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Environmental Profiles and Hazard Indices for Constituents of Municipal Sludge: Pentachlorophenol

PREFACE

This document is one of a series of preliminary assessments dealing with chemicals of potential concern in municipal sewage sludge. The purpose of these documents is to: (a) summarize the available data for the constituents of potential concern, (b) identify the key environmental pathways for each constituent related to a reuse and disposal option (based on hazard indices), and (c) evaluate the conditions under which such a pollutant may pose a hazard. Each document provides a scientific basis for making an initial determination of whether a pollutant, at levels currently observed in sludges, poses a likely hazard to human health or the environment when sludge is disposed of by any of several methods. These methods include landspreading on food chain or nonfood chain crops, distribution and marketing programs, landfilling, incineration and ocean disposal.

These documents are intended to serve as a rapid screening tool to narrow an initial list of pollutants to those of concern. If a significant hazard is indicated by this preliminary analysis, a more detailed assessment will be undertaken to better quantify the risk from this chemical and to derive criteria if warranted. If a hazard is shown to be unlikely, no further assessment will be conducted at this time; however, a reassessment will be conducted after initial regulations are finalized. In no case, however, will criteria be derived solely on the basis of information presented in this document.

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SECTION 1

INTRODUCTION

This preliminary data profile is one of a series of profiles dealing with chemical pollutants potentially of concern in municipal sewage sludges. Pentachlorophenol (PCP) was initially identified as being of potential concern when sludge is landspread (including distribution and marketing) or ocean disposed.* This profile is a compilation of information that may be useful in determining whether PCP poses an actual hazard to human health or the environment when sludge is disposed of by these methods.

The focus of this document is the calculation of "preliminary hazard indices" for selected potential exposure pathways, as shown in Section 3. Each index illustrates the hazard that could result from movement of a pollutant by a given pathway to cause a given effect (e.g., sludge → soil → plant uptake → animal uptake → human toxicity). The values and assumptions employed in these calculations tend to represent a reasonable "worst case"; analysis of error or uncertainty has been conducted to a limited degree. The resulting value in most cases is indexed to unity; i.e., values >1 may indicate a potential hazard, depending upon the assumptions of the calculation.

The data used for index calculation have been selected or estimated based on information presented in the "preliminary data profile", Section 4. Information in the profile is based on a compilation of the recent literature. An attempt has been made to fill out the profile outline to the greatest extent possible. However, since this is a preliminary analysis, the literature has not been exhaustively perused.

The "preliminary conclusions" drawn from each index in Section 3 are summarized in Section 2. The preliminary hazard indices will be used as a screening tool to determine which pollutants and pathways may pose a hazard. Where a potential hazard is indicated by interpretation of these indices, further analysis will include a more detailed examination of potential risks as well as an examination of site-specific factors. These more rigorous evaluations may change the preliminary conclusions presented in Section 2, which are based on a reasonable "worst case" analysis.

The preliminary hazard indices for selected exposure routes pertinent to landspreading and distribution and marketing and ocean disposal practices are included in this profile. The calculation formulae for these indices are shown in the Appendix. The indices are rounded to two significant figures.

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* Listings were determined by a series of expert workshops convened during March-May, 1984 by the Office of Water Regulations and Standards (OWRS) to discuss landspreading, landfilling, incineration, and ocean disposal, respectively, of municipal sewage sludge.

SECTION 2

PRELIMINARY CONCLUSIONS FOR PENTACHLOROPHENOL IN MUNICIPAL SEWAGE SLUDGE

The following preliminary conclusions have been derived from the calculation of "preliminary hazard indices", which represent conservative or "worst case" analyses of hazard. The indices and their basis and interpretation are explained in Section 3. Their calculation formulae are shown in the Appendix.

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

A. Effect on Soil Concentration of Pentachlorophenol

The landspreading of municipal sewage sludge is expected to result in slight increases of PCP concentration in amended soils (see Index 1).

B. Effect on Soil Biota And Predators of Soil Biota

PCP concentrations in sludge-amended soils are not expected to pose a toxic hazard to soil biota (see Index 2). As a result, soil biota inhabiting sludge-amended soils are unlikely to concentrate sufficient PCP in their tissue to pose a toxic hazard to their predators (see Index 3).

C. Effect on Plants and Plant Tissue Concentration

Phytotoxic effects of PCP on plants grown in sludge-amended soils were not determined due to a lack of data (see Indices 4 and 6). There may be a slight increase of PCP concentrations in plants consumed by animals and humans (see Index 5).

D. Effect on Herbivorous Animals

Forage plants grown in sludge-amended soil are unlikely to concentrate sufficient PCP in their tissues to pose a toxic hazard to herbivorous animals (see Index 7). Also, the expected dietary intake of PCP by animals ingesting sludge-amended soils while grazing is unlikely to exceed toxic concentrations (see Index 8).

E. Effect on Humans

The expected dietary intake of PCP due to the consumption of edible plants grown on sludge-amended soil is not expected to pose a human health risk (see Index 9). Direct ingestion of sludge-amended soil is unlikely to result in a PCP health risk to toddlers or adults (see Index 12). Conclusions concerning human health risk resulting from consumption of animal products derived from animals feeding on plants grown

on sludge-amended soil, and aggregate human toxicity risk were not drawn because index values could not be calculated due to lack of data (see Indices 10, 11, and 13).

II. LANDFILLING

Based on the recommendations of the experts at the OWRS meeting (April-May, 1984), an assessment of this reuse/disposal option is not being conducted at this time. The U.S. EPA reserves the right to conduct such an assessment for this option in the future.

III. INCINERATION

Based on the recommendations of the experts at the OWRS meeting (April-May, 1984), an assessment of this reuse/disposal option is not being conducted at this time. The U.S. EPA reserves the right to conduct such an assessment for this option in the future.

IV. OCEAN DISPOSAL

No significant increases of PCP levels in seawater around disposal sites are expected as a result of sludge disposal (see Index 1). Similarly, only slight increases in the PCP concentration occur at the typical site after a 24-hour dumping cycle (see Index 2).

No toxic conditions for aquatic life are expected due to PCP in the area of a disposal site. Only slight incremental increases in hazard occur under the scenarios evaluated (see Index 3). No increase in human health risks were determined to be associated with PCP when municipal sewage sludge is disposed of in the ocean (see Index 4).

SECTION 3

PRELIMINARY HAZARD INDICES FOR PENTACHLOROPHENOL IN MUNICIPAL SEWAGE SLUDGE

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

A. Effect on Soil Concentration of Pentachlorophenol

1. Index of Soil Concentration (Index 1)

a. **Explanation** - Calculates concentrations in µg/g DW of pollutant in sludge-amended soil. Calculated for sludges with typical (median, if available) and worst (95 percentile, if available) pollutant concentrations, respectively, for each of four applications. Loadings (as dry matter) are chosen and explained as follows:

0 mt/ha	No sludge applied. Shown for all indices for purposes of comparison, to distinguish hazard posed by sludge from pre-existing hazard posed by background levels or other sources of the pollutant.
5 mt/ha	Sustainable yearly agronomic application; i.e., loading typical of agricultural practice, supplying ~50 kg available nitrogen per hectare.
50 mt/ha	Higher single application as may be used on public lands, reclaimed areas or home gardens.
500 mt/ha	Cumulative loading after 100 years of application at 5 mt/ha/year.

b. **Assumptions/Limitations** - Assumes pollutant is incorporated into the upper 15 cm of soil (i.e., the plow layer), which has an approximate mass (dry matter) of 2×10^3 mt/ha and is then dissipated through first order processes which can be expressed as a soil half-life.

c. **Data Used and Rationale**

i. **Sludge concentration of pollutant (SC)**

Typical	0.0865 µg/g DW
Worst	30.434 µg/g DW

The typical and worst concentrations are the mean and 95th percentile, respectively, statistically derived from sludge concentration data presented by U.S. EPA, 1982. (See Section 4, p. 4-2.)

ii. **Background concentration of pollutant in soil (BS)** = 0.0 µg/g DW

Data are not immediately available on soil background concentrations of PCP. To calculate Index 1, the background soil concentration was assumed to be 0 µg/g DW.

iii. **Soil half-life of pollutant ($t_{\frac{1}{2}}$)** = 0.0548 years

In soil microcosm studies, 48 percent of the applied PCP persisted 20 days after application (Cole and Metcalf, 1980). (See Section 4, p. 4-6.)

d. **Index 1 Values (µg/g DW)**

Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Typical	0.0	0.00022	0.0021	0.00022
Worst	0.0	0.076	0.74	0.076

e. **Value Interpretation** - Value equals the expected concentration in sludge-amended soil.

f. **Preliminary Conclusion** - The landspreading of municipal sewage sludge is expected to result in slight increases of PCP concentration in amended soils.

B. **Effect on Soil Biota and Predators of Soil Biota**

1. **Index of Soil Biota Toxicity (Index 2)**

a. **Explanation** - Compares pollutant concentrations in sludge-amended soil with soil concentration shown to be toxic for some soil organism.

b. **Assumptions/Limitations** - Assumes pollutant form in sludge-amended soil is equally bioavailable and toxic as form used in study where toxic effects were demonstrated.

c. **Data Used and Rationale**

i. **Concentration of pollutant in sludge-amended soil (Index 1)**

See Section 3, p. 3-2.

ii. **Soil concentration toxic to soil biota (TB) =** 40.0 µg/g DW

Oxygen uptake by nitrifying soil bacteria was reduced by 50 percent in the presence of 40 µg/g PCP (Hale et al., 1957). (See Section 4, p. 4-10.)

d. **Index 2 Values**

Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Typical	0.0	0.0000054	0.000053	0.0000054
Worst	0.0	0.0019	0.019	0.0019

e. **Value Interpretation** - Value equals factor by which expected soil concentration exceeds toxic concentration. Value > 1 indicates a toxic hazard may exist for soil biota.

f. **Preliminary Conclusion** - PCP concentrations in sludge-amended soils and are not expected to pose a toxic hazard to soil biota.

