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

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. Endrin was initially identified as being of potential concern when sludge is ocean disposed.* This profile is a compilation of information that may be useful in determining whether endrin 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 → seawater → marine organisms → 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 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 ENDRIN 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

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. EPA reserves the right to conduct such an assessment for this option in the future.

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. 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. EPA reserves the right to conduct such an assessment for this option in the future.

IV. OCEAN DISPOSAL

Slight increase in the seawater concentration of endrin are evident in all the scenarios evaluated (see Index 1).

The seawater concentration of endrin increases in all the scenarios evaluated. The increases are slight in most cases, except when the disposal rate is 1650 mk/day at the worst site where the increase is moderate (see Index 2).

The hazard to aquatic life is significantly increased for all sludges disposed at the worst site. Slight increases also occur for the other scenarios evaluated (see Index 3).

No increase in risk to humans from the consumption of seafood was determined in this assessment (see Index 4).

SECTION 3

PRELIMINARY HAZARD INDICES FOR ENDRIN IN MUNICIPAL SEWAGE SLUDGE

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

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. EPA reserves the right to conduct such an assessment for this option in the future.

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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. 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.

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 4 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 1600 mt WW would be required to discharge a load in no less than 32 minutes traveling at a minimum speed of 8 nautical miles (14,816 m) per hour. Under these conditions, the barge would enter the site, 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	0.14 mg/kg DW
Worst	0.17 mg/kg DW

Typical and worst values are the mean and maximum values, respectively, from a study of sludge concentrations from 74 cities in Missouri (Clevenger et al., 1983). Endrin was not detected in a U.S. EPA study of 50 POTWs (U.S. EPA, 1982a).

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	0.00028	0.00028
	Worst	0.0	0.00034	0.00034
Worst	Typical	0.0	0.0024	0.0024
	Worst	0.0	0.0029	0.0029

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

6. **Preliminary Conclusion** - Slight increases in the seawater concentration of endrin are evident in all the scenarios evaluated.

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. 3-2 to 3-4.

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

See Section 3, p. 3-5.

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	0.000076	0.00015
	Worst	0.0	0.000092	0.00018
Worst	Typical	0.0	0.00067	0.0013
	Worst	0.0	0.00081	0.0016

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

7. **Preliminary Conclusion** - The seawater concentration of endrin increases in all the scenarios evaluated. The increases are slight in most cases, except when the disposal rate is 1650 mt/day at the worst site where the increase is moderate.

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

1. **Explanation** - Compares the effective increased concentration of pollutant in seawater around the disposal site (Index 2) expressed as a 24-hour TWA concentration with the marine ambient water quality criterion of the pollutant, or with another value judged protective of marine aquatic life. For endrin, this value is the criterion that will protect the marketability of edible marine aquatic organisms.

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 2)**

See Section 3, p. 3-6.

b. **Ambient water quality criterion (AWQC)** = 0.0023 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 endrin.

The 0.0023 μg/L value chosen as the criterion to protect saltwater organisms is expressed as a 24 hour average concentration (U.S. EPA, 1980). This concentration, the saltwater final residue value, was derived by using the FDA action level for marketability for human consumption of endrin in edible fish and shellfish products (fish oil) (0.3 mg/kg), the geometric mean of normalized bioconcentration factor (BCF) values (1,324) for aquatic species tested and the 100 percent lipid content of marine fish oil. To protect against acute toxic effects, endrin concentration should not exceed 0.037 μg/L at any time.

4. **Index 3 Values**

Disposal Conditions and Site Characteristics	Sludge Concentration	Sludge Disposal Rate (mt DW/day)		
		0	825	1650
Typical	Typical	0.0	0.033	0.066
	Worst	0.0	0.040	0.080
Worst	Typical	0.0	0.29	0.58
	Worst	0.0	0.35	0.71

5. **Value Interpretation** - Value equals the factor by which the expected seawater concentration increase in endrin exceeds the marine water quality criterion. A value > 1 indicates that a tissue residue hazard may exist for aquatic life. Even for values approaching 1, an endrin

residue in tissue hazard may exist thus jeopardizing the marketability of edible saltwater organism products (fish oil). The criterion value of 0.0023 µg/L is probably too high because on the average, the endrin residue in 50 percent of aquatic species similar to those used to derive the AWQC will exceed the FDA action level for endrin (U.S. EPA, 1980).

