



Canadian Environmental Protection Act

Priority Substances List
Assessment Report

Creosote-impregnated Waste Materials



Government
of Canada

Gouvernement
du Canada

Environment
Canada

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Health
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Canadian Environmental Protection Act

PRIORITY SUBSTANCES LIST
ASSESSMENT REPORT

CREOSOTE-IMPREGNATED WASTE MATERIALS

Government of Canada
Environment Canada
Health Canada

Also available in French under the title:
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TABLE OF CONTENTS

Synopsis.....v

1.0 Introduction..... 1

2.0 Summary of Information Critical to Assessment of "Toxic" 4

 2.1 Identity, Properties, and Uses..... 4

 2.2 Entry into the Environment..... 5

 2.3 Exposure-related Information..... 6

 2.3.1 *Fate*..... 6

 2.3.2 *Concentrations*..... 9

 2.4 Effects-related Information..... 12

3.0 Assessment of "Toxic" Under CEPA..... 16

 3.1 CEPA 11(a): Environment..... 16

 3.2 Conclusion..... 16

4.0 Recommendations for Research and Evaluation..... 18

5.0 References..... 19

LIST OF TABLES

1 Summary of Maximum Polycyclic Aromatic Hydrocarbon Concentrations at Wood Treatment/Storage Sites in Canada..... 7

2 Concentrations of Selected Polycyclic Aromatic Hydrocarbons in Biota from Canadian and American Creosote-contaminated Sites..... 11

3 Summary of Apparent Effects Threshold Concentrations for Polycyclic Aromatic Hydrocarbons Sorbed to Marine Sediments and Polycyclic Aromatic Hydrocarbon Concentrations Found at Northern Wood Preservers, Thunder Bay, Ontario, 1984.. 15

Notice to Readers

Creosote as a pesticide was not assessed in this report. The pesticide creosote is subject to the provisions of the *Pest Control Products Act*, and its regulatory status as a heavy duty wood preservative is currently being re-evaluated (see Announcement A92-02: Re-evaluation of Heavy-Duty Wood Preservatives, Agriculture Canada, Food Production and Inspection Branch, July 2, 1992). As part of the pesticide re-evaluation process, Environment Canada and Health Canada will assess the potential effects on the environment and on human health resulting from these pesticidal uses of creosote.

Synopsis

Creosote is used in Canada as a heavy-duty wood preservative for railway ties, bridge timbers, pilings, and large-sized lumber. It is composed of hundreds of compounds, the largest group being the polycyclic aromatic hydrocarbons (PAHs). In this assessment, the substance "creosote-impregnated waste materials" (CIWM) includes *creosote waste products* and *creosote-contaminated sites*. *Creosote waste products* are wood materials treated with creosote that have since been removed from service and are awaiting disposal (used railway ties, utility poles, etc.), and *creosote-contaminated sites* are areas of contaminated soil, water, or materials resulting from the application, manufacture, storage, transportation, or spillage of creosote.

Railway ties constitute the largest volume of *creosote waste products* generated in Canada. The major railways decommission 4.5 million ties per year (450 000 m³ of wood) containing an estimated 20.2 x 10⁶ kilograms of creosote. It is estimated that 90% of all railway ties removed each year are reused. This leaves roughly 2.02 x 10⁶ kg/yr of creosote in discarded railway ties. Other *creosote waste products* are generated when docks, breakwaters, railway trestles, and bridges are decommissioned. Studies were not identified that could be used to determine whether *creosote waste products* could cause harmful effects on the environment.

Estimates of the amounts of waste creosote entering the Canadian environment from *creosote-contaminated sites* are not available for many sites. However, for most of the sites where hydrogeological surveys have been done, large amounts of waste creosote have been discovered in soil, groundwater, and some surface waters. There is an estimated 256 000 m³ of moderately and highly contaminated soil from 11 abandoned or operating creosote-treating facilities in Canada. Waste creosote is known to be entering the soils, groundwaters, and surface waters at 24 *creosote-contaminated sites* spread across all of the provinces, except Prince Edward Island. Groundwater has been severely contaminated at several *creosote-contaminated sites*. Benthic organisms and the general health of the aquatic ecosystem near a major wood-treatment facility in Thunder Bay, Ontario have been adversely affected by the presence of waste creosote pooling on the sediments. Environmentally sensitive benthic invertebrates [Trichoptera (caddisflies) and Plecoptera (stoneflies)] were significantly reduced in numbers from a kilometre length (approximately) of the south half of the Bow River downstream from another major wood-treatment facility in Calgary. These species had been replaced by less sensitive Gastropods (snails) and Diptera (crane flies). Waste creosote and the PAHs found in it have been detected in Canadian freshwater sediments near creosote wood preservation plants at levels higher than those known to cause severe effects to freshwater and marine organisms. There are strong correlations between the presence of PAHs from CIWM sources in the sediments of Eagle Harbor, Washington and the Elizabeth River, Virginia, the levels of PAHs found in the tissues of fish in these two aquatic systems, and liver tumors discovered in these fish.

There is insufficient information to estimate exposure of humans to the components of waste creosote from creosote-impregnated waste materials. In addition,

information was not identified on the effects of CIWM to the environment upon which human life depends. Therefore, detailed consideration of whether this substance is "toxic" as defined under Paragraphs 11 (b) and 11(c) of the Act is not included in this assessment.

Creosote Waste Products

Therefore, on the basis of available data, it is not possible to determine whether materials leaching from *creosote waste products* (i.e., used railway ties and utility poles) are entering or may be entering the environment in a quantity or concentration or under conditions that are having or may have a harmful effect on the environment.

Creosote-contaminated Sites

Therefore, on the basis of available data, materials from *creosote-contaminated sites* are entering or may be entering the environment in a quantity or concentration or under conditions that are having or may have a harmful effect on the environment.

