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EPA

Environmental Profiles and Hazard Indices for Constituents of Municipal Sludge: Aldrin/Dieldrin

ALDRIN/DIELDRIN

p. 3-3: Index 1 Values should read:
typical at 500 mt/ha = 0.0031; worst at 500 mt/ha = 0.0098

p. 3-4: Index 2 Values should read:
typical at 500 mt/ha = 0.0001; worst at 500 mt/ha = 0.00033

p. 3-5: Index 3 Values should read:
typical at 500 mt/ha = 0.23; worst at 500 mt/ha = 0.73

p. 3-6: Index 4 Values should read:
typical at 500 mt/ha = 0.00025; worst at 500 mt/ha = 0.00079

p. 3-7: Index 5 Values (Human) should read:
typical at 500 mt/ha = 0.0023; worst at 500 mt/ha = 0.0074

p. 3-9: Index 7 Values should read:
typical at 500 mt/ha = 0.000062; worst at 500 mt/ha = 0.0002

p. 3-13 should read:

Index 9 Values

Group	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Toddler	Typical	130	140	260	190
	Worst	130	180	610	350
Adult	Typical	900	940	1300	1100
	Worst	900	1000	2200	1500

p. 3-15 should read:

Index 10 Values

Group	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Toddler	Typical	130	130	140	140
	Worst	130	130	180	150
Adult	Typical	900	900	920	920
	Worst	900	910	1000	950

p. 3-18 Index 12 Values should read:

Toddler-worst concentration at 500 mt/ha = 150

p. 3-19 should read:

Index 13 Values

Group	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Toddler	Typical	130	1400	1500	1400
	Worst	130	4700	5200	4900
Adult	Typical	910	3500	3900	3600
	Worst	910	10000	12000	11000

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

INTRODL TION

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

The focus of this document s 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, incineration 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 ALDRIN/DIELDRIN 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 Aldrin/Dieldrin

Soil levels of aldrin/dieldrin are expected to increase as sludge is applied to soil. For the short-term, the increase is related to both the insecticide's concentration in sludge and the application rate. Long-term applications (i.e., 5 mt/ha for 100 years or 500 mt/ha) are also expected to increase soil concentrations of aldrin/dieldrin, but the maximum expected concentration should not exceed the short-term level of high rates of application (i.e., 50 mt/ha). This is a function of the pesticide's half-life (see Index 1).

B. Effect on Soil Biota and Predators of Soil Biota

Increases in the soil concentration of aldrin/dieldrin resulting from sludge applications are not expected to yield a toxic hazard to soil biota (see Index 2). A toxic hazard may exist for predators of soil biota which consume biota living in soil that has been amended with municipal sewage sludge (see Index 3).

C. Effect on Plants and Plant Tissue Concentration

Land application of municipal sewage sludge may slightly increase soil concentrations of aldrin/dieldrin, but not to levels which pose a phytotoxic hazard to plants (see Index 4).

The landspreading of municipal sewage sludge is expected to result in a slight increase of aldrin/dieldrin concentrations in the tissues of plants grown in amended soils (see Index 5). Whether these increased plant tissue concentrations would be precluded by phytotoxicity could not be determined due to lack of data (see Index 6).

D. Effect on Herbivorous Animals

A toxic hazard from aldrin/dieldrin is not expected to exist for herbivorous animals feeding on plants grown in sludge-amended soils (see Index 7). Herbivorous animals that incidentally ingest sludge or sludge-amended soils are also not expected to experience a toxic hazard from aldrin/dieldrin (see Index 8).

E. **Effect on Humans**

The consumption of plants grown in sludge-amended soil is expected to result in a substantial increase in cancer risk for toddlers and adults due to the intake of aldrin/dieldrin (see Index 9). The human consumption of animal products from animals consuming plants grown in sludge-amended soils should result in a moderate increase in cancer risk from ingesting aldrin/dieldrin, especially at the higher application rates of 50 and 500 mt/ha (see Index 10). A substantial increase in the cancer risk associated with aldrin/dieldrin is expected to occur for humans consuming animal products from animals that have eaten sludge or sludge-amended soils (see Index 11). A slight increase in cancer risk is expected for toddlers consuming sludge-amended soils that have received application rates of 50 mt/ha to 500 mt/ha (see Index 12). Landspreading of municipal sewage sludge contaminated with aldrin/dieldrin may pose a substantial increase in aggregate cancer risk for humans via their diet (see Index 13).

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

The incineration of municipal sewage sludge is expected to result in substantial increases of aldrin/dieldrin concentrations in the air, especially at high (10,000 kg/hr DW) feed rates (see Index 1). Sludge incineration is also expected to result in a substantial increase in the cancer risk associated with inhaling aldrin/dieldrin, especially at high (10,000 kg/hr DW) feed rates (see Index 2).

IV. OCEAN DISPOSAL

The incremental seawater concentration of aldrin/dieldrin increases after initial mixing with sludge; however, the increase is slight (see Index 1). The effective increase of aldrin/dieldrin over a 24-hour period is also expected to be slight (see Index 2). A potential hazard to aquatic life exists where "worst" concentration sludges are disposed of at a "worst" condition site (see Index 3). The ocean disposal of "typical" concentration sludges at both the "typical" and "worst" sites should not result in an incremental risk to human cancer from seafood consumption. Slight incremental risk does occur from the disposal of "worst" concentration sludges at the "typical" and "worst" sites (see Index 4).