2. **Index of Soil Biota Predator Toxicity (Index 3)**

a. **Explanation** - Compares pollutant concentrations expected in tissues of organisms inhabiting sludge-amended soil with food concentration shown to be toxic to a predator on soil organisms.

b. **Assumptions/Limitations** - Assumes pollutant form bioconcentrated by soil biota is equivalent in toxicity to form used to demonstrate toxic effects in predator. Effect level in predator may be estimated from that in a different species.

c. **Data Used and Rationale**

i. **Concentration of pollutant in sludge-amended soil (Index 1)**

See Section 3, p. 3-2.

ii. **Uptake factor of pollutant in soil biota (UB) =** 6.2 µg/g tissue DW (µg/g soil DW)$^{-1}$

In a soil microcosm study, five terrestrial invertebrate species were exposed to PCP (Gile et al., 1982). Of the five exposed species, worms exhibited the highest uptake factor for the compound. The uptake factor for worms was chosen because it represents a worst-case value. (See Section 4, p. 4-11.)

iii. **Feed concentration toxic to predator (TR) =** 50.0 µg/g DW

Data on the effects of PCP on typical predators of soil biota were not immediately available. In a 90-day feeding study, rats fed a diet containing 50 µg/g DW exhibited elevated hematocrits, increased hemoglobin, and increased liver weights. Concentrations of PCP below 50 µg/g DW had no effect (Knudson et al., 1974). This value is conservative because it is the lowest feed concentration of PCP required to produce adverse effects in rats. (See Section 4, p. 4-9.)

d. **Index 3 Values**

Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Typical	0.0	0.000027	0.00026	0.000027
Worst	0.0	0.0094	0.092	0.0094

e. **Value Interpretation** - Values equals factor by which expected concentration in soil biota exceeds that which is toxic to predator. Value > 1 indicates a toxic hazard may exist for predators of soil biota.

f. **Preliminary Conclusion** - Soil biota inhabiting sludge-amended soils are unlikely to concentrate sufficient PCP in their tissue to pose a toxic hazard to their predators.

C. **Effect on Plants and Plant Tissue Concentration**

1. **Index of Phytotoxic Soil Concentration (Index 4)**

a. **Explanation** - Compares pollutant concentrations in sludge-amended soil with the lowest soil concentration shown to be toxic for some plants.

b. **Assumptions/Limitations** - Assumes pollutant form in sludge-amended soil is equally bioavailable and toxic as form used in study where toxic effects were demonstrated.

c. **Data Used and Rationale**

i. **Concentration of pollutant in sludge-amended soil (Index 1)**

See Section 3, p. 3-2.

ii. **Soil concentration toxic to plants (TP)** - Data not immediately available.

d. **Index 4 Values** - Values were not calculated due to lack of data.

e. **Value Interpretation** - Value equals factor by which soil concentration exceeds phytotoxic concentration. Value > 1 indicates a phytotoxic hazard may exist.

f. **Preliminary Conclusion** - Conclusion was not drawn because index values could not be calculated.

2. **Index of Plant Concentration Caused by Uptake (Index 5)**

a. **Explanation** - Calculates expected tissue concentrations, in µg/g DW, in plants grown in sludge-amended soil, using uptake data for the most responsive plant species in the following categories: (1) plants included in the U.S. human diet; and (2) plants serving as animal feed. Plants used vary according to availability of data.

b. **Assumptions/Limitations** - Assumes an uptake factor that is constant over all soil concentrations. The uptake factor chosen for the human diet is assumed to be representative of all crops (except fruits) in the human diet. The uptake factor chosen for the animal diet is assumed to be representative of all crops in the animal diet. See also Index 6 for consideration of phytotoxicity.

c. **Data Used and Rationale**

i. **Concentration of pollutant in sludge-amended soil (Index 1)**

See Section 3, p. 3-2.

ii. **Uptake factor of pollutant in plant tissue (UP)**

Animal Diet:
Rye grass 2.8 μg/g tissue DW (μg/g soil DW)$^{-1}$

Human Diet:
Rice grain 0.35 μg/g tissue DW (μg/g soil DW)$^{-1}$

In a soil microcosm study, rye grass exhibited an uptake factor of 2.8 for PCP (Gile et al., 1982). Corn plants grown in soil dosed with PCP exhibited uptake factor in the leaves of 0.81 (Lu et al., 1978). The rye grass uptake factor represents a worst-case value for forage plants. Weiss et al. (1982a,b) reported radioactive residues of 4 ppm in rice grains grown on plots amended with ^{14}C-labeled PCP. Uptake factor was based on reported tissue concentration and application rate. (See Section 4, p. 4-8.)

d. **Index 5 Values (μg/g DW)**

Diet	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Animal	Typical	0.0	0.00060	0.0059	0.00060
	Worst	0.0	0.21	2.1	0.21
Human	Typical	0.0	0.000076	0.00074	0.000076
	Worst	0.0	0.027	0.26	0.027

e. **Value Interpretation** - Value equals the expected concentration in tissues of plants grown in sludge-amended soil. However, any value exceeding the value of Index 6 for the same or a similar plant species may be unrealistically high because it would be precluded by phytoxicity.

f. **Preliminary Conclusion** - There may be a slight increase of PCP concentrations in plants consumed by animals and humans.

3. **Index of Plant Concentration Permitted by Phytotoxicity (Index 6)**

a. **Explanation** - The index value is the maximum tissue concentration, in μg/g DW, associated with phytotoxicity in the same or similar plant species used in Index 5. The purpose is to determine whether the plant tissue concentrations determined in Index 5 for high applications are realistic, or

whether such concentrations would be precluded by phytotoxicity. The maximum concentration should be the highest at which some plant growth still occurs (and thus consumption of tissue by animals is possible) but above which consumption by animals is unlikely.

b. **Assumptions/Limitations** - Assumes that tissue concentration will be a consistent indicator of phytotoxicity.

c. **Data Used and Rationale**

i. **Maximum plant tissue concentration associated with phytoxicity (PP)** - Data not immediately available.

d. **Index 6 Values** - Values were not calculated due to lack of data.

e. **Value Interpretation** - Value equals the maximum plant tissue concentration which is permitted by phytotoxicity. Value is compared with values for the same or similar plant species given by Index 5. The lowest of the two indices indicates the maximal increase that can occur at any given application rate.

f. **Preliminary Conclusion** - Conclusion was not drawn because index values could not be calculated.

D. **Effect on Herbivorous Animals**

1. **Index of Animal Toxicity Resulting from Plant Consumption (Index 7)**

a. **Explanation** - Compares pollutant concentrations expected in plant tissues grown in sludge-amended soil with feed concentration shown to be toxic to wild or domestic herbivorous animals. Does not consider direct contamination of forage by adhering sludge.

b. **Assumptions/Limitations** - Assumes pollutant form taken up by plants is equivalent in toxicity to form used to demonstrate toxic effects in animal. Uptake or toxicity in specific plants or animals may be estimated from other species.

c. **Data Used and Rationale**

i. **Concentration of pollutant in plant grown in sludge-amended soil (Index 5)**

The pollutant concentration values used are those Index 5 values for an animal diet (see Section 3, p. 3-6).

ii. **Feed concentration toxic to herbivorous animal (TA)** = 491.0 µg/g DW

Female yearling cattle fed a diet containing 491 µg/g technical grade PCP for 118 days exhibited reduced weight gain and feeding efficiency, and increased liver weights (McConnell et al., 1980). McConnell et al. (1980) also reported that female yearling cattle fed a diet containing analytical grade PCP at 647 µg/g DW for only 42 days exhibited minimal adverse effects. (See Section 4, p. 4-9.)

d. **Index 7 Values**

Sludge Concentration	Sludge Application Rate (mt/ha)			
	0	5	50	500
Typical	0.0	0.0000012	0.000012	0.0000012
Worst	0.0	0.00043	0.0042	0.00043

e. **Value Interpretation** - Value equals factor by which expected plant tissue concentration exceeds that which is toxic to animals. Value > 1 indicates a toxic hazard may exist for herbivorous animals.

f. **Preliminary Conclusion** - Forage plants grown in sludge-amended soil are unlikely to concentrate sufficient PCP in their tissues to pose a toxic hazard to herbivorous animals.

2. **Index of Animal Toxicity Resulting from Sludge Ingestion (Index 8)**

a. **Explanation** - Calculates the amount of pollutant in a grazing animal's diet resulting from sludge adhesion to forage or from incidental ingestion of sludge-amended soil and compares this with the dietary toxic threshold concentration for a grazing animal.

b. **Assumptions/Limitations** - Assumes that sludge is applied over and adheres to growing forage, or that sludge constitutes 5 percent of dry matter in the grazing animal's diet, and that pollutant form in sludge is equally bioavailable and toxic as form used to demonstrate toxic effects. Where no sludge is applied (i.e., 0 mt/ha), assumes diet is 5 percent soil as a basis for comparison.

c. **Data Used and Rationale**

i. **Sludge concentration of pollutant (SC)**

Typical	0.0865	µg/g DW
Worst	30.434	µg/g DW

See Section 3, p._____.

ii. **Fraction of animal diet assumed to be soil (GS) = 5%**

Studies of sludge adhesion to growing forage following applications of liquid or filter-cake sludge show that when 3 to 6 mt/ha of sludge solids is applied, clipped forage initially consists of up to 30 percent sludge on a dry-weight basis (Chaney and Lloyd, 1979; Boswell, 1975). However, this contamination diminishes gradually with time and growth, and generally is not detected in the following year's growth. For example, where pastures amended at 16 and 32 mt/ha were grazed throughout a growing season (168 days), average sludge content of forage was only 2.14 and 4.75 percent, respectively (Bertrand et al., 1981). It seems reasonable to assume that animals may receive long-term dietary exposure to 5 percent sludge if maintained on a forage to which sludge is regularly applied. This estimate of 5 percent sludge is used regardless of application rate, since the above studies did not show a clear relationship between application rate and initial contamination, and since adhesion is not cumulative yearly because of die-back.