1.0 Introduction

The *Canadian Environmental Protection Act* (CEPA) requires the Minister of the Environment and the Minister of Health to prepare and publish a Priority Substances List that identifies substances, including chemicals, groups of chemicals, effluents, and wastes that may be harmful to the environment or constitute a danger to human health. The Act also requires both Ministers to assess these substances and determine whether they are "toxic" as defined under Section 11 which states:

“...a substance is toxic if it is entering or may enter the environment in a quantity or concentration, or under conditions

- (a) having or that may have an immediate or long-term harmful effect on the environment;
- (b) constituting or that may constitute a danger to the environment on which human life depends; or
- (c) constituting or that may constitute a danger in Canada to human life or health.”

Substances that are assessed as "toxic" according to Section 11 may be placed on Schedule I of the Act. Consideration can then be given to developing regulations, guidelines, or codes of practice to control any aspect of these substances' life cycle, from the research and development stage, through manufacture, use, storage, transport, and ultimate disposal.

Use of creosote as a heavy-duty wood preservative in Canada is subject to control under the *Pest Control Products Act* (PCPA) which is administered by Agriculture Canada. This control does not extend to the disposal of waste products arising from the use of this substance or for the operating practices at creosote-treating facilities. The substance *creosote-impregnated waste materials* (CIWM) was added to the Priority Substances List under CEPA because of concerns about the potential for environmental contamination from waste materials generated at creosote wood-treatment facilities and from the replacement of creosote-treated wood products.

Creosote-impregnated waste materials are interpreted in this assessment to include:

- *Creosote waste products*: materials treated with creosote that have since been removed from service and are awaiting disposal (used railway ties, utility poles, etc.); and
- *Creosote-contaminated sites*: creosote-contaminated areas or materials resulting from the application, manufacture, storage, transportation, or spillage of creosote.

The assessment of whether the substance creosote-impregnated waste materials is "toxic", as defined under Section 11 of CEPA, was based on the determination of whether waste creosote or its component compounds **enter** or are likely to enter the Canadian environment in a concentration or quantities or under conditions that could lead to **exposure** of humans or other biota at levels that could cause adverse **effects**.

The potential effects of waste creosote from CIWM on human health have not been widely studied. There is some information available on the effects of polycyclic aromatic hydrocarbons (PAHs) in experimental animals and humans. Polycyclic aromatic hydrocarbons are the major group of compounds found in waste creosote. A preliminary literature survey did not identify sufficient data to assess the degree of human exposure to PAHs from CIWM. Polycyclic aromatic hydrocarbons are being addressed in a separate Assessment Report so their potential effects on human health will not be discussed herein. No information was identified to indicate that CIWM affects the environment upon which human life depends. Therefore, detailed consideration of whether the substance CIWM is "toxic" as defined under Paragraphs 11(b) and 11(c) of the Act is not included in this assessment.

Data relevant to the assessment of the entry, environmental exposure, and environmental effects of waste creosote were obtained from review documents, reference books, and papers in scientific journals identified through searches of electronic databases up to 1991. These databases included: BIOSIS Previews, Pollution Abstracts, ENVIROLINE, ENVIROFATE, Environment Canada Departmental Library Catalogue (ELIAS), International Register of Potentially Toxic Chemicals (IRPTC), Chemical Evaluation Search and Retrieval System (CESARS), the United States Environmental Protection Agency's (U.S. EPA) Risk Reduction Engineering Laboratory (RREL) Treatability database, Register of Toxic Effects of Chemical Substances (RTECS), Chemical Hazard Response Information System (CHRIS), National Institute of Occupational Safety and Health Technical Information Center (NIOSHTIC), and National Technical Information Service (NTIS). Site assessment reports prepared by governments and the wood preservation industry were used in this assessment. In addition, a study was undertaken under contract to gather trade information on the usage of creosote in Canada from the Canadian wood preservation industry, Agriculture Canada, Statistics Canada, Public Works Canada, utility companies, and other corporate users of creosoted products.

Although much of the research on CIWM has been conducted outside Canada, available Canadian data on sources, fate, levels, and effects of CIWM on the Canadian environment were emphasized. All original studies that form the basis for determining whether CIWM are "toxic" as defined under Section 11 of CEPA have been critically evaluated by the following Environment Canada staff:

A. Beckett
M. Constable
E. Gordy
T. Lambert
B. Munson, Task Group Leader

Creosote-impregnated waste materials were characterized by the following individuals from Environment Canada: J. Sproull, E. Gordy, N. Gurprasad, and G. Atkinson.

In this report, a Synopsis is presented which will appear in the Canada Gazette. A summary of technical information that is critical to the assessment is presented in Section 2.0. The assessment of whether CIWM are "toxic" as defined under the Canadian Environmental Protection Act is presented in Section 3.0. A Supporting Document that discusses the technical information in greater detail has also been prepared and is available upon request.

As part of the review and approvals process established by Environment Canada for their contributions to Priority Substance assessment reports, this Assessment Report and the Supporting Document were reviewed by a number of experts from Environment Canada, G. Brudermann (wood preservation consultant), and J. Butala (School of Pharmacy, Duquesne University). The final Assessment Report was reviewed and approved by the Environment Canada/Health Canada CEPA Management Committee.

Copies of this Assessment Report and the unpublished Supporting Document are available upon request from:

Commercial Chemicals Branch
Environment Canada
14th Floor, Place Vincent Massey
351 St. Joseph Boulevard
Hull, Quebec
K1A 0H3

Environmental Health Centre
Health Canada
Room 104
Tunney's Pasture
Ottawa, Ontario
K1A 0L2

2.0 Summary of Information Critical to Assessment of "Toxic"

2.1 Identity, Properties, and Uses

Creosote is a complex and variable mixture produced from coal that is made up of more than 300 compounds. The American Wood Preservation Association describes creosote (CAS Registry Number 8001-58-9) as:

"a distillate of coal-tar produced by high temperature carbonization of bituminous coal; it consists principally of liquid and solid aromatic hydrocarbons and contains appreciable quantities of tar acids and tar bases; it is heavier than water, and has a continuous boiling range of approximately 275°C, beginning at about 175°C" (AWPA, 1977).