6. **Preliminary Conclusion** - The hazard to aquatic life is significantly increased for all sludges disposed at the worst site. Slight increases also occur for the other 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 (Index 2) 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. 3-6.

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:

$$FS_t = \frac{AI \times 0.02\%}{7200 \text{ km}^2} = \qquad (2)$$

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

For the worst (near shore) site:

$$FS_t = \frac{AI \times 24\%}{4300 \text{ km}^2} = \qquad (3)$$

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

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:

$$FS_w = \frac{AI}{7200 \text{ km}^2} = 0.11 \qquad (4)$$

For the worst (near shore) site:

$$FS_w = \frac{AI}{4300\ km^2} = 0.040 \qquad (5)$$

d. **Bioconcentration factor of pollutant (BCF) = 5,500 L/kg**

The value chosen is the weighted average BCF of endrin for the edible portion of all freshwater and estuarine aquatic organisms consumed by U.S. citizens (U.S. EPA, 1980 as revised by Stephan, 1981). 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 toxic effects of endrin 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.

e. **Average daily human dietary intake of pollutant (DI) = 1.0 µg/day**

The reported daily intake values of endrin range from 0.033 to 1.0 µg/day (U.S. EPA, 1980; (Douggan and Corneliussen, 1972)). The value chosen represents a worst-case situation and amplifies the potential human toxicity effects of sludge disposal.

f. **Acceptable daily intake of pollutant (ADI) = 70 µg/day**

An ADI of 70 µg/day was derived by the U.S. EPA (1980) based on studies showing a no-observed-effect-level (NOEL) of 0.1 mg/kg/day in rats and dogs. Higher doses were associated with increased organ weights. An uncertainty factor of 100 was applied in calculation of the human ADI.

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	0.014	0.014	0.014
	Worst	Worst	0.014	0.014	0.014
Worst	Typical	Typical	0.014	0.014	0.014
	Worst	Worst	0.014	0.014	0.014

[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 the expected intake exceeds the ADI. A value >1 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 risk to humans from the consumption of seafood was determined in this assessment.

SECTION 4

PRELIMINARY DATA PROFILE FOR ENDRIN IN MUNICIPAL SEWAGE SLUDGE

I. OCCURRENCE

Endrin enters the environment primarily as a result of direct applications to soil and crops. The largest single use of endrin domestically is for the control of lepidopteron larvae attacking cotton crops in the southeastern and Mississippi delta states. In 1978, endrin production was approximately 400,000 lbs. Its use is declining due to increased restrictions.

A. Sludge

1. Frequency of Detection

Endrin was not mentioned in influent, effluent, or sludge in a U.S. EPA study of the fate of priority pollutants in POTWs. — U.S. EPA, 1982a (p. 41-2)

Endrin was not detected in a study of Metro Denver sewage sludge from 1969-1975. — Baxter et al., 1983 (p. 315)

Endrin was detected at levels <1 μg/L in wastewater treatment plant effluents in Ohio and Michigan — Majeti and Clark, 1980 (p. 6)

2. Concentration

In sludge samples from 74 cities in Missouri, endrin was detected as follows (μg/g DW; 1979-80 data): — Clevenger et al., 1983 (p. 1471)

Min.	Max.	Mean	Median
0.11	0.17	0.14	0.14

B. Soil - Unpolluted

1. Frequency of Detection

Endrin detected in 1 of 99 soil samples from rice-growing areas in 5 states, (1972 data) — Carey et al., 1980 (p. 25)