SECTION 3

PRELIMINARY HAZARD INDICES FOR ALDRIN/DIELDRIN IN MUNICIPAL SEWAGE SLUDGE

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

A. Effect on Soil Concentration of Aldrin/Dieldrin

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	0.22 μg/g DW
Worst	0.81 μg/g DW

The typical and worst-case sludge concentrations were statistically derived by Camp

Dresser and McKee, Inc. (CDM) (1984a) from sludge concentration data for publicly-owned treatment works (POTWs) in the States of Michigan and Indiana, the cities of New York, Galveston, Albuquerque, and Phoenix, and data from an EPA study of 50 POTWs (U.S. EPA, 1982). Weighted mean concentrations for aldrin and dieldrin were 0.15 and 0.07 μg/g DW, and maximum concentrations were 0.64 and 0.81, respectively. For this analysis, mean concentrations of aldrin and dieldrin were summed to yield a mean value of 0.22 μg/g DW for "total dieldrin," since aldrin is readily converted to dieldrin and dieldrin is the more potent carcinogen of the two. The two maximum values were not summed since it was not assumed that they were from the same analysis. Instead, the maximum dieldrin value of 0.81 μg/g DW was chosen to represent the worst case. (See Section 4, p. 4-2.)

ii. **Background concentration of pollutant in soil (BS) = 0.00063 μg/g DW**

Several studies have shown that the geometric mean concentration of aldrin plus dieldrin in U.S. agricultural soils in the early 1970s was approximately 0.010 to 0.011 μg/g DW (Carey et al., 1978, 1979b). Since aldrin and dieldrin were banned in 1974 (except for subsurface injection for termite control) and since the soil half-life of dieldrin is 2.8 years (see below), the present background level is expected to be much lower. Assuming approximately 4 half-lives have elapsed, a background value of 0.00063 μg/g DW is estimated. (See Section 4, p. 4-4.)

iii. **Soil half-life of pollutant ($t_{\frac{1}{2}}$) = 2.8 years**

The soil half-life of dieldrin is reported to range between 2.5 and 2.8 years, whereas the half-life for aldrin is only 3.1 months (Onsager et al., 1970; Ackerman, 1980). The higher value is chosen because it provides the more conservative estimate of long-term exposure to this insecticide, and because aldrin is converted to dieldrin. (See Section 4, p. 4-18.)

d. **Index 1 Values (μg/g DW)**

Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Typical	0.00063	0.0012	0.0060	0.0054
Worst	0.00063	0.0026	0.020	0.012

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

f. **Preliminary Conclusion** - Soil levels of aldrin/dieldrin are expected to increase as sludge is applied to soil. For the short-term, the increase is related to both the insecticide's concentration in sludge and the application rate. Long-term applications (i.e., 5 mt/ha for 100 years or 500 mt/ha) are also expected to increase soil concentrations of aldrin/dieldrin, but the maximum expected concentration should not exceed the short-term level for high rates of application (i.e., 50 mt/ha). This is a function of the pesticide's half-life.

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. 3-3.

ii. **Soil concentration toxic to soil biota (TB) = 30.0 μg/g DW**

The earthworm is selected as the representative of soil biota. Cathey (1982) has shown that earthworm mortality increases with the level of aldrin in worm bedding. With aldrin in "soil" at 30 μg/g, earthworms experience 37.5 percent mortality. (See Section 4, p. 4-24.)

d. **Index 2 Values**

Sludge Concentration	Sludge Application Rate (mt/ha)			
	0	5	50	500
Typical	0.000021	0.000039	0.00020	0.00018
Worst	0.000021	0.000088	0.00068	0.00040

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** - Increases in the soil concentration of aldrin/dieldrin resulting from sludge applications are not expected to yield 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. 3-3.

ii. **Uptake factor of pollutant in soil biota (UB) =** 74.4 μg/g tissue DW (μg/g soil DW)$^{-1}$

Data on uptake of aldrin and dieldrin are available for a variety of soil invertebrates including earthworms, slugs, crickets, and ground beetles. Most values are reported on a wet weight basis (both soil and tissue). Values for aldrin range from 0.17 for crickets to 5.8 μg/g tissue WW (μg/g soil WW)$^{-1}$ for ground beetles (Korschgen, 1970). Values for dieldrin range from 0.88 for crickets to 37.33 for ground beetles on a wet weight basis (Korschgen, 1970). The highest factor observed, however, is a value of 74.4 μg/g tissue DW (μg/g soil DW)$^{-1}$ for slugs, on a dry weight basis (Gish, 1970). This value is a mean of 3 values (43, 62, and 118 μg/g tissue DW [μg/g soil DW]$^{-1}$) obtained from 3 different sites, and therefore appears to be valid, although unusually high. This value is conservatively chosen as the uptake factor for soil biota. (See Section 4, p. 4-25.)

iii. **Feed concentration toxic to predator (TR) = 1.0 μg/g DW**

Immediately available studies of the toxicity of aldrin/dieldrin for soil biota predators is limited. In a summary of such research, it is reported that a feed concentration of 1 μg/g of dieldrin will affect the reproduction of Hungarian partridges, a typical predator of soil biota (U.S. EPA, 1976). This is the lowest feed concentration at which deleterious effects are found. (See Section 4, p. 4-21.)

d. **Index 3 Values**

Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Typical	0.047	0.088	0.44	0.40
Worst	0.047	0.20	1.5	0.90

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** - An aldrin/dieldrin toxic hazard may exist for soil biota predators which consume soil biota living in soil that has been amended with municipal sewage sludge.

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. 3-3.

ii. **Soil concentration toxic to plants (TP) =** 12.5 μg/g DW

The value for the soil concentration of aldrin toxic to plants is from the experimental work of Eno and Everett (1958). It represents the lowest concentration in soil at which significant deleterious effects begin to occur in plants. (See Section 4, pp. 4-18 to 4-19.)

d. **Index 4 Values**

Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Typical	0.000050	0.000094	0.00048	0.00043
Worst	0.000050	0.00021	0.0062	0.00097

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

f. **Preliminary Conclusion** - Land application of municipal sewage sludge may slightly increase soil concentrations of aldrin/dieldrin, but not to levels which pose a phytotoxic hazard to plants.