There are five major classes of compounds in creosote:

- *Aromatic Hydrocarbons* including PAHs, alkylated PAHs, benzene, toluene, and xylene (PAHs can constitute up to 90% of creosote);
- *Phenolics* including phenols, cresols, xylenols, and naphthols (1 to 3% of creosote);
- *Nitrogen-containing Heterocycles* including pyridines, quinolines, acridines, indolines, carbazoles (1 to 3% of creosote);
- *Sulphur-containing Heterocycles* including benzothiophenes (1 to 3% of creosote); and
- *Oxygen-containing Heterocycles* including dibenzofurans (5 to 7.5% of creosote) (U.S. EPA, 1987).

"Pure" creosote is denser than water. For some wood preservation uses, creosote is mixed 1:1 with fuel oil. In these uses, the density will be less than pure creosote, but will still be heavier than water (Hoffman and Hrudey, 1990). Creosote is insoluble in water (Romanowski *et al.*, 1983), although the components have a wide range of solubilities from the readily soluble tar acids and bases (i.e., phenols, cresols, acridines) to the insoluble six-ring PAHs (i.e., naphtho[2,3-e]pyrene) (CRC Press, 1973; Merck Index, 1976; Clement Int. Corp., 1990a; Syracuse Research Corp., 1989). Creosote is soluble in many organic solvents, including oil and diesel fuel (U.S. EPA, 1984; Bos *et al.*, 1983).

The vapour pressure (P_v) of creosote is variable because of the number of compounds involved and is difficult to characterize. Vapour pressures range from 2.0×10^{-10} Pascals (Pa) for ibenzo[ghi,pqr]chrysene to 11.6 Pa for naphthalene (Clement Int. Corp., 1990). The range of $\log K_{ow}$ values for PAHs is from 3.29 to 7.19 (Clement Int. Corp., 1990). Other components of creosote have widely varying $\log K_{ow}$

values, from 0.65 for pyridine (Leo *et al.*, 1971) to 3.95 for biphenyl (Miller *et al.*, 1985). The range of log K_{oc} values for PAHs is from 2.97 to 6.74 (Clement Int. Corp., 1990).

Creosote-impregnated waste materials can arise from two separate sources, *creosote waste products* and *creosote-contaminated sites*. These sources have been estimated to comprise 71% and 29% by weight, respectively, of CIWM in the Canadian environment (Konasewich *et al.*, 1991).

There are five creosote pressure-treating facilities operating in Canada, two in British Columbia, one in Ontario, and two in Quebec (Konasewich *et al.*, 1991). One facility in Ontario and one in Newfoundland stopped using creosote in 1992 (Constable, 1992). There are also 20 small facilities in Quebec using dip tanks and vapour chambers (Quebec Ministry of the Environment, 1989) and two dip tank facilities in Saskatchewan (Ertman, 1992). These facilities collectively use 21×10^6 kg of creosote per year. Preservation of railway ties uses 54% of the creosote, marine pilings use 37%, and bridge deckings, timbers, and utility poles use the remaining 9% (Konasewich *et al.*, 1991).

2.2 Entry into the Environment

Railway ties constitute the largest number of creosote waste products generated in Canada. The major railways decommission 4.5×10^6 ties per year ($450\,000\text{ m}^3$ of wood) containing an estimated 20.2×10^6 kg of creosote. It is estimated that 90% of all railway ties removed each year are reused. This leaves roughly 2.02×10^6 kg/yr of creosote in discarded railway ties as *creosote waste products* (Konasewich *et al.*, 1991). Some of the waste ties are burned by railway companies under permits from provincial environment authorities. Little is known about what happens to the rest of the waste-treated wood, although some of it is landfilled. Since the concentrations of PAHs found in waste railway ties vary, generalizations cannot be made about the composition of the CIWM arising from *creosote waste products* (Sproull and Gurprasad, 1992).

Many of the marine pilings removed from service are also reused. Out-of-service marine pilings and utility poles do not represent a significant source of *creosote waste products* compared to the volume of *creosote waste products* from discarded railway ties.

A study of water soluble leachates from out-of-service railway ties found many PAHs and associated compounds. One gram of wood was shaved from the surface of the railway ties and agitated in water for 24 hours. Up to 88.9 $\mu\text{g/L}$ of naphthalene, 92.7 $\mu\text{g/L}$ of dibenzofuran, 120 $\mu\text{g/L}$ of fluorene, 119 $\mu\text{g/L}$ of phenanthrene, and 58.9 $\mu\text{g/L}$ of carbazole were found in the water. Other compounds were detected at lower concentrations (Rotard and Mailahn, 1987). Little other information is available to determine the leaching potential of creosote components remaining in *creosote waste products*.

Estimates of the amounts of waste creosote entering the Canadian environment from *creosote-contaminated sites* are not available for many sites. At most of the sites

where hydrogeological surveys have been done to track subsurface contamination, however, high levels of compounds from CIWM have been discovered in soil, groundwater, and some surface waters. Estimating quantities of waste creosote at a site and amounts leaching from a site is complex and expensive, and has been attempted in detail at only two sites in Canada. There is an estimated 256 000 m³ of soil that is moderately to highly contaminated with waste creosote at 11 abandoned or operating creosote-treating facilities in Canada (see Table 1). There are at least 13 other potentially contaminated sites in Canada, both operational and non-operational, but no information was obtained on these sites. It is therefore likely that *creosote-contaminated sites* are a more significant source of waste creosote to the Canadian environment than are *creosote waste products*, but the data are not available to confirm this.