Studies of grazing animals indicate that soil ingestion, ordinarily <10 percent of dry weight of diet, may reach as high as 20 percent for cattle and 30 percent for sheep during winter months when forage is reduced (Thornton and Abrams, 1983). If the soil were sludge-amended, it is conceivable that up to 5 percent sludge may be ingested in this manner as well. Therefore, this value accounts for either of

these scenarios, whether forage is harvested or grazed in the field.

iii. **Feed concentration toxic to herbivorous animal (TA)** = 491 μg/g DW

See Section 3, p. 3-8.

d. **Index 8 Values**

Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Typical	0.0	0.0000088	0.0000082	0.0000082
Worst	0.0	0.0031	0.0031	0.0031

e. **Value Interpretation** - Value equals factor by which expected dietary concentration exceeds toxic concentration. Value > 1 indicates a toxic hazard may exist for grazing animals.

f. **Preliminary Conclusion** - The expected dietary intake of PCP by animals ingesting sludge-amended soils while grazing is unlikely to exceed toxic concentrations.

E. **Effect on Humans**

1. **Index of Human Toxicity Resulting from Plant Consumption (Index 9)**

a. **Explanation** - Calculates dietary intake expected to result from consumption of crops grown on sludge-amended soil. Compares dietary intake with the acceptable daily intake (ADI) of the pollutant.

b. **Assumptions/Limitations** - Assumes that all crops are grown on sludge-amended soil and that all those considered to be affected take up the pollutant at the same rate. Divides possible variations in dietary intake into two categories: toddlers (18 months to 3 years) and individuals over 3 years old.

c. **Data Used and Rationale**

i. **Concentration of pollutant in plant grown in sludge-amended soil (Index 5)**

The pollutant concentration values used are those Index 5 values for a human diet (see Section 3, p. 3-6).

ii. **Daily human dietary intake of affected plant tissue (DT)**

Toddler	74.5	g/day
Adult	205	g/day

The intake value for adults is based on daily intake of crop foods (excluding fruit) by vegetarians (Ryan et al., 1982); vegetarians were chosen to represent the worst case. The value for toddlers is based on the FDA Revised Total Diet (Pennington, 1983) and food groupings listed by the U.S. EPA (1984b). Dry weights for individual food groups were estimated from composition data given by the U.S. Department of Agriculture (USDA) (1975). These values were composited to estimate dry-weight consumption of all non-fruit crops.

iii. **Average daily human dietary intake of pollutant (DI)**

Toddler	0.326	µg/day
Adult	0.987	µg/day

Total diet studies did not detect PCP in the diet of adults in FY 1978 (FDA, 1979). PCP residues were detected sporadically between FY 1976 and 1977. The daily dietary intake (DI) of PCP is based on the mean value of the FDA Total Relative Daily Intake (µg/kg/body weight/day) for PCP between 1975 and 1977 of 0.0141 µg/kg body weight/day. An adult body weight of 70 kg is assumed for determining DI from FDA data or 0.987 µg/day. Toddler intake is assumed to be 33 percent of the adult value or 0.326 µg/day. (See Section 4, p. 4-3.)

iv. **Acceptable daily intake of pollutant (ADI) =** 2100 µg/day

An ADI of 2100 µg/day was derived by the U.S. EPA (1980) based on studies showing a NOEL of 3 mg/kg/day in rats. The effect of concern in these studies was teratogenicity. An uncertainty factor of 100 was applied in calculation of the human ADI. (See Section 4, p. 4-3.)

d. **Index 9 Values**

Group	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Toddler	Typical	0.00016	0.00016	0.00018	0.00016
	Worst	0.0016	0.0011	0.0094	0.0011
Adult	Typical	0.00047	0.00048	0.00054	0.00048
	Worst	0.00047	0.0031	0.026	0.0031

e. **Value Interpretation** - Value equals factor by which expected intake exceeds ADI. Value > 1 indicates a possible human health threat. Comparison with the null index value at 0 mt/ha indicates the degree to which any hazard is due to sludge application, as opposed to pre-existing dietary sources.

f. **Preliminary Conclusion** - The expected dietary intake of PCP due to the consumption of edible plants grown on sludge-amended soil is not expected to pose a human health risk.

2. **Index of Human Toxicity Resulting from Consumption of Animal Products Derived from Animals Feeding on Plants (Index 10)**

a. **Explanation** - Calculates human dietary intake expected to result from pollutant uptake by domestic animals given feed grown on sludge-amended soil (crop or pasture land) but not directly contaminated by adhering sludge. Compares expected intake with ADI.

b. **Assumptions/Limitations** - Assumes that all animal products are from animals receiving all their feed from sludge-amended soil. Assumes that all animal products consumed take up the pollutant at the highest rate observed for muscle of any commonly consumed species or at the rate observed for beef liver or dairy products (whichever is higher). Divides possible variations in dietary intake into two categories: toddlers (18 months to 3 years) and individuals over 3 years old.

c. **Data Used and Rationale**

i. **Concentration of pollutant in plant grown in sludge-amended soil (Index 5)**

The pollutant concentration values used are those Index 5 values for an animal diet (see Section 3, p. 3-6).

ii. **Uptake factor of pollutant in animal tissue (UA)** - Data not immediately available.

Parker et al. (1980) reported terminal serum PCP concentrations of 33 to 77 ppm in cattle fed a diet containing 491 µg/g PCP for 160 days. However, the relationship between serum and tissue concentrations is not well understood. Therefore, an uptake factor could not be estimated.

iii. **Daily human dietary intake of affected animal tissue (DA)**

Toddler	43.7 g/day
Adult	88.5 g/day

The fat intake values presented, which comprise meat, fish, poultry, eggs and milk products, are derived from the FDA Revised Total Diet (Pennington, 1983), food groupings listed by the U.S. EPA (1984b) and food composition data given by USDA (1975). Adult intake of meats is based on males 25 to 30 years of age and that for milk products on males 14 to 16 years of age, the age-sex groups with the highest daily intake. Toddler intake of milk products is actually based on infants, since infant milk consumption is the highest among that age group (Pennington, 1983).

iv. **Average daily human dietary intake of pollutant (DI)**

Toddler	0.326 µg/day
Adult	0.987 µg/day

See Section 3, p. 3-11.

v. **Acceptable daily intake of pollutant (ADI)** = 2100 µg/day

See Section 3, p. 3-11.

d. **Index 10 Values** - Values were not calculated due to lack of data.

e. **Value Interpretation** - Same as for Index 9.

f. **Preliminary Conclusion** - Conclusion was not drawn because index values could not be calculated.

3. **Index of Human Toxicity Resulting from Consumption of Animal Products Derived from Animals Ingesting Soil (Index 11)**

a. **Explanation** - Calculates human dietary intake expected to result from consumption of animal products derived from grazing animals incidentally ingesting sludge-amended soil. Compares expected intake with ADI.

b. **Assumptions/Limitations** - Assumes that all animal products are from animals grazing sludge-amended soil, and that all animal products consumed take up the pollutant at the highest rate observed for muscle of any commonly consumed species or at the rate observed for beef liver or dairy products (whichever is higher). Divides possible variations in dietary intake into two categories: toddlers (18 months to 3 years) and individuals over 3 years old.

c. **Data Used and Rationale**

i. **Animal tissue** - Data not immediately available.

ii. **Sludge concentration of pollutant (SC)**

Typical	0.0865	µg/g DW
Worst	30.434	µg/g DW

See Section 3, p. 3-1.

iii. **Background concentration of pollutant in soil (BS) = 0.0 µg/g DW**

See Section 3, p. 3-2.

iv. **Fraction of animal diet assumed to be soil (GS) = 5%**

See Section 3, p. 3-9.

v. **Uptake factor of pollutant in animal tissue (UA)** - Data not immediately available.

vi. **Daily human dietary intake of affected animal tissue (DA)**

Toddler	39.4 g/day
Adult	82.4 g/day

The affected tissue intake value is assumed to be from the fat component of meat only (beef, pork, lamb, veal) and milk products (Pennington, 1983). This is a slightly more limited choice than for Index 10. Adult intake of meats is based on males 25 to 30 years of age and the intake for milk products on males 14 to 16 years of age, the age-sex groups with the highest daily intake. Toddler intake of milk products is actually based on infants, since infant milk consumption is the highest among that age group (Pennington, 1983).

vii. **Average daily human dietary intake of pollutant (DI)**

Toddler	0.326 µg/day
Adult	0.987 µg/day

See Section 3, p. 3-11.

viii. **Acceptable daily intake of pollutant (ADI)** = 2100 µg/day

See Section 3, p. 3-11.

d. **Index 11 Values** - Values were not calculated due to lack of data.

e. **Value Interpretation** - Same as for Index 9.

f. **Preliminary Conclusion** - Conclusion was not drawn because index values could not be calculated.