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. 3-3.

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

Animal Diet:
Corn (plant)
0.020 µg/g tissue DW (µg/g soil DW)$^{-1}$

Human Diet:
Peanut (meats)
0.75 µg/g tissue DW (µg/g soil DW)$^{-1}$

Corn is used as a representative of crops typically utilized for herbivorous animal feed. The uptake factor for corn is among the highest associated with such crops (cf. alfalfa, oats); the uptake factor applies to dieldrin which is more persistent in soil and more readily taken up by plants than aldrin (Harris and Sans, 1969). For human crops, the available data are limited to root crops, e.g., sugar beets, carrots, and peanuts. The selected uptake factor is the highest available for the edible portion (i.e., roots versus tops) of such plants (Nash, 1974). Both values have been adjusted for moisture content and thus represent dry weights as opposed to the reported wet weights. (See Section 4, p. 4-20.)

d. **Index 5 Values (µg/g DW)**

Diet	Sludge Concentration	Sludge Application Rate (mt/ha)			
		0	5	50	500
Animal	Typical	0.000012	0.000023	0.00012	0.00011
	Worst	0.000012	0.000052	0.00041	0.00024
Human	Typical	0.00047	0.00088	0.0045	0.0040
	Worst	0.00047	0.0020	0.015	0.0090

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 phytotoxicity.

f. **Preliminary Conclusion** - The landspreading of municipal sewage sludge is expected to result in a slight increase of aldrin/dieldrin concentrations in the tissues of plants grown in amended soils.

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 phytotoxicity (PP)** - Data not immediately available.

d. **Index 6 Values (μg/g DW)** - 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. 3-7).

ii. **Feed concentration toxic to herbivorous animal (TA) = 1.0 μg/g DW**

Reproduction has been impaired by dietary levels of aldrin as low as 1 (Hungarian partridge), 2 (raccoon), and 3 μg/g DW (mallard) in partly or wholly herbivorous species (U.S. EPA, 1976; Menzie, 1972). Duration of exposure was not stated. In the only available long-term study of a grazing animal, growth of deer was slowed by 3 years exposure to dietary concentrations of 5 to 25 μg/g DW. Lacking more complete information, 1 μg/g DW will be used as the toxic concentration for all herbivorous animals. (See Section 4, p. 4-21.)

d. **Index 7 Values**

Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Typical	0.000012	0.000023	0.00012	0.00011
Worst	0.000012	0.000052	0.00041	0.00024

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** - A toxic hazard from aldrin/dieldrin is not expected to exist for herbivorous animals feeding on plants grown in sludge-amended soils.

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	0.22 μg/g DW
Worst	0.81 μg/g DW

See Section 3, p. 3-1.

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) = 1.0 μg/g DW**

See Section 3, p. 3-9.

d. **Index 8 Values**

Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Typical	0.0	0.011	0.011	0.011
Worst	0.0	0.040	0.040	0.040

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** - Herbivorous animals that incidentally ingest sludge or sludge-amended soils are not expected to experience a toxic hazard from aldrin/dieldrin.

E. **Effect on Humans**

1. **Index of Human Cancer Risk 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 cancer risk-specific intake (RSI) 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. 3-7).

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 (1984). 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	0.297 μg/day
Adult	2.079 μg/day

The values represent the estimated dietary intake of dieldrin by a 10 kg child and a 70 kg adult. These estimates are based on the estimated average dietary intake of dieldrin (μg/kg/day) for the 1975-78 period as determined by the FDA (no date). This is the most current data available, and hence, more reflective of current intake than earlier dietary levels. Dieldrin intake tends to be much higher than that for aldrin.

iv. **Cancer potency** = 30.4 $(mg/kg/day)^{-1}$

The cancer potency for dieldrin is almost 3 times that for aldrin (i.e., 30.4 versus 11.4) and thus is more conservative. The value is derived from the dose-response curve relating oral ingestion of dieldrin to hepatocellular carcinoma in mice (U.S. EPA, 1980). It assumes that the ingested dosage of dieldrin is absorbed completely. (See Section 4, p. 4-11.)

v. **Cancer risk-specific intake (RSI) =** 2.3×10^{-3} μg/day

The RSI is the pollutant intake value which results in an increase in cancer risk of 10^{-6} (1 per 1,000,000). The RSI is calculated from the cancer potency using the following formula:

$$RSI = \frac{10^{-6} \times 70 \text{ kg} \times 10^{3} \text{ μg/mg}}{\text{Cancer potency}}$$

d. **Index 9 Values**

Group	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Toddler	Typical	140	160	270	260
	Worst	140	190	620	420
Adult	Typical	950	980	1300	1300
	Worst	950	1100	2300	1700

e. **Value Interpretation** - Value > 1 indicates a potential increase in cancer risk of > 10^{-6} (1 per 1,000,000). 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 consumption of plants grown in sludge-amended soil is expected to result in a substantial increase in cancer risk for toddlers and adults due to the intake of aldrin/dieldrin.

2. **Index of Human Cancer Risk 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 RSI.

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. 3-7).

ii. **Uptake factor of pollutant in animal tissue (UA) = 6.5 μg/g tissue DW (μg/g feed DW)$^{-1}$**

Aldrin/dieldrin has an affinity for fat tissue. The value for the uptake factor reflects the potential bioconcentration in sheep body fat. It is based on a feed concentration of dieldrin of 25 μg/g and a tissue concentration of ∿162 μg/g DW (Fries, 1982). The tissue concentration has been statistically derived based on the average water content of fat in lamb shoulder, which is 22 percent; the water content of this tissue is the highest average for lamb. Higher values available for chicken fat were not used because the plant uptake value selected is for the whole corn plant. Corn grain and other grains that may be fed to chickens show little or no uptake. (See Section 4, p. 4-23.) The uptake factor of pollutant in animal tissue (UA) used is assumed to apply to all animal fats.