Endrin detected in 1 of 380 urban soil samples from 5 cities, (Macon, GA; 1971 data) — Carey et al., 1979a (p. 19)

Endrin detected in 10 of 1,483 samples from U.S. cropland soils (37 states) in 1971 (0.7%)	Carey et al., 1979b (p. 212)
Endrin detected in 14 of 1,486 samples from U.S. cropland soils (37 states) in 1971 (0.9%)	Carey et al., 1978 (p. 120)
% positive samples from 6 Air Force Installations, 1975-6:	Lang et al., 1979 (p. 231)

Land Use	Year	% of Samples with Endrin
Residential	1975	5.0
	1976	0
Non-use	1975	0
	1976	0
Golf Course	1975	0
	1976	5.9

Endrin was not detected in 34 soil samples collected in and around Everglades National Park (1976)	Requejo et al., 1979 (p. 934)

2. **Concentration**

U.S. Soil Levels (data 1960s)	Edwards, 1973 (p. 416-17)

	Max (μg/g)	Mean (μg/g)
Orchard Soils	12.61	6.30
Cranberry Soil	1.17	0.10
Vegetable Soils	0.48	0.01
Onion Soils	2.05	0.06

Rice-growing areas, endrin at level of 0.17 μg/g DW (1972)	Carey et al., 1980 (p. 25)
Endrin was detected at a level of 0.17 μg/g DW in 1 urban soil	Carey et al., 1979a (p. 19)
Cropland soils in 1972 (μg/g DW)	Carey et al., 1979b (p. 212)

Min	Max	Arith. Mean	Geom. Mean
0.01	2.13	<0.01	<0.001

In 14 out of 1,486 samples from U.S. cropland soils in 1971 (μg/g DW): — Carey et al., 1978 (p. 120)

Min	Max	Arith. Mean	Geom. Mean
0.02	1.00	<0.01	<0.001

Residues from six Air Force Installations, 1975-6: — Lang et al., (p. 231)

Land Use	Range (μg/g)	Avg.	Year
Residential	ND-0.01	<0.01	1975
Residential	0	0	1976
Non-use	0	0	1975
Non-use	0	0	1976
Golf Course	0	0	1975
Golf Course	ND-0.04	<0.01	1976

C. Water - Unpolluted

1. Frequency of Detection

No endrin residues observed in 1974 upper Great Lakes water study — Glooshenko, 1976 (p. 63)

Endrin was not detected in 368 samples from southern Florida surface waters, 1968-72 — Mattraw, 1975 (p. 108)

Endrin was detected in 156 out of 458 finished water samples (34%) between 1964 and 1967 from the Mississippi and Missouri Rivers. However, the number of samples containing concentrations of endrin in excess of 0.1 μg/L decreased from 23 (10%) to 0 between 1964 and 1967. — U.S. EPA, 1980 (p. C-4)

2. Concentration

a. Freshwater

0.0002 mg/L interim drinking water standard — U.S. EPA, 1984 (p. I-5)

0.001 mg/L present ambient water standard — U.S. EPA, 1984 (p. I-5)

In 1968, it was reported that endrin levels entering Tule Lake National Wildlife Refuge were highest (50-70 μg/L) in summer and declined to non-detectable levels in winter. — Grant, 1976 (p. 288)

Occasionally, ground water may contain >0.1 μg/L of endrin, but levels as high as 3 μg/L have been correlated with precipitation and runoff following endrin applications. — U.S. EPA, 1980 (p. C-4)

Edwards, 1973 (p. 440-441)

	Endrin (μg/L)	
	Max	Mean
97 major river basins (1965)	0.094	0.005
Miss. River Delta (1966)	4.23	0.541
99 major river basins (1967)	0.116	0.002
11 major western rivers (1967)	0.040	0.001
109 major rivers (1967)	0.069	0.004
20 streams (western) (1969)	0.070	0.0003
110 surface waters (1967)	0.133	0.002

b. **Seawater**

Data not immediately available.