4. **Index of Human Toxicity from Soil Ingestion (Index 12)**

a. **Explanation** - Calculates the amount of pollutant in the diet of a child who ingests soil (pica child) amended with sludge. Compares this amount with ADI.

b. **Assumptions/Limitations** - Assumes that the pica child consumes an average of 5 g/day of sludge-amended soil. If an ADI specific for a child is not available, this index assumes the ADI for a 10 kg child is the same as that for a 70 kg adult. It is thus assumed that uncertainty factors used in deriving the ADI provide protection for the child, taking into account the smaller body size and any other differences in sensitivity.

c. **Data Used and Rationale**

i. **Concentration of pollutant in sludge-amended soil (Index 1)**

See Section 3, p. 3-2.

ii. **Assumed amount of soil in human diet (DS)**

Pica child	5	g/day
Adult	0.02	g/day

The value of 5 g/day for a pica child is a worst-case estimate employed by U.S. EPA's Exposure Assessment Group (U.S. EPA, 1983b). The value of 0.02 g/day for an adult is an estimate from U.S. EPA, 1984b.

iii. **Average daily human dietary intake of pollutant (DI)**

Toddler	0.326	µg/day
Adult	0.987	µg/day

See Section 3, p. 3-11.

iv. **Acceptable daily intake of pollutant (ADI)** = 2100 µg/day

See Section 3, p. 3-11.

d. **Index 12 Values**

Group	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Toddler	Typical	0.00016	0.00016	0.00016	0.00016
	Worst	0.00016	0.00034	0.0019	0.00034
Adult	Typical	0.00047	0.00047	0.00047	0.00047
	Worst	0.00047	0.00047	0.00048	0.00047

e. **Value Interpretation** - Same as for Index 9.

f. **Preliminary Conclusion** - Direct ingestion of sludge-amended soil is unlikely to result in a PCP health risk to toddlers or adults.

5. **Index of Aggregate Human Toxicity (Index 13)**

a. **Explanation** - Calculates the aggregate amount of pollutant in the human diet resulting from pathways described in Indices 9 to 12. Compares this amount with ADI.

b. **Assumptions/Limitations** - As described for Indices 9 to 12.

c. **Data Used and Rationale** - As described for Indices 9 to 12.

d. **Index 13 Values** - Values were not calculated due to lack of data.

e. **Value Interpretation** - Same as for Index 9.

f. **Preliminary Conclusion** - Conclusion was not drawn because index values could not be calculated.

II. LANDFILLING

Based on the recommendations of the experts at the OWRS meetings (April-May, 1984), an assessment of this reuse/disposal option is not being conducted at this time. The U.S. EPA reserves the right to conduct such an assessment for this option in the future.

III. INCINERATION

Based on the recommendations of the experts at the OWRS meetings (April-May, 1984), an assessment of this reuse/disposal option is not being conducted at this time. The U.S. EPA reserves the right to conduct such an assessment for this option in the future.

IV. OCEAN DISPOSAL

For the purpose of evaluating pollutant effects upon and/or subsequent uptake by marine life as a result of sludge disposal, two types of mixing were modeled. The initial mixing or dilution shortly after dumping of a single load of sludge represents a high, pulse concentration to which organisms may be exposed for short time periods but which could be repeated frequently; i.e., every time a recently dumped plume is encountered. A subsequent additional degree of mixing can be expressed by a further dilution. This is defined as the average dilution occurring when a day's worth of sludge is dispersed by 24 hours of current movement and represents the time-weighted average exposure concentration for organisms in the disposal area. This dilution accounts for 8 to 12 hours of the high pulse concentration encountered by the organisms during daylight disposal operations and 12 to 16 hours of recovery (ambient water concentration) during the night when disposal operations are suspended.

during daylight disposal operations and 12 to 16 hours of recovery (ambient water concentration) during the night when disposal operations are suspended.

A. Index of Seawater Concentration Resulting from Initial Mixing of Sludge (Index 1)

1. **Explanation** - Calculates increased concentrations in μg/L of pollutant in seawater around an ocean disposal site assuming initial mixing.

2. **Assumptions/Limitations** - Assumes that the background seawater concentration of pollutant is unknown or zero. The index also assumes that disposal is by tanker and that the daily amount of sludge disposed is uniformly distributed along a path transversing the site and perpendicular to the current vector. The initial dilution volume is assumed to be determined by path length, depth to the pycnocline (a layer separating surface and deeper water masses), and an initial plume width defined as the width of the plume four hours after dumping. The seasonal disappearance of the pycnocline is not considered.

3. **Data Used and Rationale**

   a. **Disposal conditions**

	Sludge Disposal Rate (SS)	Sludge Mass Dumped by a Single Tanker (ST)	Length of Tanker Path (L)
Typical	825 mt DW/day	1600 mt WW	8000 m
Worst	1650 mt DW/day	3400 mt WW	4000 m

The typical value for the sludge disposal rate assumes that 7.5 x 10^6 mt WW/year are available for dumping from a metropolitan coastal area. The conversion to dry weight assumes 4 percent solids by weight. The worst-case value is an arbitrary doubling of the typical value to allow for potential future increase.

The assumed disposal practice to be followed at the model site representative of the typical case is a modification of that proposed for sludge disposal at the formally designated 12-mile site in the New York Bight Apex (City of New York, 1983). Sludge barges with capacities of 3400 mt WW would be required to discharge a load in no less than 53 minutes traveling at a minimum speed of 5 nautical miles (9260 m) per hour. Under these conditions, the barge would enter the site, discharge the sludge over 8180 m and exit the site. Sludge barges with capacities of

discharge the sludge over 7902 m and exit the site. The mean path length for the large and small tankers is 8041 m or approximately 8000 m. Path length is assumed to lie perpendicular to the direction of prevailing current flow. For the typical disposal rate (SS) of 825 mt DW/day, it is assumed that this would be accomplished by a mixture of four 3400 mt WW and four 1600 mt WW capacity barges. The overall daily disposal operation would last from 8 to 12 hours. For the worst-case disposal rate (SS) of 1650 mt DW/day, eight 3400 mt WW and eight 1600 mt WW capacity barges would be utilized. The overall daily disposal operation would last from 8 to 12 hours. For both disposal rate scenarios, there would be a 12 to 16 hour period at night in which no sludge would be dumped. It is assumed that under the above described disposal operation, sludge dumping would occur every day of the year.

The assumed disposal practice at the model site representative of the worst case is as stated for the typical site, except that barges would dump half their load along a track, then turn around and dispose of the balance along the same track in order to prevent a barge from dumping outside of the site. This practice would effectively halve the path length compared to the typical site.

b. Sludge concentration of pollutant (SC)

Typical	0.0865 mg/kg DW
Worst	30.434 mg/kg DW

See Section 3, p. 3-1.

c. Disposal site characteristics

	Depth to pycnocline (D)	Average current velocity at site (V)
Typical	20 m	9500 m/day
Worst	5 m	4320 m/day

Typical site values are representative of a large, deep-water site with an area of about 1500 km^2 located beyond the continental shelf in the New York Bight. The pycnocline value of 20 m chosen is the average of the 10 to 30 m pycnocline depth range occurring in the summer and fall; the winter and spring disappearance of the pycnocline is not considered and so represents a conservative approach in

evaluating annual or long-term impact. The current velocity of 11 cm/sec (9500 m/day) chosen is based on the average current velocity in this area (CDM, 1984a).

Worst-case values are representative of a near-shore New York Bight site with an area of about 20 km^2. The pycnocline value of 5 m chosen is the minimum value of the 5 to 23 m depth range of the surface mixed layer and is therefore a worst-case value. Current velocities in this area vary from 0 to 30 cm/sec. A value of 5 cm/sec (4320 m/day) is arbitrarily chosen to represent a worst-case value (CDM, 1984b).

4. Factors Considered in Initial Mixing

When a load of sludge is dumped from a moving tanker, an immediate mixing occurs in the turbulent wake of the vessel, followed by more gradual spreading of the plume. The entire plume, which initially constitutes a narrow band the length of the tanker path, moves more-or-less as a unit with the prevailing surface current and, under calm conditions, is not further dispersed by the current itself. However, the current acts to separate successive tanker loads, moving each out of the immediate disposal path before the next load is dumped.

Immediate mixing volume after barge disposal is approximately equal to the length of the dumping track with a cross-sectional area about four times that defined by the draft and width of the discharging vessel (Csanady, 1981, as cited in NOAA, 1983). The resulting plume is initially 10 m deep by 40 m wide (O'Connor and Park, 1982, as cited in NOAA, 1983). Subsequent spreading of plume band width occurs at an average rate of approximately 1 cm/sec (Csanady et al., 1979, as cited in NOAA, 1983). Vertical mixing is limited by the depth of the pycnocline or ocean floor, whichever is shallower. Four hours after disposal, therefore, average plume width (W) may be computed as follows:

W = 40 m + 1 cm/sec x 4 hours x 3600 sec/hour x 0.01 m/cm = 184 m = approximately 200 m

Thus the volume of initial mixing is defined by the tanker path, a 200 m width, and a depth appropriate to the site. For the typical (deep water) site, this depth is chosen as the pycnocline value of 20 m. For the worst (shallow water) site, a value of 10 m was chosen. At times the pycnocline may be as shallow as 5 m, but since the barge wake causes initial mixing to at least 10 m, the greater value was used.

5. **Index 1 Values (μg/L)**

Disposal Conditions and Site Characteristics	Sludge Concentration	Sludge Disposal Rate (mt DW/day) 0	825	1650
Typical	Typical	0.0	0.00017	0.00017
	Worst	0.0	0.061	0.061
Worst	Typical	0.0	0.0015	0.0015
	Worst	0.0	0.52	0.52

6. **Value Interpretation** - Value equals the expected increase in PCP concentration in seawater around a disposal site as a result of sludge disposal after initial mixing.