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 (1984) 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 0.297 μg/day
Adult 2.079 μg/day

See Section 3, p. 3-12.

v. **Cancer risk-specific intake (RSI) =** 2.3×10^{-3} μg/day

See Section 3, p. 3-13.

d. **Index 10 Values**

Group	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Toddler	Typical	130	130	140	140
	Worst	130	140	180	160
Adult	Typical	910	910	930	930
	Worst	910	920	1000	960

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

f. **Preliminary Conclusion** - The human consumption of animal products from animals consuming plants grown in sludge-amended soils should result in a moderate increase in cancer risk from ingesting aldrin/dieldrin. This is especially true at the higher application rates of 50 and 500 mt/ha.

3. **Index of Human Cancer Risk 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 RSI.

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** = Sheep (fat)

See Section 3, p. 3-14.

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

Typical	0.22 µg/g DW
Worst	0.81 µg/g DW

See Section 3, p. 3-1.

iii. **Background concentration of pollutant in soil (BS)** = 0.00063 µg/g DW

See Section 3, p. 3-2.

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

See Section 3, p. 3-10.

v. **Uptake factor of pollutant in animal tissue (UA)** = 6.5 µg/g tissue DW (µg/g feed DW)$^{-1}$

See Section 3, p. 3-14.

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 0.297 μg/day
Adult 2.079 μg/day

See Section 3, p. 3-12.

viii. **Cancer risk-specific intake (RSI)** = 2.3×10^{-3} μg/day

See Section 3, p. 3-13.

d. **Index 11 Values**

Group	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Toddler	Typical	130	1400	1400	1400
	Worst	130	4600	4600	4600
Adult	Typical	910	3500	3500	3500
	Worst	910	10000	10000	10000

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

f. **Preliminary Conclusion** - A substantial increase in the cancer risk associated with aldrin/dieldrin ingestion is expected to occur for humans consuming animal products from animals that have eaten sludge or sludge-amended soils.

4. **Index of Human Cancer Risk 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 RSI.

b. **Assumptions/Limitations** - Assumes that the pica child consumes an average of 5 g/day of sludge-amended soil. If the RSI specific for a child is not available, this index assumes the RSI 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 RSI 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. 3-3.

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, 1983). The value of 0.02 g/day for an adult is an estimate from U.S. EPA, 1984.

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

Toddler	0.297 μg/day
Adult	2.097 μg/day

See Section 3, p. 3-12.

iv. **Cancer risk-specific intake (RSI)** = 2.3×10^{-3} μg/day

See Section 3, p. 3-13.

d. **Index 12 Values**

Group	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Toddler	Typical	130	130	140	140
	Worst	130	130	170	160
Adult	Typical	900	900	900	900
	Worst	900	900	900	900

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

f. **Preliminary Conclusion** - A slight increase in the cancer risk associated with the ingestion of aldrin/dieldrin is expected for toddlers consuming sludge-amended soils. This is true for soils that have received sludge application rates of 50 to 500 mt/ha.

5. **Index of Aggregate Human Cancer Risk (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 RSI.

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**

Group	Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Toddler	Typical	150	1400	1500	1500
	Worst	150	4700	5200	5000
Adult	Typical	960	3600	3900	3800
	Worst	960	10000	12000	11000

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

f. **Preliminary Conclusion** - Landspreading of municipal sewage sludge contaminated with aldrin/dieldrin may pose a substantial increase in aggregate cancer risk for humans via their diet.

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

A. Index of Air Concentration Increment Resulting from Incinerator Emissions (Index 1)

1. **Explanation** - Shows the degree of elevation of the pollutant concentration in the air due to the incineration of sludge. An input sludge with thermal properties defined by the energy parameter (EP) was analyzed using the BURN model (CDM, 1984b). This model uses the thermodynamic and mass balance relationships appropriate for multiple hearth incinerators to relate the input sludge characteristics to the stack gas

parameters. Dilution and dispersion of these stack gas releases were described by the U.S. EPA's Industrial Source Complex Long-Term (ISCLT) dispersion model from which normalized annual ground level concentrations were predicted (U.S. EPA, 1979). The predicted pollutant concentration can then be compared to a ground level concentration used to assess risk.

2. **Assumptions/Limitations** - The fluidized bed incinerator was not chosen due to a paucity of available data. Gradual plume rise, stack tip downwash, and building wake effects are appropriate for describing plume behavior. Maximum hourly impact values can be translated into annual average values.

3. **Data Used and Rationale**

   a. **Coefficient to correct for mass and time units (C)** = 2.78×10^{-7} hr/sec x g/mg

   b. **Sludge feed rate (DS)**

      i. **Typical** = 2660 kg/hr (dry solids input)

      A feed rate of 2660 kg/hr DW represents an average dewatered sludge feed rate into the furnace. This feed rate would serve a community of approximately 400,000 people. This rate was incorporated into the U.S. EPA-ISCLT model based on the following input data:

      EP = 360 lb H_2O/mm BTU
      Combustion zone temperature - 1400°F
      Solids content - 28%
      Stack height - 20 m
      Exit gas velocity - 20 m/s
      Exit gas temperature - 356.9°K (183°F)
      Stack diameter - 0.60 m

      ii. **Worst** = 10,000 kg/hr (dry solids input)

      A feed rate of 10,000 kg/hr DW represents a higher feed rate and would serve a major U.S. city. This rate was incorporated into the U.S. EPA-ISCLT model based on the following input data:

      EP = 392 lb H_2O/mm BTU
      Combustion zone temperature - 1400°F
      Solids content - 26.6%
      Stack height - 10 m
      Exit gas velocity - 10 m/s
      Exit gas temperature - 313.8°K (105°F)
      Stack diameter - 0.80 m