c. **Drinking water**

In an area of high endrin usage in Louisiana, drinking water was found to contain a maximum of 0.023 μg/L — U.S. EPA, 1980 (p. C-4)

Endrin was detected in a water plant in New Orleans. The highest level measured was 0.004 μg/L. — U.S. EPA, 1980 (p. C-5)

Endrin was detected in 156 out of 458 finished water samples between 1964 and 1967 from the Mississippi and Missouri Rivers. The number of samples containing endrin in excess of 0.1 μg/L. decreased from 23 (10%) to 0 between 1964 and 1967. — U.S. EPA, 1980 (p. C-4)

D. Air

1. **Frequency of detection**

Endrin occurred in 25 out of 875 samples from 9 U.S. cities. All 25 samples were from Stoneville, Miss. (data 1960s)	Stanley et al., 1971 (p. 435)

2. **Concentration**

Boston, MA: ave = 0.20 ng/m^3 data 1978	Bidleman, 1981 (p. 623)
25 out of 98 air samples from Stoneville, Miss. in 1969 contained endrin. The maximum level was 58.5 ng/m^3	Stanley et al., 1971 (p. 435)

E. **Food**

1. **Total average intake**

Daily Dietary Intake, mg — NAS, 1977 (p. 558)

1965	1966	1967	1968	1969	1970	6 yr. ave.
Trace	Trace	Trace	0.001	Trace	Trace	0.001

1973 average daily intake = 0.033 µg/d or 0.0005 µg/kg/day for a 69.1 kg man	U.S. EPA, 1980 (p. C-2)

2. **Food concentrations**

Observed in 1 garden fruit sample at 0.002 µg/g (Attachment E)	FDA, no date
Levels of endrin found by food class - summary of 5 regions in U.S., June 1971 - July 1972 (p. 96-102)	Manske and Johnson, 1975

Food	Fraction of Positive Composites	Ave. (µg/g)	Range (µg/g)
Potatoes	3/35	Trace	Trace
Garden Fruits	1/35	Trace	0.006

Levels of endrin found by food class - Summary of 5 regions in U.S., Aug. 1972 - July 1973				Johnson and Manske, 1976 (p. 162-166)

Food	Fraction of Positive Composites	Ave. (µg/g)	Range (µg/g)
Potatoes	1/35	Trace	0.005

II. HUMAN EFFECTS

A. Ingestion

1. Carcinogenity

"No malignancies attributed to endrin have been reported." — U.S. EPA, 1980 (p. C-33)

2. Chronic Toxicity

a. ADI

70 µg/day — U.S. EPA, 1980 (p. C-39)

b. Effects

Data not immediately available.

B. Inhalation

Data not immediately available.

III. PLANT EFFECTS

A. Phytotoxicity

Data not immediately available

B. Uptake

See Table 4-1.

IV. DOMESTIC ANIMAL AND WILDLIFE EFFECTS

A. Toxicity

A 50 percent reduction in a brown pelican population in Louisiana in 1975 has been attributed in a large part to endrin because endrin residues were detected in the brains of several pelicans and because the reduction coincided with the peak in endrin — U.S. EPA, 1984 (V-42) residues in pelican eggs. It is believed that endrin contributed to reduced eggshell thickness.

See Table 4-2.

B. Uptake

Endrin residues in carcasses of 168 Bald Eagles from 29 states, 1975-77 — Kaiser et al., 1980 (p. 147)

Year	# Specimens with residues	Median μg/g (WW)	Range μg/g (W/W)
1975	5	0.16	0.09-1.0
1976	6	0.48	0.18-3.0
1977	5	0.07	0.06-2.5

Endrin residues in brains of 168 Bald Eagles from 29 states, 1975-77 — Kaiser et al., 1980 (p. 147)

Year	# Specimens with residues	Median μg/g (WW)	Range μg/g (W/W)
1975	3	0.44	0.12-0.50
1976	6	0.32	0.15-0.71
1977	5	0.14	0.05-1.2

See Table 4-3.