7. **Preliminary Conclusion** - No significant increases of PCP levels in seawater around disposal sites are expected as a result of sludge disposal.

B. **Index of Seawater Concentration Representing a 24-Hour Dumping Cycle (Index 2)**

1. **Explanation** - Calculates increased effective concentrations in μg/L of pollutant in seawater around an ocean disposal site utilizing a time weighted average (TWA) concentration. The TWA concentration is that which would be experienced by an organism remaining stationary (with respect to the ocean floor) or moving randomly within the disposal vicinity. The dilution volume is determined by the tanker path length and depth to pycnocline or, for the shallow water site, the 10 m effective mixing depth, as before, but the effective width is now determined by current movement perpendicular to the tanker path over 24 hours.

2. **Assumptions/Limitations** - Incorporates all of the assumptions used to calculate Index 1. In addition, it is assumed that organisms would experience high-pulsed sludge concentrations for 8 to 12 hours per day and then experience recovery (no exposure to sludge) for 12 to 16 hours per day. This situation can be expressed by the use of a TWA concentration of sludge constituent.

3. **Data Used and Rationale**

See Section 3, pp. 3-18 to 3-20.

4. **Factors Considered in Determining Subsequent Additional Degree of Mixing (Determination of TWA Concentrations)**

See Section 3, p. 3-21.

5. **Index 2 Values (µg/L)**

Disposal Conditions and Site Characteristics	Sludge Concentration	Sludge Disposal Rate (mt DW/day) 0	825	1650
Typical	Typical	0.0	0.000047	0.000094
	Worst	0.0	0.016	0.033
Worst	Typical	0.0	0.00041	0.00082
	Worst	0.0	0.14	0.29

6. **Value Interpretation** - Value equals the effective increase in PCP concentration expressed as a TWA concentration in seawater around a disposal site experienced by an organism over a 24-hour period.

7. **Preliminary Conclusion** - Only slight increases in the PCP concentration occur at the typical site after a 24-hour dumping cycle.

C. **Index of Toxicity to Aquatic Life (Index 3)**

1. **Explanation** - Compares the effective increased concentration of pollutant in seawater around the disposal site resulting from the initial mixing of sludge (Index 1) with the marine ambient water quality criterion of the pollutant, or with another value judged protective of marine aquatic life. For PCP, this value is the criterion that will protect marine aquatic organisms from both acute and chronic toxic effects.

   Wherever a short-term, "pulse" exposure may occur as it would from initial mixing, it is usually evaluated using the "maximum" criteria values of EPA's ambient water quality criteria methodology. However, under this scenario, because the pulse is repeated several times daily on a long-term basis, potentially resulting in an accumulation of injury, it seems more appropriate to use values designed to be protective against chronic toxicity. Therefore, to evaluate the potential for adverse effects on marine life resulting from initial mixing concentrations, as quantified by Index 1, the chronically derived criteria values are used.

2. **Assumptions/Limitations** - In addition to the assumptions stated for Indices 1 and 2, assumes that all of the released pollutant is available in the water column to move through predicted pathways (i.e., sludge to seawater to aquatic organism to man). The possibility of effects arising from accumulation in the sediments is neglected since the U.S. EPA presently lacks a satisfactory method for deriving sediment criteria.

3. **Data Used and Rationale**

   a. **Concentration of pollutant in seawater around a disposal site (Index 1)**

   See Section 3, p. 3-21.

   b. **Ambient water quality criterion (AWQC)** = 34 µg/L

   Water quality criteria for the toxic pollutants listed under Section 307(a)(1) of the Clean Water Act of 1977 were developed by the U.S. EPA under Section 304(a)(1) of the Act. These criteria were derived by utilization of data reflecting the resultant environmental impacts and human health effects of these pollutants if present in any body of water. The criteria values presented in this assessment are excerpted from the ambient water quality criteria document for PCP.

   The value chosen to protect marine organisms is based on the results of chronic toxicity tests on adult Eastern oysters (crassostrea virginia). The lowest acute toxicity value is 53 µg/L for a fish species (U.S. EPA, 1980). (See Section 4, p. 4-5.)

4. **Index 3 Values**

Disposal Conditions and Site Characteristics	Sludge Concentration	Sludge Disposal Rate (mt DW/day) 0	825	1650
Typical	Typical	0.0	0.0000051	0.0000051
	Worst	0.0	0.0018	0.0018
Worst	Typical	0.0	0.000043	0.000043
	Worst	0.0	0.015	0.015

5. **Value Interpretation** - Value equals the factor by which the expected seawater concentration increase in PCP exceeds the protective value. A value > 1 indicates that acute or chronic toxic conditions may exist for organisms at the site.

6. **Preliminary Conclusion** - No toxic conditions due to PCP in sludge were determined. Only slight incremental increases in hazard occur under the scenarios evaluated.

D. **Index of Human Toxicity Resulting from Seafood Consumption (Index 4)**

1. **Explanation** - Estimates the expected increase in human pollutant intake associated with the consumption of seafood, a fraction of which originates from the disposal site vicinity, and compares the total expected pollutant intake with the acceptable daily intake (ADI) of the pollutant.

2. **Assumptions/Limitations** - In addition to the assumptions listed for Indices 1 and 2, assumes that the seafood tissue concentration increase can be estimated from the increased water concentration by a bioconcentration factor. It also assumes that, over the long term, the seafood catch from the disposal site vicinity will be diluted to some extent by the catch from uncontaminated areas.

3. **Data Used and Rationale**

a. **Concentration of pollutant in seawater around a disposal site (Index 2)**

See Section 3, p. 3-22.

Since bioconcentration is a dynamic and reversible process, it is expected that uptake of sludge pollutants by marine organisms at the disposal site will reflect TWA concentrations, as quantified by Index 2, rather than pulse concentrations.

b. **Dietary consumption of seafood (QF)**

Typical	14.3 g WW/day
Worst	41.7 g WW/day

Typical and worst-case values are the mean and the 95th percentile, respectively, for all seafood consumption in the United States (Stanford Research Institute (SRI) International, 1980).

c. **Fraction of consumed seafood originating from the disposal site (FS)**

For a typical harvesting scenario, it was assumed that the total catch over a wide region is mixed by harvesting, marketing and consumption practices, and that exposure is thereby diluted. Coastal areas have been divided by the National Marine Fishery

Service (NMFS) into reporting areas for reporting on data on seafood landings. Therefore it was convenient to express the total area affected by sludge disposal as a fraction of an NMFS reporting area. The area used to represent the disposal impact area should be an approximation of the total ocean area over which the average concentration defined by Index 2 is roughly applicable. The average rate of plume spreading of 1 cm/sec referred to earlier amounts to approximately 0.9 km/day. Therefore, the combined plume of all sludge dumped during one working day will gradually spread, both parallel to and perpendicular to current direction, as it proceeds down-current. Since the concentration has been averaged over the direction of current flow, spreading in this dimension will not further reduce average concentration; only spreading in the perpendicular dimension will reduce the average. If stable conditions are assumed over a period of days, at least 9 days would be required to reduce the average concentration by one-half. At that time, the original plume length of approximately 8 km (8000 m) will have doubled to approximately 16 km due to spreading.

It is probably unnecessary to follow the plume further since storms, which would result in much more rapid dispersion of pollutants to background concentrations are expected on at least a 10-day frequency (NOAA, 1983). Therefore, the area impacted by sludge disposal (AI, in km^2) at each disposal site will be considered to be defined by the tanker path length (L) times the distance of current movement (V) during 10 days, and is computed as follows:

$$AI = 10 \times L \times V \times 10^{-6}\ km^2/m^2 \qquad (1)$$

To be consistent with a conservative approach, plume dilution due to spreading in the perpendicular direction to current flow is disregarded. More likely, organisms exposed to the plume in the area defined by equation 1 would experience a TWA concentration lower than the concentration expressed by Index 2.

Next, the value of AI must be expressed as a fraction of an NMFS reporting area. In the New York Bight, which includes NMFS areas 612-616 and 621-623, deep-water area 623 has an area of approximately 7200 km^2 and constitutes approximately 0.02 percent of the total seafood landings for the Bight (CDM, 1984a). Near-shore area 612 has an area of approximately 4300 km^2 and constitutes

approximately 24 percent of the total seafood landings (CDM, 1984b). Therefore the fraction of all seafood landings (FS_t) from the Bight which could originate from the area of impact of either the typical (deep-water) or worst (near-shore) site can be calculated for this typical harvesting scenario as follows:

For the typical (deep water) site:

$$FS_t = \frac{AI \times 0.02\%}{7200\ km^2} = \tag{2}$$

$$\frac{[10 \times 8000\ m \times 9500\ m \times 10^{-6}\ km^2/m^2] \times 0.0002}{7200\ km^2} = 2.1 \times 10^{-5}$$

For the worst (near shore) site:

$$FS_t = \frac{AI \times 24\%}{4300\ km^2} = \tag{3}$$

$$\frac{[10 \times 4000\ m \times 4320\ m \times 10^{-6}\ km^2/m^2] \times 0.24}{4300\ km^2} = 9.6 \times 10^{-3}$$

To construct a worst-case harvesting scenario, it was assumed that the total seafood consumption for an individual could originate from an area more limited than the entire New York Bight. For example, a particular fisherman providing the entire seafood diet for himself or others could fish habitually within a single NMFS reporting area. Or, an individual could have a preference for a particular species which is taken only over a more limited area, here assumed arbitrarily to equal an NMFS reporting area. The fraction of consumed seafood (FS_w) that could originate from the area of impact under this worst-case scenario is calculated as follows:

For the typical (deep water) site:

$$FS_w = \frac{AI}{7200\ km^2} = 0.11 \tag{4}$$

For the worst (near shore) site:

$$FS_w = \frac{AI}{4300\ km^2} = 0.040 \tag{5}$$

d. Bioconcentration factor of pollutant (BCF) = 11 L/kg

The value chosen is the weighted average BCF of PCP for the edible portion of all freshwater and estuarine aquatic organisms consumed by U.S.

citizens (U.S. EPA, 1980). The weighted average BCF is derived as part of the water quality criteria developed by the U.S. EPA to protect human health from the potential toxic effects of PCP induced by ingestion of contaminated water and aquatic organisms. The weighted average BCF is calculated by adjusting the mean normalized BCF (steady-state BCF corrected to 1 percent lipid content) to the 3 percent lipid content of consumed fish and shellfish. It should be noted that lipids of marine species differ in both structure and quantity from those of freshwater species. Although a BCF value calculated entirely from marine data would be more appropriate for this assessment, no such data are presently available. (See Section 4, p. 4-5.)

e. **Average daily human dietary intake of pollutant (DI)** = 0.987 µg/day

See Section 3, p. 3-11.

f. **Acceptable daily intake of pollutant (ADI)** = 2100 µg/day

4. **Index 4 Values**

Disposal Conditions and Site Characteristics	Sludge Concentration[a]	Seafood Intake[a,b]	Sludge Disposal Rate (mt DW/day) 0	825	1650
Typical	Typical	Typical	0.00047	0.00047	0.00047
	Worst	Worst	0.00047	0.00047	0.00047
Worst	Typical	Typical	0.00047	0.00047	0.00047
	Worst	Worst	0.00047	0.00047	0.00047

[a] All possible combinations of these values are not presented. Additional combinations may be calculated using the formulae in the Appendix.

[b] Refers to both the dietary consumption of seafood (QF) and the fraction of consumed seafood originating from the disposal site (FS). "Typical" indicates the use of the typical-case values for both of these parameters; "worst" indicates the use of the worst-case values for both.

5. **Value Interpretation** - Value equals factor by which theexpected intake exceeds the ADI. A value >1 indicates a possible human health threat. Comparison with the null index value at 0 mt/day indicates the degree to which any

hazard is due to sludge disposal, as opposed to preexisting dietary sources.

6. **Preliminary Conclusion** - No increase in human health risks were determined in this assessment.

SECTION 4

PRELIMINARY DATA PROFILE FOR PENTACHLOROPHENOL IN MUNICIPAL SEWAGE SLUDGE

I. OCCURRENCE

PCP is a commercially produced bactericide, fungicide, and slimicide used primarily for the preservation of wood, wood products, and other materials. As a chlorinated hydrocarbon, its biological properties have also resulted in its use as an herbicide, insecticide, and molluscicide. Technical PCP contains significant contaminants such as chlorinated benzenes and dibenzofurans. Although PCP and Na-PCP are disseminated in the environment, there is a paucity of data on their environmental concentration, fate, and effects.	U.S. EPA, 1980 (p. A-1, A-2)

A. Sludge

1. Frequency of Detection

62 out of 438 samples (14%) from 40 POTWs contained PCP	U.S. EPA, 1982 (p. 41, 50)
2 out of 42 samples (5%) from 10 POTWs contained PCP	
In samples from 25 municipal sewage plants, PCP occurred in 50% of the samples	DeWalle et al., 1982 (p. 144)
68 out of 223 sludge samples (30.5%) from Michigan contained measureable amounts of PCP (Detection Limit = 0.03 µg/g)	U.S. EPA, 1983a (p. A-14)

2. Concentration

10 to 10,500 µg/L range for 62 of 438 samples from 40 POTWs 150 to 250 µg/L range for 2 of 42 samples from 10 POTWs	U.S. EPA, 1982 (p. 41, 50)
Maximum levels of PCP from 25 municipal plants - liquid phase: 58 µg/L anaerobically digested sludge: 1200 µg/kg effluent: 12 µg/L	DeWalle et al., 1982 (p. 145)

0.0865 and 30.434 mg/kg DW, mean and 95th percentile, respectively, from 40 POTWs study.	Statistically derived from sludge concentration data presented in U.S. EPA, 1982 (p. 41)
Out of 223 sludge samples from Michigan, 68 contained PCP at the following levels (µg/g):	U.S. EPA, 1983a (p. A-14)

Range	Mean	Median
0.2-8,495	81 ± 685	5.0

B. Soil - Unpolluted

Data not immediately available.

C. Water - Unpolluted

1. Frequency of Detection

Data not immediately available.

2. Concentration

a. Freshwater

Williamette River - 1969, daily and hourly samples over a 24-hour period showed PCP levels ranging between 0.10 and 0.70 µg/L	Buhler et al., 1973 (p. 929)

b. Seawater

Data not immediately available.

c. Drinking water

Finished drinking water from Corvallis, Oregon in 1970 contained 0.06 µg/L	Buhler et al., 1973 (p. 933)
Highest concentration reported in drinking water was 1.4 µg/L PCP	NAS, 1977 (p. 750)

D. Air

No airborne concentrations reported in the literature	NRC, 1982 (p. 55)

E. Food

1. Total Average Intake

µg/kg body weight/day			
FY75	FY76	FY77	FY78
0.024	0.0174	0.0009	ND

FDA, no date (Attachment G)

2. Concentration

PCP not detected in FY78 diet study

FDA, 1979 (Attachment E)

Food Type	Total No. Samples	No. With PCP	Range of Conc. (µg/g)
Dairy	30	2	Trace-0.010
Legumes	30	1	0.010
Sugars and Adjuncts	30	6	0.01-0.02

Johnson and Manske, 1976

PCP not found in other food types

Peanut butter - 11 samples contained an average of 0.028 µg/g PCP

Heikes, 1980 (p. 341)

II. HUMAN EFFECTS

A. Ingestion

1. Carcinogenicity

Data not immediately available.

2. Chronic Toxicity

a. ADI

2100 µg/day for a 70 kg person

U.S. EPA, 1980 (p. C-37)

b. Effects

Female rats were exposed to PCP at several doses. At the 30 mg/kg/day level of treatment, a reduced rate of body weight gained and increased specific gravity of the urine were observed. Pigmentation of the liver and kidneys was observed in females exposed to 10 or 30 mg/kg/day.

U.S. EPA, 1984c (p. 6)

3. **Absorption Factor**

Data not immediately available.

4. **Existing Regulations**

U.S. EPA ambient water quality criteria for protection of human health = 1010 µg/L.	U.S. EPA, 1980 (p. C-37)

B. **Inhalation**

Not included because incineration is not evaluated.

III. PLANT EFFECTS

A. **Phytotoxicity**

Tomatoes and tree seedlings grown in PCP impregnated wood flats exhibited severe toxic symptoms	U.S. EPA, 1979 (p. 274-277)

B. **Uptake**

See Table 4-1.

PCP is readily absorbed by the roots of sugar cane but is not translocated to other portions of the plants (grown in culture solution, tissue concentration not provided)	U.S. EPA, 1979 (p. 273)
PCP is absorbed readily by plant roots and leaves	U.S. EPA, 1979 (p. 18)

IV. DOMESTIC ANIMAL AND WILDLIFE EFFECTS

A. **Toxicity**

See Table 4-2.

"Information on the toxicity of PCP is complicated by the presence of contaminants, such as dibenzo-p-dioxins and dibenzo furans, in technical PCP samples."	NRC, 1982 (p. 33)
The toxicity of technical PCP is directly proportional to the amount of toxic contaminants present such as hexachlorobenzene, dibenzodioxin, dibenzofurans.	Parker et al., 1980 (p. 366)
PCP contains a wide variety of potentially toxic contaminants	Plimmer, 1973 (p. 42)

B. **Uptake**

Available data indicate that the biological handling of PCP is rather similar across mammalian species. PCP is rapidly absorbed and once absorbed is distributed throughout the body. Half-life for elimination of an acute single dose is 8 to 9 days. Half-life for chronic dosages is 20 days. — U.S. EPA, 1984a (p. III-16)

In a microcosm experiment, the following terminal levels of PCP were measured: — Gile et al., 1982 (p. 298-299)

Soil	-	1.22 µg/g
Rye grass	-	3.5 µg/g
Crickets	-	1.16 µg/g
Vole	-	3.20 µg/g

In a microcosm experiment with a soil application of 1.12 kg/ha, the mean accumulation in terrestrial animals (5 species exposed for 5 days) was 0.672 µg/g, 15% of which was the parent compound. Accumulation in the entire body of the vole was 0.530 µg/g, 7% of which was the parent compound. — Cole and Metcalf, 1980

V. **AQUATIC LIFE EFFECTS**

A. **Toxicity**

1. **Freshwater**

Data not immediately available.

2. **Saltwater**

a. **Acute**

53 µg/L for fish species — U.S. EPA, 1980 (p. B-21)

b. **Chronic**

34 µg/L for Eastern oyster (*crassostrea virginica*) — U.S. EPA, 1980 (p. B-27)

B. **Uptake**

Bioconcentration factor = 11. Based on edible portion of all freshwater and estuarine organisms consumed by Americans. — U.S. EPA, 1980 (p. C-3)

VI. SOIL BIOTA EFFECTS

A. Toxicity

PCP is extremely toxic to almost all forms of bacteria, algae and fungi.	U.S. EPA, 1979 (p. 231)
PCP applied to soils at 20 and 10 kg/ha did not cause any apparent toxicity, but did cause an increase in PCP-decomposing microorganisms by about 3 orders of magnitude within 2-3 weeks.	Watanabe, 1977 (p. 99)

See Table 4-3.