There are at least 28 creosote-treating facilities in Canada for which site information is not available. The only province that apparently does not have a *creosote-contaminated site* is Prince Edward Island.

2.3 Exposure-related Information

2.3.1 Fate

Elevated levels of PAHs from CIWM have been found in both Canada and the United States. Almost all of the information gathered pertains to environmental contamination from non-operational wood preservation facilities (i.e., *creosote-contaminated sites*). Although some studies were found on the transport of PAH components from in-service treated products, it appears that no studies have been undertaken to determine the mobility of creosote components from *creosote waste products*.

The environmental transport, transformation, and accumulation of the components of creosote are strongly influenced by the components' physical and chemical properties. As a result of the chemical complexity of waste creosote, studies on the behaviour of individual PAHs in the environment may not reflect the behaviour of the compound when it is a component of creosote. Consequently, observed contaminant distributions at creosote facilities are the best indicators of how PAHs from CIWM will behave in the environment (Hoffman and Hruday, 1990).

At some sites, there appears to have been a mass transport of creosote, usually at sites where the soil was close to being saturated. This may have been due to a combination of gravity and groundwater flow. Polycyclic aromatic hydrocarbon levels in subsoils vary depending on the amount of creosote in the soil, the type of soil, the slope of the land, and the amount of groundwater present. Waste creosote in soil can occur as lighter- and heavier-than-water fractions, and consequently can be found above and below the water table, or even as a free liquid pool. The light fraction includes the nitrogen-, oxygen-, and sulphur-substituted PAHs, naphthalenes, acenaphthene, fluorene, phenols, and hydrocarbons from the oil with which the creosote was diluted. Low molecular weight PAHs are more water soluble than other creosote components and are dissolved and transported in groundwater and surface water. The light fraction has also been found to move with fluctuating water levels and, as a result, can contaminate

Table 1 Summary of Maximum Polycyclic Aromatic Hydrocarbon Concentrations at Wood Treatment/Storage Sites in Canada

Site	Media	Maximum PAH Concentration Detected					Total PAHs **	References	
		ANT	BbF	BaP	NAP	PHE			
Northern Wood Preservers, Thunder Bay, Ontario	Sediments	1 124	632	450	7 654	5 687	26 388	Berard and Tseng, 1986; Pugh, 1989; DeBrou, 1989; Beak Consultants Ltd. and Dominion Soil Investigation Inc., 1988; Berard, 1988	
	Groundwater				1.355				
	Air	3			40				
Domtar Sultana, Calgary, Alberta	Soil ⁵	5 300*	390	290	8 700	5 300*	39 630	Golder Assoc., 1990a; b	
	groundwater	40*	8	4	66	40*			
	Upstream								
	Sediments	0.13*	0.04	0.02	0.02	0.13			0.57
	Site Sediments	2.50*	2.60	1.00	2.50	2.50			66.87
Pore water ⁸	2.80	2.10	0.89	27.00	9.00	75.36			
Domtar, Truro, Nova Scotia	Soil ⁶	1 600	510	390	ND	7 200	26 530	Kieley <i>et al.</i> , 1986; Henning and Konasewich, 1984; Bamwoya <i>et al.</i> , 1991	
	Sediments ¹	42	120	150	50	1 900			6 300
	Sediments ²		0.17	0.22	ND	1.4			5.2
Domtar , Newcastle, New Brunswick	Soil ⁵		250	350	30	6 700	16 000	Golder Assoc., 1987; 1988; 1989	
	Sediments		120	190	ND	5 600			11 000
	Groundwater	0.360	0.335	0.130	4.280	2.045			9.27
Domtar, Transcona Manitoba	Soil ⁵	34.91*	5.02	2.60	4.70	34.91*	89.46	Cherry and Smith, 1990	
	Groundwater	0.02*	0.000 3	0.000 14	0.378	0.020			76
Saskatchewan Forest Products, Prince Albert Saskatchewan	Soil ⁶	1 496.64*		0.458	2 057.88	1 496.64*	7 795	Beak Assoc. Consulting, 1990	
	Soil ⁷	4 910.65*		0.219	11 989.1	4 910.64*			27 435
Koppers, Burnaby, British Columbia	Soil ^p						1 750	Stanley Assoc., 1982; Batterson, 1981; Gough and Konasewich, 1985; Wile, 1984	
Liverpool Tank Farm, Surrey British Colombia	Soil ³						130	Domtar Inc., 1983	
							to 19 000	Golder Assoc., 1991	

Table 1 Summary of Maximum Polycyclic Aromatic Hydrocarbon Concentrations at Wood Treatment/Storage Sites in Canada (Cont.)

Site	Media	Maximum PAH Concentration Detected					Total PAHs**	References
		ANT	BbF	BaP	NAP	PHE		
Bell Pole, Lumby, British Columbia	Soil ⁴	0.50	3.2	22	1.5	5.6	23 656 5.406	Conestoga-Rovers & Assoc. 1991a; b
	Soil ⁵	1 910	500	300	850	2 260		
	Groundwater	0.032	0.022	0.019	3.140	0.730		
Cedar Pole, Galloway, British Columbia	Soil ⁴	15	8.4	17	44	170	2 400	Envirochem, 1989; 1990
	Groundwater	0.015	0.000 08	0.000 22	1.50	0.52	1.85	
Domtar, New Westminster British Columbia	Sediments	0.066	0.110	0.057	ND	0.038	0.863	Environment Canada, 1983; Ito, 1991

Abbreviations Used in Table

- 1 sediments from effluent culvert
- 2 sediments from the Salmon River
- 3 soil from surface to 4 metres deep
- 4 surface soils
- 5 subsurface soils at various depths
- 6 soils around treatment site
- 7 soils from sludge pits
- 8 water associated with sediments