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

Typical 0.22 mg/kg DW
Worst 0.81 mg/kg DW

See Section 3, p. 3-1.

d. **Fraction of pollutant emitted through stack (FM)**

Typical 0.05 (unitless)
Worst 0.20 (unitless)

These values were chosen as best approximations of the fraction of pollutant emitted through stacks (Farrell, 1984). No data was available to validate these values; however, U.S. EPA is currently testing incinerators for organic emissions.

e. **Dispersion parameter for estimating maximum annual ground level concentration (DP)**

Typical 3.4 $\mu g/m^3$
Worst 16.0 $\mu g/m^3$

The dispersion parameter is derived from the U.S. EPA-ISCLT short-stack model.

f. **Background concentration of pollutant in urban air (BA) = 0.000216 $\mu g/m^3$**

In this analysis, the ambient atmospheric concentration of dieldrin in urban air is approximated by the mean of the average concentration in Columbia, SC, and Boston in 1978 (Bidleman, 1981); these cities may be regarded as representative of agriculturally- and industrially-based cities, respectively. Nationally, the 1970-72 ambient air level of dieldrin was 1.6×10^{-3} $\mu g/m^3$ (Ackerman, 1980). However, while the national level is probably a more statistically reliable estimate, it is based on rural air concentrations which tend to be substantially higher than urban air concentrations, and hence represents a less satisfactory estimate of urban air levels. In addition, the Bidleman values are based on more recent measurements. Ambient urban air levels of dieldrin are higher than those for aldrin, providing for the more conservative analysis. (See Section 4, p. 4-9.)

4. **Index 1 Values**

Fraction of Pollutant Emitted Through Stack	Sludge Concentration	Sludge Feed Rate (kg/hr DW)[a] 0	2660	10,000
Typical	Typical	1.0	1.1	3.2
	Worst	1.0	1.5	9.3
Worst	Typical	1.0	1.5	10
	Worst	1.0	2.9	34

[a] The typical (3.4 μg/m^3) and worst (16.0 μg/m^3) dispersion parameters will always correspond, respectively, to the typical (2660 kg/hr DW) and worst (10,000 kg/hr DW) sludge feed rates.

5. **Value Interpretation** - Value equals factor by which expected air concentration exceeds background levels due to incinerator emissions.

6. **Preliminary Conclusion** - The incineration of municipal sewage sludge is expected to result in substantial increases of aldrin/dieldrin concentrations in the air, especially at high (10,000 kg/hr DW) feed rates.

B. **Index of Human Cancer Risk Resulting from Inhalation of Incinerator Emissions (Index 2)**

1. **Explanation** - Shows the increase in human intake expected to result from the incineration of sludge. Ground level concentrations for carcinogens typically were developed based upon assessments published by the U.S. EPA Carcinogen Assessment Group (CAG). These ambient concentrations reflect a dose level which, for a lifetime exposure, increases the risk of cancer by 10^{-6}.

2. **Assumptions/Limitations** - The exposed population is assumed to reside within the impacted area for 24 hours/day. A respiratory volume of 20 m^3/day is assumed over a 70-year lifetime.

3. **Data Used and Rationale**

   a. **Index of air concentration increment resulting from incinerator emissions (Index 1)**

   See Section 3, p. 3-22.

b. **Background concentration of pollutant in urban air (BA)** = 0.000216 $\mu g/m^3$

See Section 3, p. 3-21.

c. **Cancer potency** = 30.4 $(mg/kg/day)^{-1}$

The cancer potency associated with dieldrin is from the U.S. EPA (1980). It is estimated from the dose-response research relating dietary dieldrin intake with the occurrence of hepatocellular carcinoma in female mice. It is based on the assumption of 100 percent absorption and the equivalence of ingestion and inhalation in terms of dose-response. (See Section 4, p. 4-13.)

d. **Exposure criterion (EC)** = 1.151×10^{-4} $\mu g/m^3$

A lifetime exposure level which would result in a 10^{-6} cancer risk was selected as ground level concentration against which incinerator emissions are compared. The risk estimates developed by CAG are defined as the lifetime incremental cancer risk in a hypothetical population exposed continuously throughout their lifetime to the stated concentration of the carcinogenic agent. The exposure criterion is calculated using the following formula:

$$EC = \frac{10^{-6} \times 10^{3}\ \mu g/mg \times 70\ kg}{\text{Cancer potency} \times 20\ m^3/day}$$

4. **Index 2 Values**

Fraction of Pollutant Emitted Through Stack	Sludge Concentration	Sludge Feed Rate (kg/hr DW)[a] 0	2660	10,000
Typical	Typical	1.9	2.1	6.1
	Worst	1.9	2.8	18
Worst	Typical	1.9	2.8	19
	Worst	1.9	5.4	64

[a] The typical (3.4 $\mu g/m^3$) and worst (16.0 $\mu g/m^3$) dispersion parameters will always correspond, respectively, to the typical (2660 kg/hr DW) and worst (10,000 kg/hr DW) sludge feed rates.

5. **Value Interpretation** - Value > 1 indicates a potential increase in cancer risk of > 10^{-6} (1 per 1,000,000). Comparison with the null index value at 0 kg/hr DW indicates the degree to which any hazard is due to sludge

incineration, as opposed to background urban air concentration.

c. **Preliminary Conclusion** - Sludge incineration is expected to result in a substantial increase in the cancer risk associated with inhaling aldrin/dieldrin, especially at high (10,000 kg/hr DW) feed rates.

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 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 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	0.22 mg/kg DW
Worst	0.81 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, 1984c).

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, 1984d).