B. Uptake

See Table 4-4.

VII. PHYSICOCHEMICAL DATA FOR ESTIMATING FATE AND TRANSPORT

Soluble in water at 20 mg/L at 30°C Vapor pressure = 1.1×10^{-4} mm Hg at 20°C	NAS, 1977 (p. 750)
PCP is not persistent in soil. It is partly volatilized or mineralized, partly degraded and incorporated into soil constituents as unextractable residues.	Weiss et al., 1982b
Molecular formula: C_6HCl_5O Molecular weight: 266 Melting point: 190°C Boiling point: 310°C Specific gravity: 1.978 (at 20°C	NRC, 1982
Soluble in alcohol, acetone, ether, pine oil, and benzene. Slightly soluble in water.	
Persistence after application = 3 years (medium not stated)	NRC, 1982 (p. 55)
After 20 days in the soil, 48% of the applied PCP remained, 19% as the parent compound or transformation products.	Cole and Metcalf, 1980 (p. 987)
Factors affecting decomposition in soil: -- PCP more persistent in dry soils than water-saturated soils -- PCP more persistent in clay soils than sandy soils	Bevenue et al., 1967 (p. 88)

-- PCP more persistent when there is less organic matter in the soil -- PCP more persistent when temperatures not optimum for microbial growth	Kaufman, 1978 (p. 28)

TABLE 4-1. UPTAKE OF PENTACHLOROPHENOL BY PLANTS

Plant	Tissue	Soil Type	Chemical Form Applied	Range of Soil Concentration (μg/g)	Range of Tissue Concentration (μg/g)	Uptake Factor	References
Rye grass	leaf	topsoil in lab	PCP	0.93-5.36 mean 1.22 μg/g	3.5	2.8	Gile et al., 1982 (p. 298)
Rice	grains	sandy clay	PCP (99% pure)	23 kg/ha	4	0.35[a]	Weiss et al., 1982a (p. 1189)
Corn	leaf	silty clay loam	PCP	1.25 μg/g	1.01	0.81	Lu et al., 1978 (p. 60)

[a] Value derived by converting reported application rate (kg/ha) to soil concentration (μg/g) by assuming 2000 mt/ha (see Section 3, p. 3-1). The reported plant tissue concentration was divided by the derived soil concentration to yield the uptake factor.

TABLE 4-2. TOXICITY OF PENTACHLOROPHENOL TO DOMESTIC ANIMALS AND WILDLIFE

Species (N)[a]	Chemical Form Administered	Feed Concentration (µg/g DW)	Water Concentration (mg/l)	Daily Intake (mg/kg)	Duration of Study	Effects	References
Mouse	PCP	NR[b]	NR	120-140	--	LD_{50} Acute oral doses	NAS, 1977 (p. 751)
Rat	PCP	NR	NR	27-100	--	LD_{50}	
Guinea Pig	PCP	NR	NR	100	--	LD_{50}	
Rabbit	PCP	NR	NR	100-130	--	LD_{50}	
Dog	PCP	NR	NR	150-200	--	LD_{50}	
Rats (20 per group)	PCP	0-25	NR	0-1.25	90 days	No effect	Knudson et al., 1974 (p. 141)
	PCP	50	NR	2.5	90 days	Increased hemoglobin, hematocrit, and liver wt.	
		200	NR	NR	90 days	Reduced growth rate	
Hamster	PCP	NR	NR	5	Days 6-15 of gestation	Fetal death or resorption	NAS, 1977 (p. 753)
Rats (30 per group)	PCP	NR	NR	0-30	22-24 mos	No significant increase in tumors at any dosage. No toxic effects in males at 10 mg/kg/day or less. No toxic effects in females at 3 mg/kg/day or less.	Schwetz et al., 1978 (p. 301)
Rat	PCP	NR	NR	146-175	NR	Oral LD_{50}	NRC, 1982 (p. 34)
Pig (24)	PCP	NR	NR	0-15	30 days	All groups (except control) experienced a 3-20% reduction in total leucocycles	Hillam and Greichus, 1983 (p. 601)
Cattle - female yearlings (15)	Analytical and technical PCP	647	NR	20	42 days	Analytical PCP: minimal adverse effects	McConnell et al., 1980 (p. 468, 487)
		491	NR	15	118 days	Technical PCP: reduced weight gain; decreased feed efficiency; progressive anemia; increase in liver and lung weights decrease in thymus weight	
Calf (1)	PCP	NR	60	NR	7 weeks	No apparent effect	Bevenue and Beckman, 1967 (p. 91)

[a] N = Number of experimental animals when reported.
[b] NR = Not reported.

TABLE 4-3. TOXICITY OF PENTACHLOROPHENOL TO SOIL BIOTA

Species	Chemical Form Applied	Soil Type	Soil Concentration (µg/g)	Effects	References
Soil Microbes	PCP[a]	Silt Loam	0-200	At 40 µg/g, oxygen uptake by soil microbes was reduced by 50%; at 200 µg/g, almost complete oxygen uptake retardation occurred	Hale et al., 1957 (p. 336, 339)

[a] Sodium pentachlorophenate

TABLE 4-4. UPTAKE OF PENTACHLOROPHENOL BY SOIL BIOTA

Species	Chemical Form Application	Soil Type	Range of Soil Concentration (μg/g)	Range of Tissue Concentration (μg/g)	Bioconcentration Factor	References
Crickets	PCP	topsoil	1.22	0.78-1.16	0.67-0.94	Gile et al., 1982 (p. 298)
Snails	PCP	topsoil	1.22	1.56-2.71	1.3-2.2	Gile et al., 1982 (p. 298)
Pillbugs	PCP	topsoil	1.22	2.14	1.7	Gile et al., 1982 (p. 298)
Worms	PCP	topsoil	1.22	7.67	6.2	Gile et al., 1982 (p. 298)
Mealworm larvae	PCP	topsoil	1.22	1.22	ND	Gile et al., 1982 (p. 298)

SECTION 5

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APPENDIX

PRELIMINARY HAZARD INDEX CALCULATIONS FOR PENTACHLOROPHENOL IN MUNICIPAL SEWAGE SLUDGE

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

A. Effect on Soil Concentration of Pentachlorophenol

1. Index of Soil Concentration (Index 1)

a. Formula

$$CS_s = \frac{(SC \times AR) + (BS \times MS)}{AR + MS}$$

$$CS_r = CS_s \left[1 + 0.5^{(1/t\frac{1}{2})} + 0.5^{(2/t\frac{1}{2})} + \ldots + 0.5^{(n/t\frac{1}{2})}\right]$$

where:

- CS_s = Soil concentration of pollutant after a single year's application of sludge (µg/g DW)
- CS_r = Soil concentration of pollutant after the yearly application of sludge has been repeated for n + 1 years (µg/g DW)
- SC = Sludge concentration of pollutant (µg/g DW)
- AR = Sludge application rate (mt/ha)
- MS = 2000 mt ha/DW = assumed mass of soil in upper 15 cm
- BS = Background concentration of pollutant in soil (µg/g DW)
- $t\frac{1}{2}$ = Soil half-life of pollutant (years)
- n = 99 years

b. Sample calculation

CS_s is calculated for AR = 0, 5, and 50 mt/ha only

$$0.000215 \mu g/g\ DW = \frac{(0.0865\ \mu g/g\ DW \times 5\ mt/ha) + (0.0\ \mu g/g\ DW \times 2000\ mt/ha)}{(5\ mt/ha\ DW + 2000\ mt/ha\ DW)}$$

CS_r is calculated for AR = 5 mt/ha applied for 100 years

$$0.00022\ \mu g/g\ DW = 0.000215\ \mu g/g\ DW\ [1 + 0.5^{(1/0.0548)} + 0.5^{(2/0.0548)} + \ldots + 0.5^{(99/0.0548)}]$$

B. Effect on Soil Biota and Predators of Soil Biota

1. Index of Soil Biota Toxicity (Index 2)

a. **Formula**

$$\text{Index 2} = \frac{I_1}{TB}$$

where:

I_1 = Index 1 = Concentration of pollutant in sludge-amended soil (µg/g DW)
TB = Soil concentration toxic to soil biota (µg/g DW)

b. **Sample calculation**

$$0.00000539 = \frac{0.000215 \text{ µg/g DW}}{40 \text{ µg/g DW}}$$

2. **Index of Soil Biota Predator Toxicity (Index 3)**

a. **Formula**

$$\text{Index 3} = \frac{I_1 \times UB}{TR}$$

where:

I_1 = Index 1 = Concentration of pollutant in sludge-amended soil (µg/g DW)
UB = Uptake factor of pollutant in soil biota (µg/g tissue DW [µg/g soil DW]$^{-1}$)
TR = Feed concentration toxic to predator (µg/g DW)

b. **Sample calculation**

$$0.0000267 = \frac{0.000215 \text{ µg/g DW} \times 6.2 \text{ µg/g tissue DW (µg/g soil DW)}^{-1}}{50 \text{ µg/g DW}}$$

C. **Effect on Plants and Plant Tissue Concentration**

1. **Index of Phytotoxic Soil Concentration (Index 4)**

a. **Formula**

$$\text{Index 4} = \frac{I_1}{TP}$$

where:

I_1 = Index 1 = Concentration of pollutant in sludge-amended soil (µg/g DW)
TP = Soil concentration toxic to plants (µg/g DW)

b. **Sample calculation** - Values were not caluclated due to lack of data.