ANT – anthracene
 BbF – benzo[b]fluoranthene
 BaP – benzo[a]pyrene
 NAP – naphthalene
 PHE – phenanthrene
 ND – not detected

Concentrations Used in Table

Air – µg/m³
 Water – mg/L
 Soil and Sediment – mg/kg dry weight

* sample was combined an anthracene/phenanthrene
 ** Total PAHs refers to the amount of PAHs detected, not the total amount presented in this table
 Detection limit for NAP = 0.000 1 mg/kg in soil and sediments

the whole soil layer. The heavy fraction is indistinguishable from "pure" creosote. It tends to travel downwards until it encounters an impervious layer. It will flow along the impervious interface through the more porous soil in the downslope direction. This environmental behaviour has been responsible for the contamination of surface waters and groundwaters at many *creosote-contaminated sites* (W.L. Wardrop & Assoc., 1977; Thompson *et al.*, 1978; Ehrlich *et al.*, 1980; Black, 1982; Hickok *et al.*, 1982; Goerlitz *et al.*, 1985; Rostad *et al.*, 1985; Hult and Stark, 1986; Berard, 1988; Coover *et al.*, 1988; Elder and Dresler, 1988; U.S. EPA, 1988; Golder Associates, 1988; 1990b; 1991; Cherry and Smith, 1990; Reitman *et al.*, 1990).

"Weathered" waste creosote has been found at several contaminated sites in Canada and the United States and consists of PAH components that remain after light components, such as phenol, cresol, naphthalene, phenanthrene, anthracene, and quinoline, have either degraded or been removed through evaporation or dissolution into water. Typically, weathered creosote is composed primarily of the three-, four-, and higher-ring PAHs (Merrill and Wade, 1985; Bieri *et al.*, 1986). At one Canadian site, soil samples contained up to 7200 mg/kg dry weight of phenanthrene and 390 mg/kg dry weight of benzo[*a*]pyrene (Kieley *et al.*, 1986). Researchers studying creosote-contaminated sediments from the Elizabeth River in Virginia found that, after an initial period of dissolution of the light PAHs, the PAH composition of creosote remaining in the sediments did not change over an 80-year period (Bieri *et al.*, 1986).

In some aquatic systems, sedimentation can isolate creosote-contaminated layers from the water, thereby slowing and eventually halting the dissipation of the more water soluble PAHs. This was noted in studies of sediments from Thunder Bay Harbour where pools of waste creosote were later found with a cap of sediment forming over them (Superior Diving, 1988; Beak Consultants Ltd. and Dominion Soil Investigation Inc., 1988; de Geus, 1990; Pugh, 1989). The same situation was reported for the Elizabeth River in Virginia where creosote was quickly covered with sediment at a rate of 2 cm/yr (Bieri *et al.*, 1986).

2.3.2 Concentrations

The maximum levels of five PAHs from waste creosote measured in soils, sediments, groundwater, and air are shown in Table 1. The highest PAH concentration in soil at Canadian *creosote-contaminated sites* was 8700 mg/kg dry weight of naphthalene. Total PAH concentrations in soil have measured up to 39 630 mg/kg of dry weight. Groundwater has been severely contaminated with PAHs at several Canadian sites. Naphthalene has been found in concentrations of up to 66 mg/L and benzo[*a*]pyrene up to 4 mg/L. Total PAH concentrations in groundwater have been found at up to 950 mg/L, the creosote having displaced much of the groundwater. In Thunder Bay Harbour, pools of creosote have been found containing an estimated 292 m³ of creosote; surrounding the pools was a "creosote globule field approximately 8800 m² in extent (Beak Consultants Ltd. and Dominion Soil Investigation Inc., 1988; Superior Diving, 1988; O'Connor Assoc., 1989; de Geus, 1990; Reitman *et al.*, 1990; Golder Associates, 1990b).

Although exposure of mussels and lobsters to creosote originating from in-service products was examined in a small number of studies, no exposure information exists on concentrations of waste creosote originating from *creosote waste products*. In contrast, data for *creosote-contaminated sites* does exist, and exposure for certain aquatic biota may be established (Table 2). Most of the information presented is from the United States.

With the exception of laboratory studies, no relevant data were found concerning exposure of terrestrial populations to waste creosote or its components arising from *creosote-contaminated sites*.

Preliminary information from the Domtar Sunalta/Canada Creosote site in Calgary indicates that mountain whitefish (*Prosopium williamsoni*) are taking in more benzo[*a*]pyrene and phenanthrene from the site than fish from a control site upstream. Benzo[*a*]pyrene metabolites were detected in whitefish bile at levels of up to 200 µg/mL while fish from a control area contained 25 µg/mL. Phenanthrene levels in whitefish bile from the contaminated area ranged up to 1600 µg/mL, while whitefish from the control area contained 75 µg/mL. These analyses were done using a fluorescence technique, so the confirmation of the PAHs is tentative (Environmental Management Assoc., 1993).

In the United States, shellfish have been used to show that PAHs (phenanthrene, fluoranthene, pyrene, benzo[*a*]pyrene, naphthalene, anthracene, and benzo[*b*]fluoranthene) from creosote wood preservation operations and spill sites are readily accumulated. Oysters (*Crassostrea virginica*) taken from a relatively pristine river were exposed to PAH-contaminated sediments near a creosote wood-treating facility on the Elizabeth River in Virginia. After three days, oysters had accumulated total PAHs from non-detectable levels to 10.1 to 11.7 µg/g wet weight (Pittinger *et al.*, 1985). Clams (*Rangia cuneata*) exposed to water flowing over a creosote spill near Bayou Bonfouca, Louisiana accumulated approximately five times more anthracene, five times more fluoranthene, thirty times more benzo[*a*]pyrene, and twice as much naphthalene and phenanthrene as did clams upstream from the spill (DeLeon *et al.*, 1988). Snails (*Thais haemastoma*) taken downstream from a creek running through a creosote-contaminated site in Florida had accumulated fluoranthene and phenanthrene to levels significantly higher than snails from an uncontaminated area. Only fluoranthene was accumulated in oysters (*C. virginica*) from the same area (Elder and Dresler, 1988).