Endrin administered in the diet of 12 rats was quickly metabolized and eliminated — U.S. EPA, 1984 (p. III-20)

V. AQUATIC LIFE EFFECTS

A. Toxicity

1. Freshwater

0.0023 μg/L as a 24 hour average concentration; not to exceed 0.18 μg/L at any time. — U.S. EPA, 1980

2. Saltwater

0.0023 μg/L as a 24 hour average concentration; not to exceed 0.037 μg/L at any time. — U.S. EPA, 1980 (p. B-12)

B. Uptake

1. Bioconcentration factor (BCF) — Stephan, 1981

BCF = 5500 L/kg for edible portion of all freshwater and estuarine aquatic organisms consumed by U.S. citizens.

2. Water concentrations causing unacceptable tissue concentrations

Data not immediately available.

VI. SOIL BIOTA EFFECTS

In a study of the influence of 5 annual applications of 8 organic insecticides to 2 field soils on soil biological and physical properties, endrin exerted no measurable effect on numbers of soil bacteria and fungi, on kinds of soil fungi developing on dilution plates, on the ability of the soil population to perform the normal functions of organic matter decomposition and ammonia oxidation, on water infiltration, or on soil aggregation. — Martin et al. 1958 (p. 337-8)

VII. PHYSICOCHEMICAL DATA FOR ESTIMATING FATE AND TRANSPORT

U.S. EPA, 1984 (II-1, V-7)

Specific gravity: 1.7 at 20°C
Vapor pressure: 2.7×10^{-7} at 25°C
Formula: $C_{12}H_8Cl_6O$
Molecular wt.: 380.93
Solubility: 0.024 mg/l in water
Organic soil adsorption constant: 3.4×10^4
Soluble in nonpolar solvents
Octanol/water partition coefficient: 2.18×10^5

TABLE 4-1. UPTAKE OF ENDRIN BY PLANTS

Plant/Tissue	Soil Type	Chemical Form Applied	Soil Concentration (µg/g)	Range of Tissue Concentration (µg/g)	Bioconcentration Factor[b]	References
Alfalfa	sandy loam	endrin	0.11-0.14	0	0	Harris and Sans, 1969 (p. 184)
Corn	sandy loam	endrin	0.11-0.14	0.01	0.077	Harris and Sans, 1969 (p. 184)
Potatoes	sandy loam	endrin	0.11-0.14	T		Harris and Sans, 1969 (p. 184)
Carrots	sandy loam	endrin	0.11-0.14	0.01	0.077	Harris and Sans, 1969 (p. 184)
Oats	muck	endrin	5.80-5.94	0.01	.0017	Harris and Sans, 1969 (p. 184)
Corn	muck	endrin	5.80-5.94	0	0	Harris and Sans, 1969 (p. 184)
Sugar beets/tops	muck	endrin	5.80-5.94	0	0	Harris and Sans, 1969 (p. 184)
Potatoes	muck	endrin	5.80-5.94	0.01	0.017	Harris and Sans, 1969 (p. 184)
Carrots	muck	endrin	5.80-5.94	0.02	0.034	Harris and Sans, 1969 (p. 184)
Sugar beets/tops	muck	endrin	5.80-5.94	0.01	0.017	Harris and Sans, 1969 (p. 184)