2. **Index of Plant Concentration Caused by Uptake (Index 5)**

a. **Formula**

Index 5 = I_1 x UP

where:

I_1 = Index 1 = Concentration of pollutant in sludge - amended soil (µg/g DW)
UP = Uptake factor of pollutant in plant tissue (µg/g tissue DW [µg/g soil DW]$^{-1}$)

b. **Sample Calculation**

0.000604 µg/g DW = 0.000215 µg/g DW x 2.8 µg/g tissue DW (µg/g soil DW)$^{-1}$

3. **Index of Plant Concentration Increment Permitted by Phytotoxicity (Index 6)**

a. **Formula**

Index 6 = PP

where:

PP = Maximum plant tissue concentration associated with phytotoxicity (µg/g DW)

b. **Sample calculation** - Values were not calculated due to lack of data.

D. **Effect on Herbivorous Animals**

1. **Index of Animal Toxicity Resulting from Plant Consumption (Index 7)**

a. **Formula**

$$\text{Index 7} = \frac{I_5}{TA}$$

where:

I_5 = Index 5 = Concentration of pollutant in plant grown in sludge-amended soil (µg/g DW)
TA = Feed concentration toxic to herbivorous animal (µg/g DW)

b. **Sample calculation**

$$0.00000123 = \frac{0.000604\ \mu g/g\ DW}{491.0\ \mu g/g\ DW}$$

2. **Index of Animal Toxicity Resulting from Sludge Ingestion (Index 8)**

a. **Formula**

If AR = 0; Index 8 = 0

If AR ≠ 0; $\text{Index 8} = \frac{SC \times GS}{TA}$

where:

AR = Sludge application rate (mt DW/ha)
SC = Sludge concentration of pollutant (µg/g DW)
GS = Fraction of animal diet assumed to be soil
TA = Feed concentration toxic to herbivorous animal (µg/g DW)

b. **Sample calculation**

If AR = 0; Index 8 = 0

If AR ≠ 0; $0.00000881 = \frac{0.0865\ \mu g/g\ DW \times 0.05}{491.0\ \mu g/g\ DW}$

E. **Effect on Humans**

1. **Index of Human Toxicity Resulting from Plant Consumption (Index 9)**

a. **Formula**

$$\text{Index 9} = \frac{(I_5 \times DT) + DI}{ADI}$$

where:

I_5 = Index 5 = Concentration of pollutant in plant grown in sludge-amended soil (µg/g DW)
DT = Daily human dietary intake of affected plant tissue (g/day DW)
DI = Average daily human dietary intake of pollutant (µg/day)
ADI = Acceptable daily intake of pollutant (µg/day)

b. **Sample calculation (toddler)**

$$0.000158 = \frac{(0.000076\ \mu g/g\ DW \times 74.5\ g/day) + 0.326\ \mu g/day}{2100\ \mu g/day}$$

2. **Index of Human Toxicity Resulting from Consumption of Animal Products Derived from Animals Feeding on Plants (Index 10)**

a. **Formula**

$$\text{Index 10} = \frac{(I_5 \times UA \times DA) + DI}{ADI}$$

where:

I_5 = Index 5 = Concentration of pollutant in plant grown in sludge-amended soil (µg/g DW)
UA = Uptake factor of pollutant in animal tissue (µg/g tissue DW [µg/g feed DW]$^{-1}$)
DA = Daily human dietary intake of affected animal tissue (g/day DW) (milk products and meat, poultry, eggs, fish)
DI = Average daily human dietary intake of pollutant (µg/day)
ADI = Acceptable daily intake of pollutant (µg/day)

b. **Sample calculation (toddler)** - Values were not calculated due to lack of data.

3. **Index of Human Toxicity Resulting from Consumption of Animal Products Derived from Animals Ingesting Soil (Index 11)**

a. **Formula**

$$\text{If } AR = 0;\ \text{Index 11} = \frac{(BS \times GS \times UA \times DA) + DI}{ADI}$$

$$\text{If } AR \neq 0;\ \text{Index 11} = \frac{(SC \times GS \times UA \times DA) + DI}{ADI}$$

where:

AR = Sludge application rate (mt DW/ha)
BS = Background concentration of pollutant in soil (µg/g DW)
SC = Sludge concentration of pollutant (µg/g DW)
GS = Fraction of animal diet assumed to be soil
UA = Uptake factor of pollutant in animal tissue (µg/g tissue DW [µg/g feed DW]$^{-1}$)

DA = Daily human dietary intake of affected animal tissue (g/day DW) (milk products and meat only)
DI = Average daily human dietary intake of pollutant (μg/day)
ADI = Acceptable daily intake of pollutant (μg/day)

b. **Sample calculation (toddler)** - Values were not calculated due to lack of data.

4. **Index of Human Toxicity Resulting from Soil Ingestion (Index 12)**

a. **Formula**

$$\text{Index 12} = \frac{(I_1 \times DS) + DI}{ADI}$$

where:

I_1 = Index 1 = Concentration of pollutant in sludge-amended soil (μg/g DW)
DS = Assumed amount of soil in human diet (g/day)
DI = Average daily human dietary intake of pollutant (μg/day)
ADI = Acceptable daily intake of pollutant (μg/day)

b. **Sample calculation (toddler)**

$$0.000156 = \frac{(0.000215\ \mu g/g\ DW \times 5\ g/day) + 0.326\ \mu g/day}{2100\ \mu g/day}$$

5. **Index of Aggregate Human Toxicity (Index 13)**

a. **Formula**

$$\text{Index 13} = I_9 + I_{10} + I_{11} + I_{12} - \left(\frac{3DI}{ADI}\right)$$

where:

I_9 = Index 9 = Index of human toxicity resulting from plant consumption (unitless)
I_{10} = Index 10 = Index of human toxicity resulting from consumption of animal products derived from animals feeding on plants (unitless)
I_{11} = Index 11 = Index of human toxicity resulting from consumption of animal products derived from animals ingesting soil (unitless)

I_{12} = Index 12 = Index of human toxicity resulting from soil ingestion (unitless)
DI = Average daily human dietary intake of pollutant (µg/day)
ADI = Acceptable daily intake of pollutant (µg/day)

b. **Sample calculation (toddler)** - Values were not calculated due to lack of data.

II. LANDFILLING

Based on the recommendations of the experts at the OWRS meetings (April-May, 1984), an assessment of this reuse/disposal option is not being conducted at this time. The U.S. EPA reserves the right to conduct such an assessment for this option in the future.

III. INCINERATION

Based on the recommendations of the experts at the OWRS meetings (April-May, 1984), an assessment of this reuse/disposal option is not being conducted at this time. The U.S. EPA reserves the right to conduct such an assessment for this option in the future.

IV. OCEAN DISPOSAL

A. Index of Seawater Concentration Resulting from Initial Mixing of Sludge (Index 1)

1. **Formula**

$$\text{Index 1} = \frac{SC \times ST \times PS}{W \times D \times L}$$

where:

SC = Sludge concentration of pollutant (mg/kg DW)
ST = Sludge mass dumped by a single tanker (kg WW)
PS = Percent solids in sludge (kg DW/kg WW)
W = Width of initial plume dilution (m)
D = Depth to pycnocline or effective depth of mixing for shallow water site (m)
L = Length of tanker path (m)

2. **Sample Calculation**

$$0.00017\ \mu g/L \quad \frac{0.0865\ mg/kg\ DW \times 1600000\ kg\ WW \times 0.04\ kg\ DW/kg\ WW \times 10^3\ \mu g/mg}{200\ m \times 20\ m \times 8000\ m \times 10^3\ L/m^3}$$

B. **Index of Seawater Concentration Representing a 24-Hour Dumping Cycle (Index 2)**

1. **Formula**

$$\text{Index 2} = \frac{SS \times SC}{V \times D \times L}$$

where:

SS = Daily sludge disposal rate (kg DW/day)
SC = Sludge concentration of pollutant (mg/kg DW)
V = Average current velocity at site (m/day)
D = Depth to pycnocline or effective depth of mixing for shallow water site (m)
L = Length of tanker path (m)

2. **Sample Calculation**

$$0.000047\ \mu g/L = \frac{825000\ kg\ DW/day \times 0.0865\ mg/kg\ DW \times 10^3\ \mu g/mg}{9500\ m/day \times 20\ m \times 8000\ m \times 10^3\ L/m^3}$$

C. **Index of Toxicity to Aquatic Life (Index 3)**
(Select toxicity or hazard)

1. **Formula**

$$\text{Index 3} = \frac{I_1}{AWQC}$$

where:

I_1 = Index 1 = Index of seawater concentration resulting from initial mixing after sludge disposal (µg/L)
AWQC = Criterion or other value expressed as an average concentration to protect marine organisms from acute and chronic toxic effects (µg/L)

2. **Sample Calculation**

$$0.000005 = \frac{0.00017\ \mu g/L}{34\ \mu g/L}$$

D. **Index of Human Toxicity Resulting from Seafood Consumption (Index 4)**

1. **Formula**

$$\text{Index 4} = \frac{(I_2 \times BCF \times 10^{-3}\ kg/g \times FS \times QF) + DI}{ADI}$$

where:

I_2 = Index 2 = Index of seawater concentration representing a 24-hour dumping cycle (µg/L)
QF = Dietary consumption of seafood (g WW/day)
FS = Fraction of consumed seafood originating from the disposal site (unitless)
BCF = Bioconcentration factor of pollutant (L/kg)
DI = Average daily human dietary intake of pollutant (µg/day)
ADI = Acceptable daily intake of pollutant (µg/day)

2. Sample Calculation

$$0.00047 = \frac{(0.000047\ \mu g/L \times 11\ L/kg \times 10^{-3}\ kg/g \times 0.000021 \times 14.3\ g\ WW/day) + 0.987\ \mu g/day}{2100\ \mu g/day}$$