Sediment-associated PAHs from *creosote-contaminated sites* have been shown to accumulate in English sole (*Parophrys vetulus*) (Malins *et al.*, 1985), guppies (*Poecilia reticulata*) (Schoor *et al.*, 1991), brown trout (*Salmo trutta*), lamprey (species unknown), and white suckers (*Catostomus commersoni*) (Black *et al.*, 1980). Concentrations of metabolites of PAHs in bile from English sole were at levels roughly 40 times greater than English sole from an unpolluted area (2.10 µg/g wet weight versus 0.067 µg/g wet weight) (Malins *et al.*, 1985). Guppies exposed to creosote-contaminated sediments accumulated significant quantities of anthracene, fluoranthene, benz[*b*]fluoranthene, benz[*a*]pyrene, and phenanthrene in their muscle tissues (Schoor *et al.*, 1991). Brown trout and white suckers from the creosote-contaminated Hersey River in Michigan had

Table 2 Concentrations of Selected Polycyclic Aromatic Hydrocarbons in Biota from Canadian and American Creosote-contaminated Sites

Site	Treatment	Species	PAH Concentration (µg/g wet weight)						References
			ANT	FLU	BbF	BaP	NAP ¹	PHE ¹	
Elizabeth River, VA ³	Contaminated	Oyster		1.7	0.66	0.2		0.1	Pittinger <i>et al.</i> , 1985
Bayou Bonfouca, LA ³	Contaminated	Clams	0.039	0.130		0.60	0.120	0.028	DeLeon <i>et al.</i> , 1988
	Control	Clams	0.009	0.033		0.022	0.057	0.016	DeLeon <i>et al.</i> , 1988
Eagle Harbor, WA ⁴	Contaminated	English Sole	9.58	20.7	7.6	5.0	0.65	19.6	Malins <i>et al.</i> , 1985
	Control	English Sole	0.013	0.089	0.035	0.03	0.14	0.06	Malins <i>et al.</i> , 1985
Pensacola, FL ⁴	Contaminated	Snails		0.06			0.036	0.19	Elder and Dresler, 1988
		Oyster		0.028			0.002	0.03	“
	Control	Guppies	6.8	0.16	0.15	0.23	ND	6.4	Schoor <i>et al.</i> , 1991
		Snails		ND			0.022	0.03	Elder and Dresler, 1988
Calgary, Alta. ⁵	Contaminated	Oyster		0.005			0.008	0.007	“
		Insects				3.9	0.5	0.520	Golder Assoc., 1990a
	Control	Fish Muscle				ND	0.22	0.03	“
		Fish Fat					0.24	0.200	“
	Control	Fish Bile				6 ^{2,6}		50 ^{2,6}	Hamilton, 1992
		Insects				ND	ND	ND	Golder Assoc., 1990a
	Control	Fish Muscle				ND	ND	ND	“
		Fish Fat				ND	ND	ND	“
	Control	Fish Bile				5.4 ²		20 ²	Hamilton, 1992
		Insects				0.725		5.49	Black <i>et al.</i> , 1980
Hersey River, MI ⁴	Contaminated	Crayfish				0.008		0.45	“
		Lamprey				0.001		0.038	“
	Control	Trout				0.000 07		0.029	“
		Sucker				0.000 08			“
	Control	Insects				0.001		0.042	Black <i>et al.</i> , 1980
		Crayfish				0.000 6		0.006	“
	Control	Lamprey				0.000 8		0.035	“
		Trout				0.000 04		0.002	“
		Sucker				0.000 05		0.004	“

ANT - anthracene

FLU - Fluoranthene

BbF - benzo[*b*]fluorantheneBaP - benzo[*a*]pyrene

NAP - naphthalene

PHE - phenanthrene

¹ NAP and PHE metabolites in fish bile² measured as µg/mL in bile³ only one value reported⁴ mean value reported⁵ composite sample report⁶ median value

ND - not detected

tissue levels of phenanthrene roughly an order of magnitude greater than unexposed fish, and lamprey had levels of phenanthrene over two orders of magnitude greater than their unexposed counterparts (Black *et al.*, 1980). Benthic insects (species unknown) taken from the Hersey River concentrated phenanthrene to levels slightly higher than those found in sediments (5.49 vs 4.10 µg/g wet weight) at the contaminated site and were found to have benzo[a]pyrene concentrations 725 times greater than non-exposed insects (Black *et al.*, 1980).

These studies show that aquatic organisms living close to *creosote-contaminated sites* absorb PAHs above the background concentrations found elsewhere. The types of species that are likely to absorb PAHs are those that are in intimate contact with the sediments or those that feed on species in contact with sediments.

2.4 Effects-related Information

Ecotoxicology. No information was found on the toxicity of waste creosote to aquatic or terrestrial biota resulting from *creosote waste products*.

The exposure information presented in Subsection 2.3.2 and the effects data in this subsection are the only available data for Canadian sites. The characterization of Canadian sites has generally not included biotic environmental exposure and effects data, except at the Northern Wood Preservers (NWP) site in Thunder Bay and the Domtar Sunalta/Canada Creosote site in Calgary. Since Canadian environmental effects data are limited, data from the United States are also presented.

