for indeno[1,2,3-c,d]pyrene to 7.5 for benzo[a]pyrene and 9.8 for benz[a]anthracene. Possible factors contributing to these seasonal variations in PAH levels include the following: changes in emission patterns; changes in meteorological conditions (i.e., daylight hours and temperature); and changes in space heating emissions, volatilization, and photochemical activity [881].

Natural Occurring Sources [366]:

... Present in leaves of various kinds of trees (26-234 ug/kg) & in tobacco leaves (18-38 ug/kg), & it has been detected in algae.

Algae cells produced 1.50 ug indeno(1,2,3-cd)pyrene (IP)/kg (dry weight) when acetate was the sole carbon source(1). Since polycyclic aromatic hydrocarbons (PAH) may form in most combustion or elevated temperature processes which involve compounds containing carbon and hydrogen(2), IP may form during forest fires(SRC).

Artificial Sources [366]:

... Isolated 82 mg/kg of exhaust tar from first run gasoline engine exhaust, & 5.7 ug/min run from automobile exhaust. In diesel engine exhaust, up to 11 ug/cu m were found. Concn ranging from 135-457 mg/kg ... Were found in tar samples in detroit area; in road dust 8-61 mg/kg were found, & in dust from air 0.96 mg/kg.

Polycyclic aromatic hydrocarbons (PAH) of flue gases from oil heating systems incl indeno(1,2,3-cd)pyrene.

Two persons smoked 5 cigarettes/hr from 9 am to 5 pm in 36 cu m room, an air sample collected contained indeno(1,2,3-cd)pyrene.

In the smoke condensate of 100 cigarettes concn ranged from 0.4 ug to 2 ug. /It/ ... Is formed on pyrolysis of the tobacco constituents dotriacontane or stigmasterol @ 700 deg c, & of benzene & pyrene @ 700 deg c.

Indeno(1,2,3-cd)pyrene (IP) is formed in most combustion or elevated temperature processes which involve compounds containing carbon and hydrogen(1). IP sources include gasoline engines (11-87 ug IP/cu m; 268 ug IP/g exhaust condensate; 32-86 ug IP in exhaust condensate/l gasoline consumed)(2), stack gases (0.18 mg IP/100 cu m stack gas from a municipal incinerator, after spray tower and electrostatic precipitator)(2), coke ovens(2), cigarette smoke (0.4 ug IP/100 cigarette)(2), wood and coal fires(3), and road runoff (4200 ng IP/l)(4). IP has been found in gasoline (59 ug/l), low octane gasoline (0.04-0.18 mg/kg), high octane gasoline (0.07-2.88 mg/kg), fresh motor oil (0.03 mg/kg), and in used motor oil (after 5,000 km, 34.0-59.4 mg/kg; after 10,000 km, 46.7-83.2 mg/kg)(2). [(1) Santodonato J et al; Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons; Lee SD, Grant LG eds; Park Forest South Pathotox Publ (1981) (2) Verschueren K; Handbook of environmental data on organic chemicals. 2nd ed Von Nostrand Reinhold NY p 760-2 (1983) (3) Cretney JR et al;

Env Sci Technol 19: 397-404 (1985) (4) Crane RI et al;; A Survey of Polycyclic Aromatic Hydrocarbon Levels in British Waters Medmenham UK; Water Research Centre TR-158 (1981).

Avg value of 14.7 mg/kg was isolated from soot samples. ... Detected indenopyrene in coal-tar, & ... Determined 7300-9300 mg/kg in coal-tar pitch & up to 1 mg/kg in petroleum asphalts.

Occurs in fossil fuels and ubiquitously in products of incomplete combustion.

Indeno(1,2,3-cd)pyrene (IP) concentrations (ppm) in domestic open fire soots were: 8 (coal/wood), 14 (coal/coke), 5 (wood), 5 and 12 (demol wood) and from 1 to 77 (coal)(1). IP concn in a soot extract was 1.1 mg IP/g soot(2). IP was found in road runoff in the UK at 4200 ng/l(3). [(1) Cretney JR et al; Env Sci Technol 19: 397-404 (1985) (2) Perry R; Inter Symp Ident Meas Environ Pollut pp 130-7 (1971) (3) Crane RI et al; A Survey of Polycyclic Aromatic Hydrocarbon Levels in British Waters Medmenham UK: Water Research Centre TR-158 (1981).

Forms/Preparations/Formulations:

No information found.

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

Information from HSDB [366]:

Solubilities:

0.062 mg/l water [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume I. EPA-440/4 79-029a. Washington, DC: U.S.Environmental Protection Agency, December 1979.,p. 98-1.

Octanol/Water Partition Coefficient:

Log Kow = 6.584 [GEMS; Graphical Exposure Modeling System CLOGP3 (1986).
Log Kow = 7.0 [971]

Boiling Point:

530 deg C [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 760.

Melting Point:

> 162.5-164 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 229 (1973).

Color/Form:

> Yellow plates or needles from light petroleum [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 229 (1973).
>
> Soln show greenish yellow fluorescence [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 230 (1973).

PAH concentrations (ug/g oil sampled) were determined for three different crude oil sample types (weathered and unweathered oil) taken from the Exxon Valdez oil spill. Indeno(1,2,3-c,d)pyrene was not detected in any of them [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].