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	0.00044	0.00044
	Worst	0.0	0.0016	0.0016
Worst	Typical	0.0	0.0037	0.0037
	Worst	0.0	0.014	0.014

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

7. **Preliminary Conclusion** - This assessment shows that the incremental seawater concentration of aldrin/dieldrin increases after mixing with the sludge; however, the increase is slight in all 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. 3-25 to 3-26.

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

   See Section 3, p. 3-28.

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	0.00012	0.00024
	Worst	0.0	0.00044	0.00088
Worst	Typical	0.0	0.0010	0.0021
	Worst	0.0	0.0039	0.0077

6. **Value Interpretation** - Value equals the effective increase in aldrin/dieldrin 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 effective increase of aldrin/dieldrin over a 24-hour period is expected to be slight.

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 aldrin/dieldrin, 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. 3-28.

   b. **Ambient water quality criterion (AWQC) = 0.0019 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 aldrin/dieldrin.

      The 0.0019 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 aldrin/dieldrin in edible fish and shellfish products (fish oil) (0.3 mg/kg), the geometric mean of normalized bioconcentration factor (BCF) values (1,557) for aquatic species tested and the 100 percent lipid content of marine fish oil. To protect against acute toxic effects, aldrin/dieldrin concentration should not exceed 0.71 μg/L at any time. (See Section 4, p. 4-17.)

4. **Index 3 Values**

Disposal Conditions and Site Characteristics	Sludge Concentration	Sludge Disposal Rate (mt DW/day)		
		0	825	1650
Typical	Typical	0.0	0.063	0.12
	Worst	0.0	0.23	0.46
Worst	Typical	0.0	0.55	1.1
	Worst	0.0	2.0	4.1

5. **Value Interpretation** - Value equals the factor by which the expected seawater concentration increase in aldrin/dieldrin 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 aldrin/dieldrin residue in tissue hazard may exist thus jeopardizing the marketability of edible seawater organism products (fish oil). The criterion value of 0.0019 μg/L is probably too high because on the average, the aldrin/dieldrin residue in 50 percent of aquatic species similar to those used to derive the AWQC will exceed the FDA action level for aldrin/dieldrin (U.S. EPA, 1980).

6. **Preliminary Conclusion** - This assessment shows that a potential hazard to aquatic life exists where "worst" concentration sludges are disposed at the "worst" site. All scenarios evaluated showed increases in index values.

D. **Index of Human Cancer Risk 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 cancer risk-specific intake (RSI) 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. 3-28.

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, 1984c). Near-shore area 612 has an area of approximately 4300 km^2 and constitutes approximately 24 percent of the total seafood landings (CDM, 1984d). 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:

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

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

For the worst (near shore) site:

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

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

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:

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

For the worst (near shore) site:

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

d. **Bioconcentration factor of pollutant (BCF) = 4670 L/kg**

The value chosen is the weighted average BCF of aldrin/dieldrin 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 carcinogenic effects of aldrin/dieldrin 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. 4-17.)

e. **Average daily human dietary intake of pollutant (DI) = 2.079 μg/day**

See Section 3, p. 3-12.

f. **Cancer potency** = 30.4 $(mg/kg/day)^{-1}$

See Section 3, p. 3-12.

g. **Cancer risk-specific intake (RSI)** = 2.3×10^{-3} µg/day

The RSI is the pollutant intake value which results in an increase in cancer risk of 10^{-6} (1 per 1,000,000). The RSI is calculated from the cancer potency using the following formula:

$$RSI = \frac{10^{-6} \times 70 \text{ kg} \times 10^{3} \text{ µg/mg}}{\text{Cancer potency}}$$

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	900	900	900
	Worst	Worst	900	910	910
Worst	Typical	Typical	900	900	900
	Worst	Worst	900	920	930

[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 RSI. 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** - This assessment shows that the disposal of "typical" concentration sludges at both the "worst" and "typical" sites will not result in an incremental risk of human cancer from seafood consumption. Slight incremental risk does occur from "worst" concentration sludges disposed at the "typical" and "worst" sites.

SECTION 4

PRELIMINARY DATA PROFIL. FOR IN ALDRIN/DIELDRIN MUNICIPAL SEWAGE SLUDGE

I. OCCURRENCE

Aldrin was used extensively for agriculture for over 20 years until its use was suspended by EPA in 1974. Its use for termite control has been retained. Aldrin is readily converted to dieldrin which is regarded as one of the most persistert pesticides. — NRC, 1982 (p. 23)

A. Sludge

1. Frequency of Detection

Aldrin/dieldrin was detected in 2 percent of sludges from 50 POTWs — CDM; 1984a (p. 15)

2. Concentration

Aldrin/dieldrin (μg/g DW) in sludges of 74 Missouri wastewater treatment plants (date NS): — Clevenger et al., 1983 (p. 1471)

	Min.	Max.	Mean	Median
Aldrin	0.05	0.64	0.13	0.08
Dieldrin	0.05	0.81	0.14	0.11

In municipal sludges from 14 U.S. cities (1972-1973): — Furr et al., 1976 (p. 684)

Dieldrin - Range <0.03 to 2.2 (μg/g DW)
Mean 0.31
Median 0.13

Median concentration of dieldrin residues (μg/g) in Metro Denver sewage sludges (1975-76) — Baxter et al., 1983a (p. 315)

Digested	Waste Activated
0.101	0.035 (μg/g WW)
0.505	0.175 (μg/g DW)

Five sludges sources in Chicago averaged <10 µg/L of both aldrin and dieldrin	Jones and Lee, 1977 (p. 52)
Aldrin/dieldrin (mg/kg DW) in sludges of 63 POTWs (EPA study, New York City, Galveston, Albuquerque, Phoenix, Indiana, and Michigan)	CDM, 1984a (p. 8)