Gross autopsies of whitefish taken from the Bow River near the Domtar Sunalta/Canada Creosote site did not detect any abnormalities. Plecoptera (stoneflies) Trichoptera (caddisflies) and chironomids (midges) were generally absent from an area on the south side of the Bow River approximately 1 km in length. They were largely replaced by Gastropods (snails) and Diptera (crane flies) that are known to be more tolerant of pollutants (Environmental Management Assoc., 1993). Undiluted pore water taken from Bow River sediments from the cut-off berm to 250 m downstream from the berm was determined to be toxic in 19 of 45 samples using the Microtox test (endpoint was a 20% reduction in light generation) (Shaw, 1992). These "toxic" pore water samples were associated with a "creosote odour" and the presence of shallow Non-Aqueous Phase Liquid (i.e., waste creosote) (Hamilton, 1992).

In 1986, benthos distribution surveys were done at the Northern Wood Preservers facility in Thunder Bay Harbour. The results of these surveys indicated that benthic habitat in the vicinity of the facility wharf was degraded, with the most severe degradation located closest to the wharf. Habitat alteration, sediment contamination with PAHs, and organic enrichment caused reduced diversity of benthic invertebrates and increased the dominance of sludgeworms (Beak Consultants Limited and Dominion Soil Investigation Inc., 1988). A bioassay study on the sediments indicated that they were lethal to aquatic organisms (leeches, fathead minnows, and mayflies). Sediments from stations near the facility were lethal to all species during a 10-day exposure study;

sediments from other locations were non-lethal, indicating the existence of a 150-m wide toxic zone emanating from the facility (Metcalf and Hayton, 1989).

Studies exposing the amphipod *Rhepoxynius abronius* to aerated water from the sediments of Eagle Harbor, Washington showed that none survived a four-day exposure at sediment water concentrations of 5%. Most of the amphipods exposed to undiluted sediment water immediately displayed abnormal swimming behaviour, a few managed to burrow into the sediment, and all died within 10 to 60 minutes (Swartz *et al.*, 1989).

Long-term, or chronic effects of waste creosote-contaminated sediments have been observed in populations of English sole from Eagle Harbor and Puget Sound, Washington (Maims *et al.*, 1985; 1988; Myers *et al.*, 1987; 1990; Stein *et al.*, 1990). There is strong evidence that the high rates of abnormal alterations of the liver, including tumors and cancers, found in the fish inhabiting the waste creosote-contaminated areas of Eagle Harbor are the result of exposure to PAH-contaminated sediments. The abnormal alterations observed in the livers of English sole closely parallel the changes and tumors that have been induced experimentally in the rat, mouse, and in certain fish by chemicals that are known to be toxic to their livers (Myers *et al.*, 1990).

A study was conducted to determine whether contaminant exposure was associated with altered ovarian development in English sole from four areas of Puget Sound, including Eagle Harbor (Johnson *et al.*, 1988). The results suggested that exposure to PAHs from Eagle Harbor had a significant effect on reproductive processes in English sole. Polycyclic aromatic hydrocarbons appeared to be most closely associated with inhibited ovarian development and depressed blood hormone levels in these fish. There is evidence that populations of English sole in the Sound have been declining, but the role of contaminant exposure in this decline is not known (Johnson *et al.*, 1988).

A study conducted in the Elizabeth River in Virginia found that mummichog (*Fundulus heteroclitus*) had a very high prevalence of liver cancer in a population located at a site contaminated with waste creosote. Grossly visible liver lesions were present in 93% of the fish and 33% had liver cancers. Sediment PAH concentrations were 2200 mg/kg dry weight. Mummichog at two other sites having low levels of PAHs (730 and 35 times less) in the sediments showed no such indication of disease (Vogelbein *et al.*, 1990).

Macrophages from oyster toadfish (*Opsanus tau*) taken from the creosote-contaminated Elizabeth River in Virginia have altered abilities to migrate towards bacteria, to engulf them, and to generate reactive oxygen species required for the degradation of engulfed material, as compared with macrophages of fish taken from the relatively non-polluted York River, Virginia. Adult oyster toadfish and sediments were sampled from four locations in the Elizabeth River. The sediment-bound PAH levels were highest near an operating creosote wood-treatment facility. Macrophage function was also most severely affected at this site (Seeley and Weeks-Perkins, 1991).

The effects of an eight-day exposure of the bottom-feeding fish, *Leiostomus xanthurus*, to waste creosote-contaminated sediments from the Elizabeth River have

been studied under laboratory conditions (Hargis Jr. *et al.*, 1984; Roberts *et al.*, 1989). Exposed fish developed skin lesions, pancreatic and liver alterations, and experienced reduced weight gain, reduced numbers of red blood cells, and increased mortality. No effects were observed in fish exposed to clean sediment. Analyses of these sediments showed heavy contamination with PAHs compared to uncontaminated sediment controls. Phenanthrene and fluoranthene were the two most abundant PAHs in the sediment, each accounting for 5 to 12% of the total PAH load. Benzo[*a*]pyrene was detected at 43 mg/kg dry weight in the Elizabeth River sediments compared to 0.009 mg/kg dry weight in the uncontaminated sediments. *L. xanthurus* are largely bottom-feeders, actively agitating the surface of the sediments with their fins and body movements while foraging. This action would account for the observed high incidence of severe fin erosion of the pectoral, caudal, and pelvic fins and dilation of the blood vessels around fins in those fish exposed to Elizabeth River sediments (Hargis Jr. *et al.*, 1984).