Indeno(1,2,3-c,d)pyrene content (mg/kg or ppm) in one fresh sample of Exxon Valdez Crude Oil [971]: 1 mg/kg = ppm

Indeno(1,2,3-c,d)pyrene content in one fresh sample of NSFO (Fuel Oil 5, Chuck Rafkind, National Park Service, Personal Communication, 1996): 2.3 ng/mg or ppm.

Indeno(1,2,3-c,d)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): 106.8 ng/L or 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).

IP concentration ranges in gasoline and in used motor oil were 0.04-0.38 mg/kg and 0.06-12.5 mg/kg, respectively [847].

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

Environmental Fate [366]:

TERRESTRIAL FATE: Indeno(1,2,3-cd)pyrene that is transported to soil will sorb strongly (estimated Koc = 20,146) and hence is not expected to leach extensively. Volatilization from soil surfaces will probably not be important because of its low vapor pressure. No information was found on hydrolysis or biodegradation.

AQUATIC FATE: Indeno(1,2,3-cd)pyrene (IP) that is transported to water will sorb strongly to suspended particulate matter, biota, and sediments (estimated log Kow = 6.584(1)). Based on its low water solubility and high estimated Kow, there is also a high potential for bioconcentration; however, this is not likely in organisms that have microsomal oxidase, such as fish, since this enzyme allows polyaromatic hydrocarbons to be metabolized(2). No information was found about volatilization, photolysis, hydrolysis or biodegradation. IP will probably be persistent in the aquatic environment and concentrate in sediments.

ATMOSPHERIC FATE: Most indeno(1,2,3-cd)pyrene (IP) in the atmosphere will be sorbed to particulate matter(1). Therefore, in the absence of major photodecomposition or other chemical transformations, the atmospheric fate of IP will depend primarily on physical processes such as dry and wet deposition. A computer estimated half-life for IP in the vapor phase of the atmosphere is 20 hours due to reaction with photochemically produced hydroxyl radicals(2).

Biodegradation [366]:

No information was found about indeno(1,2,3-cd)pyrene (IP) biodegradation. In general, however, an increased number of rings in polynuclear aromatic hydrocarbons decreases the initial oxidation rate(1). Thus, IP will probably biodegrade very slowly, if at all(1,SRC).

The ultimate fate of /polycyclic aromatic hydrocarbons/ ... is believed to be biodegradation and biotransformation by benthic organisms, although the processes may be very slow.

Abiotic Degradation [366]:

Indeno(1,2,3-cd)pyrene (IP) strongly adsorbs solar radiation (no other data given)(1). However, when dissolved in n-heptane (initial concn was 0.4 ug IP/ml n-heptane) and exposed to sunlight for one month (November), 94% of IP was recovered(2) indicating the direct photolysis does not appear to be a significant environmental fate process. A computer estimated half-life for IP in the vapor phase of the atmosphere is 20 hours due to reaction with photochemically produced hydroxyl radicals(3). [(1) Sims RC, Overcash MR; Res Rev 88: 1-68 (1983) (2) Muel B, Saguem S; Inter J Environ Anal Chem 19: 111-31 (1985) (3) GEMS; Graphical Exposure Modeling System Fate of atmospheric pollutants (FAP) data base Office of Toxic

Substances USEPA (1986).

Soil Adsorption/Mobility [366]:

An estimated soil adsorption coefficient (Koc) for indeno(1,2,3-cd)pyrene (IP), using eqn 4-5(1) and a water solubility of 0.062 mg/l(2), is 20,146. This indicates that IP will be tightly bound to soil and sediment and will not leach extensively(3).

Volatilization from Water/Soil [366]:

Using a water solubility of 0.062 mg/l(1) and a vapor pressure of 1.0X10-10 torr(1), the estimated Henry's Law constant for indeno(1,2,3-cd)pyrene (IP) is 5.89X10-10 atm-cu m/mol. This indicates that volatilization of IP from water will probably not be an important transport process(SRC).

Absorption, Distribution and Excretion [366]:

It has been observed that /indeno(1,2,3-cd)pyrene/ is highly soluble in adipose tissue and lipids. [Sittig, M. Handbook of Toxic and Hazardous Chemicals and Carcinogens, 1985. 2nd ed. Park Ridge, NJ: Noyes Data Corporation, 1985. 741.

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

Laboratory and/or Field Analyses:

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

Recommended detection limits:

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

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

EPA NPDES method 610 as specified in 40 CFR Part

136 (method 610 includes 16 PAH parent compounds) [1010],

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

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

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

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

If a Park Service groundwater investigation at Colonial National Historical Park performed in response to contamination by Fuel Oil 5 had utilized EPA semi-volatile scan 8270 or any of the other typical EPA scans (625, etc.) all of which only include parent compounds and typically utilize detection limits in the 170-600 ppb range, the false conclusion reached would have been that no PAHs were present in significant (detection limit) amounts. This false negative conclusion would have been made because the parent compound PAHs present constituted only 7.6% of the PAHs detected in groundwater by the expanded scan [828], and the highest concentration found for any parent compound was 8.4 ppb, far below the detection limits used on the older standard EPA scans.

Utilizing the NOAA protocol expanded scan [828], it was determined that 92.4% of the total concentration values of the PAHs detected in groundwater were alkyl PAHs, and that all 39 PAHs and alkyl PAHs were present. Of course, all 39 PAHs were also present in the fresh product, in much higher concentrations, and also having alkyl compounds with the highest percentage of higher values compared to parent compounds (see Chem.Detail section in separate PAHs entry for more details).

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

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

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

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

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).