	Min.	Max.	Wt. Mean
Aldrin	0.01	0.64	0.15
Dieldrin	0.0006	0.81	0.07

B. Soil - Unpolluted

1. Frequency of Detection

In 99 soil samples from rice-growing areas in 5 states, 39 samples (39.4%) contained aldrin and 84 samples (84.8%) contained dieldrin (1972 data).	Carey et al., 1980 (p. 25)
In 380 urban soil samples from 5 cities, dieldrin was present in 61 samples from 5 cities, and aldrin was present in 8 samples from 2 cities (1971 data).	Carey et al., 1980 (p. 19)
Dieldrin - % positive samples from 6 Air Force Installations	Lang et al., 1979 (p. 231)

Land Use	Year	% of Samples With Dieldrin
Residential	1975	55.0
Residential	1976	47.6
Non-use	1975	17.4
Non-use	1976	24.0
Golf Course	1975	23.5
Golf Course	1976	23.5

% occurrence of aldrin and dieldrin in U.S. agricultural soils, 1968-73	Carey, 1979 (p. 25)

Year	Aldrin	Dieldrin
1968	13.4	32.0
1969	14.2	32.3
1971	10.2	28.8
1972	9.4	28.1
1973	3.8	25.7

In 90 samples from hayfield soils in 9 states, 5.6% contained dieldrin residues (1971).	Gowen et al., 1976 (p. 115)
In 1,486 samples from U.S. cropland soils (37 states) in 1971, aldrin was detected in 144 samples (9.7%); dieldrin was detected in 408 samples (27.5%)	Carey et al., 1978 (p. 120)
In 1,483 samples from U.S. cropland soils (37 states) in 1972: aldrin was detected in 129 samples (8.7%); dieldrin was detected in 403 samples (27.2%).	Carey et al., 1979b (p. 212)

2. **Concentration**

Trace levels of dieldrin (<0.010 μg/g) detected in <u>both</u> control sludge-applied and control soils	Baxter et al., 1983a (p. 315)
Dieldrin - (μg/g DW) in U.S. soils	Edwards, 1973 (p. 416 to 417)

Land Type	Max.	Mean
Pasture/grassland 227 sites (1965)	2.20	0.03
Non-cropland 13 sites (1971)	0.0013	0.0003
Desert, none found 5 sites (1966)	-	-

Dieldrin - 3 out of 34 soil samples in and around Everglades Nat. Park contained >1.0 ng/g dieldrin as follows: 2.0, 16, and 238 ng/g. Aldrin - one out of 34 soils samples in and around Everglades Nat. Park contained 11 ng/g (1976 data).	Requejo et al., 1979 (p. 934)
Aldrin - 99 samples from rice-growing areas in 5 states Range: 0.01 to 0.25 (µg/g DW) Mean: 0.01 Dieldrin - 99 samples from rice-growing area in 5 states Range: 0.01 to 0.27 µg/g Mean: 0.04 µg/g (1972 data)	Carey et al., 1980 (p. 25)
Dieldrin - 61 urban samples from 5 cities Range: 0.01 to 6.02 µg/g DW; Geometric mean: 0.004 µg/g DW (380 samples) Aldrin - 8 urban samples from 2 cities Range: 0.01 to 2.04 µg/g DW; Geometric mean: 0.002 µg/g DW (204 samples)	Carey et al., 1979a (p. 19)
Dieldrin - residues from 6 Air Force Installations, 1975-76	Lang et al., 1979 (p. 231)

Land Use	Range	Avg.	Year
Residential	ND-0.04	0.01	1975
Residential	ND-0.02	<0.01	1976
Non-use	ND-0.31	0.01	1975
Non-use	ND-0.10	0.01	1976
Golf Course	ND-0.05	0.01	1975
Golf Course	ND-0.03	0.01	1976

Dieldrin residues in hayfield soils from nine states, 1971 max.: 0.12 µg/g (DW) arithmetic mean: <0.01 µg/g	Gowen et al., 1976 (p. 115)

In 1,486 samples from U.S. cropland soils (37 states) in 1971: — Carey et al., 1978 (p. 120)

Pesticide	Min. (μg/g DW)	Max.	Arith. Mean	Geom. Mean
Aldrin	0.01	1.88	0.02	0.002
Dieldrin	0.01	9.83	0.05	0.009

In 1,483 samples from U.S. cropland soils (37 states) in 1972: — Carey et al., 1979b (p. 212)

Pesticide	Min. (μg/g DW)	Max.	Arith. Mean	Geom. Mean
Aldrin	0.01	13.28	0.03	0.002
Dieldrin	0.01	6.18	0.04	0.008

Dieldrin residues in soil in 6 U.S. cities (1970) — Carey et al., 1976 (pp. 56 to 58)

City	Positive Percent	Site No.	PPM Residue Range	PPM Arith. Mean	PPM Geom. Mean
Greenville, MS	3.6	1	0.41	0.02	--
Memphis, TN	57.1	16	0.02-12.80	1.07	0.0525
Mobile, AL	10.3	3	0.04-0.36	0.02	0.0035
Portland, OR	8.0	2	0.08-1.19	0.05	0.0032
Richmond, VA	14.8	4	0.07-2.99	0.14	0.0075
Sikeston, MO	3.7	1	0.33	0.01	--

Soil Residues in U.S. Agricultural Areas (data 1965-1972) — Edwards, 1973 (pp. 416 to 417)

Pesticide/Site	µg/g Max.	µg/g Mean
Dieldrin:		
30 U.S. orchard sites	2.84	1.41
12 carrot fields	1.47	0.67
6 cranberry fields	3.15	2.08
27 soybean fields	0.31	0.08
41 vegetable fields	0.77	0.06
25 potato fields	0.20	0.10
92 sweet potato fields	2.18	0.17
71 onion fields	16.72	0.79
35 corn fields	1.22	0.50
5 peanut fields	0.20	0.15
Aldrin:		
27 soybean fields	0.18	0.02
41 vegetable fields	0.28	0.03
92 sweet potato fields	0.11	0.01
71 onion fields	0.96	0.02
11 grain fields	0.61	0.23