Another approach for estimating effects of pollutants on benthic dwelling organisms is to correlate known effects from polluted areas with the concentrations of pollutants in the sediments. The United States National Oceanic and Atmospheric Administration (NOAA) uses the apparent effects threshold (AET) approach to estimate biological effects from sediment-associated PAHs on marine organisms (NOAA, 1990). An AET is defined as the lowest concentration of a compound in sediment at which biological effects (usually changes in composition of benthic invertebrate communities) are observed to occur. The Ontario Ministry of the Environment (OMOE) uses Sediment Quality Guidelines for pollutants in sediments, including total PAHs, to estimate biological effects levels (Persaud *et al.*, 1992). The data generated by the NOAA on creosote-associated effects on marine organisms and the OMOE data on total PAHs can be used to estimate a relationship between PAH sediment concentrations and potential effects on Canadian aquatic ecosystems where these sediments are found. The marine effects data may not be directly comparable to Canadian freshwater ecosystems, but they do at least provide a criterion against which to judge the potential effects of CIWM in freshwater sediments. Table 3 lists the AET concentrations of many PAHs in marine sediments on a dry weight basis and compares them with maximum PAH concentrations from around the Northern Wood Preservers dock in 1988. The Ontario Ministry of the Environment's tentative Lowest-Effect-Level for total PAHs in sediment is 2 mg/kg dry weight, and their tentative Severe-Effect-Level is 11 000 mg/kg dry weight (Persaud *et al.*, 1992). The AET for total PAHs is 22 mg/kg dry weight (NOAA, 1990). In 1984, sediments in Thunder Bay Harbour close to the Northern Wood Preservers facility, contained 26 388 mg/kg dry weight of total PAHs (Berard and Tseng, 1986). Ecological impacts observed at the Northern Wood Preservers facility (reduced benthic diversity and a community shift towards Oligochaetes) would be expected at the concentrations of PAHs present.

No mammalian toxicology data were identified for creosote-impregnated waste materials. Toxicity data for creosote have been derived for mammals from laboratory exposure tests, but little data exists for environmental exposures or effects to mammals outside of this context. In many cases, testing has been performed on organic extracts of creosote, creosote wastes, or contaminated sediments. This laboratory data will not be

used to estimate the toxicity of CIWM to wildlife as it does not sufficiently resemble the exposure to wildlife.

Table 3 Summary of Apparent Effects Threshold Concentrations for Polycyclic Aromatic Hydrocarbons Sorbed to Marine Sediments and Polycyclic Aromatic Hydrocarbon Concentrations Found at Northern Wood Preservers, Thunder Bay, Ontario, 1984

PAH	AET Concentration* (mg/kg dry weight)	Maximum Sediment Concentration at NWP** (mg/kg dry weight)	
Acenaphthene	0.150	15	
Anthracene	0.300	120	
Benzo[<i>a</i>]anthracene	0.550	600	
Benzo[<i>a</i>]pyrene	0.700	450	
Chrysene	0.900	600	
Dibenz[<i>a,h</i>]anthracene	0.100	61	
Fluoranthene	1.000	780	
Fluorene	0.350	25	
2-Methylnaphthalene	0.300	NA	
Naphthalene	0.500	75	
Phenanthrene	0.260	250	
Pyrene	1.000	338	
Total PAHs***	220.0	4331 ^a	26 388 ^b

* adapted from NOAA (1990)

** Beak Consultants Ltd. and Dominion Soil Investigation Inc. (1988)

*** Total PAHs present in NWP sediments only

^a Total PAHs in 1984

^b Total PAHs in 1986

3.0 Assessment of "Toxic" Under CEPA

Estimates of the amounts of waste creosote entering the Canadian environment from *creosote-contaminated sites* are not available for many sites. However, at most of the sites where hydrogeological surveys have been done, large amounts of waste creosote have been discovered in soil, groundwater, and some surface waters. There is an estimated 256 000 m³ of moderately and highly contaminated soil at 11 abandoned or operating creosote-treating facilities in Canada. Waste creosote is known to be entering the soils, groundwaters, and surface waters at 24 *creosote-contaminated sites* in all of the provinces, except Prince Edward Island.

3.1 CEPA 11(a): Environment

Little information was found on the leaching of waste creosote or component PAHs from *creosote waste products*, and no information was found on the environmental toxicity of these leachates.

Groundwater has been severely contaminated at several *creosote-contaminated sites*. Benthic organisms and the general health of the aquatic ecosystem have been adversely affected near a major wood-treatment facility in Thunder Bay, Ontario by the presence of waste creosote pooling on the sediments. Environmentally sensitive benthic invertebrates (Trichoptera and Plecoptera) were generally absent from approximately a kilometre length of the south half of the Bow River downstream from another major wood-treatment facility in Calgary. These organisms were replaced by less sensitive Gastropods (snails) and Diptera (crane flies). Mountain whitefish in the Bow River have highly elevated concentrations of benzo[*a*]pyrene and phenanthrene metabolites in their bile compared to fish from a control site. Concentrations of waste creosote and the component PAHs have been found in Canadian freshwater sediments near creosote wood-preservation plants in excess of concentrations known to have severe effects on freshwater and marine organisms, although these correlations do not provide direct evidence of environmental impacts. There are strong correlations between the presence of PAHs from waste creosote sources in the sediments of Eagle Harbor, Washington and the Elizabeth River, Virginia, the levels of PAHs found in the tissues of fish in these two aquatic systems, and liver tumors discovered in these fish.

3.2 Conclusion

Creosote Waste Products

Therefore, on the basis of available data, it is not possible to determine whether materials leaching from *creosote waste products* (i.e., used railway ties and utility poles) are entering or may be entering the environment in a quantity or concentration or under conditions that are having or may have a harmful effect on the environment.

Creosote-contaminated Sites

Therefore, on the basis of available data, materials from *creosote-contaminated sites* are entering or may be entering the environment in a quantity or concentration or under conditions that are having or may have a harmful effect on the environment.

4.0 Recommendations for Research and Evaluation

The available information was sufficient to conduct an assessment of CIWM originating from creosote-contaminated sites. In order to do an assessment of whether CIWM from *creosote waste products* are "toxic", the following studies are required.

1. Leaching studies would enable a determination of the specific components of creosote from *creosote waste products* (i.e., railroad ties and marine pilings), their rates of loss, and their bioavailability. This research is considered to be of medium priority.
2. Bioassay tests on leachates from creosote waste products would enable a determination of their toxicity to a standard set of bioassay organisms. This research is considered to be of medium priority.

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