[a] BF = tissue conc./soil conc.
[b] NR = not reported

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

Species (Na)[a]	Chemical Form Fed	Feed Concentration (µg/g)	Water Concentration (mg/L)	Daily Intake (mg/kg)	Duration of Study	Effects	References
Rats (male)	endrin	-	-	17.8	NR[b]	LD_{50}	NAS, 1977
Rats (female)	endrin	-	-	7.5	NR	LD_{50}	(p. 564-567)
Rats	endrin	1	-	-	Life	No obvious effects	
Rats	endrin	5	-	-	Life	Liver enlargement	
Rats	endrin	25	-	-	Life	Increased mortality, degeneration in brain, liver, kidneys & adrenals	
Mice	endrin	0.1-4.0	-	-	Life	Increased liver weights at 2 & 4 µg/g and vascular damage of liver cells	
Dogs (female - 7) (male - 7)	endrin	2 and 4	-	-	2 years	Convulsions and pathologic changes in the brain	
Dogs	endrin	0.5	-	-	2 years	Highest no-adverse-effect level	
Rats & Mice (pregnant)	endrin	≥ 2	-	-	NR	Increased maternal mortality, increased resportions, decrease in survival of offspring at 21 days after birth	U.S. EPA, 1984 (V-60)
Rats (pregnant)	endrin	-	-	0.075	NR	Highest no-adverse-effect level in relation to maternal weight gain and alterations in behavior	U.S. EPA, 1984 (V-61)
Rats	endrin	-	-	≥0.150	NR	Reduced maternal weight	Kavlock, et al., 1981
Mice	endrin			0.5		Maternal liver enlargement	(p. 141)
				1.0		Reduced maternal weight gain	
				1.5		Increased maternal mortality	

[a] N = number of experimental animals when reported
[b] NR = not reported

TABLE 4-3. UPTAKE OF ENDRIN BY DOMESTIC ANIMALS AND WILDLIFE

Species	Chemical Form Fed	Range of Feed Concentration (µg/g)	Tissue Analyzed	Range Tissue Concentration (µg/g)	Bioconcentration Factor[a]	References
Hen	Endrin	0.13	Meat	<0.0032-0.095	<00.02-0.73	U.S. EPA, 1984 (p. III-10)
Hen	Endrin	0.13	Liver	0.013-0.20	0.10-1.54	U.S. EPA, 1984 (p. III-10)
Hen	Endrin	0.13	Kidney	0.035-0.13	0.27-1.0	U.S. EPA, 1984 (p. III-10)
Hen	Endrin	0.13	Fat	0.32-1.21	2.46-9.31	U.S. EPA, 1984 (p. III-10)
Mallard	Endrin	10.0	Carcass	1.41-1.9	0.14-1.9	U.S. EPA, 1984 (p. III-10)

[a] B = tissue concentration/feed concentration

SECTION 5

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APPENDIX

PRELIMINARY HAZARD INDEX CALCULATIONS FOR ENDRIN IN MUNICIPAL SEWAGE SLUDGE

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

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. EPA reserves the right to conduct such an assessment for this option in the future.

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. 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. 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

$$0.00028\ \mu g/L = \frac{0.14\ mg/kgDW \times 1600000\ kgWW \times 0.04\ kgDW/kg\ WW \times 10^3\ \mu g/mg}{200\ m \times 20\ m \times 8000\ m \times 10^3\ L/m^3}$$

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**

$$0.000076\ \mu g/L = \frac{825000\ \text{kg DW/day} \times 0.14\ \text{mg/kg DW} \times 10^3\ \mu g/mg}{9500\ \text{m/day} \times 20\ \text{m} \times 8000\ \text{m} \times 10^3\ L/m^3}$$

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

1. **Formula**

$$\text{Index 3} = \frac{I_2}{AWQC}$$

where:

I_2 = Index 2 = Index of seawater concentration representing a 24-hour dumping cycle (μg/L)
AWQC = Criterion expressed as an average concentration to protect the marketability of edible marine organisms (μg/L)

2. **Sample Calculation**

$$0.033 = \frac{0.000076\ \mu g/L}{0.0023\ \mu g/L}$$

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

1. **Formula**

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

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**

$$0.014 = \frac{(0.000076\ \mu g/L \times 5500\ L/kg \times 10^{-3}\ kg/g \times 0.000021 \times 14.3\ g\ WW/day) + 1.0\ \mu g/day}{70\ \mu g/day}$$