C. Water - Unpolluted

1. Frequency of Detection

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

In a 1964-68 survey of pesticides in water, dieldrin dominated pesticide occurrences in all regions. It appeared in 39% of the samples. — Ackerman, 1980 (p. 65)

Dieldrin in surface water in southern Florida 1968-72 — Mattraw, 1975 (p. 109)

	1968	1969	1970	1971	1972
% Positive Samples	22	0	0	10	15

2. **Concentration**

Dieldrin found in 117 of 715 samples of U.S. drinking and raw water (1975 data)	U.S. EPA, 1980 (p. C-5,

a. **Freshwater**

Edwards, 1973 (pp. 440 to 441)

Water Type	Aldrin (ng/L) Max.	Aldrin (ng/L) Mean	Dieldrin (ng/L) Max.	Dieldrin (ng/L) Mean
97 major river basins (1965)	85.0	0.9	118.0	7.5
Miss. River delta (1966)	30.0	5.0	60.0	10.0
99 major river basins (1967)	--	--	68.0	6.9
11 major rivers (western) (1967)	5.0	0.2	15.0	2.3
109 major rivers (1967)	--	--	167.0	5.9
20 streams (western) (1969)	40.0	0.6	70.0	1.1
110 surface waters (1967)	--	--	87.0	5.0
114 surface water (1968)	--	--	407.0	8.2
6 Iowa rivers (1968)	--	--	10.0	1.8
10 Iowa rivers (1969)	--	--	63.0	8.5
10 Iowa rivers (1970)	--	--	65.0	8.7
101 river and drinking water (Hawaii) (1971)	--	--	19.0	9.4

"Dieldrin remained as the most serious pollutant in the surface waters of the United States"	Matsumura, 1972 (p. 43)
Mean monthly dieldrin concentrations (ng/L) in the Des Moines River (1971-73)	Kellogg and Bulkley, 1976 (p. 189)

Month	1971	1972	1973
May	10	<10	8
June	50	24	10
July	40	23	12
Aug.	30	<10	6
Sept.	30	<10	4
Mean	32	<15	8

Dieldrin found at 1 to 2 ng/L in drinking water of Miami, Seattle,	NAS, 1977 (pp. 558 to 559)

Ottumwa (Iowa) and Cincinnati and at 50 to 70 ng/L in New Orleans

Mean concentrations of dieldrin in U.S. water systems (data ca 1966)	Matsumura, 1972 (p. 42)

	No. Sites Sampled	Mean (ng/L)
Major River Basins	99	6.9
	97	7.5
	109	5.9
Mississippi Delta	10	10.0
Western Streams	11	2.3

Lake Michigan water 1 to 3 ng/L dieldrin	U.S. EPA, 1976 (p. 129)

b. Seawater

Data not immediately available.

c. Drinking water

1 to 50 ng/L, 1975 data	U.S. EPA, 1980 (p. C-5)
In 500 samples of finished drinking water and raw water from the Mississippi and Missouri rivers, only one sample contained >0.017 mg/L dieldrin (the suggested permissible criteria). 1969. However, dieldrin was present in 40% of the samples.	Edwards, 1973 (p. 449) Ackerman, 1980 (p. 65)
Recommended drinking water standards in 1968: Aldrin - 17 μg/L Dieldrin - 17 μg/L	NAS, 1977 (p. 559)

D. Air

1. Frequency of Detection

Dieldrin was present in 94% of 2,479 samples taken nationwide (1970 to 1972 data).	Ackerman, 1980 (p. 65)
Aldrin occurred in 1 out of 875 samples collected from 9 U.S.A. cities (1969 data).	Stanley et al., 1971 (p. 435)

Dieldrin occurred in 50 out of 875 samples of U.S.A. cities (1969 data).

2. Concentration

0.40 ng/m^3 in Columbia, SC; 0.033 ng/m^3 in Boston, MA (1978 data)	Bidleman, 1981 (p. 632)
0.010 ng/m^3 (0.006 to 0.018) from Enewetak Atoll	Atlas and Giam, 1981 (p. 163)
2,479 air samples collection nationwide from 1970 to 1972 had a mean concentration of dieldrin equal to 1.6 ng/m^3.	Ackerman, 1980 (p. 65)
Ambient air levels of 20 ng/m^3 (dieldrin) have been recorded in agricultural areas.	Ackerman, 1980 (p. 68)
One air sample from Iowa City in 1969 contained aldrin at a level of 8.0 ng/m^3.	Stanley et al., 1971 (p. 435)
In 99 samples from Orlando in 1969, 50 contained dieldrin, and the maximum level was 29.7 ng/m^3.	

E. Food

1. Total Average Intake

1978 is most recent data available from FDA

Relative daily intakes of aldrin and dieldrin (µg/kg body weight/day)	FDA, no date (Attachment G)

	FY75	FY76	FY77	FY78	Average FY75-78
Total	0.0409	0.0405	0.0226	0.0170	0.03025
Aldrin	0.0022	ND	ND	ND	0.0022
Dieldrin	0.0387	0.0405	0.0226	0.0170	0.0297

	Daily Dietary Intake, mg					
Pesticide	1965	1966	1967	1968	1969	1970
Aldrin	0.001	0.002	0.001	T	T	0.001
Dieldrin	0.005	0.007	0.001	0.004	0.005	0.005

NAS, 1977 (p. 558)

2. Concentration

Levels of dieldrin found by food class - summary of 5 regions in U.S., June 1971 to July 1972

Manske and Johnson, 1975 (pp. 96 to 102)

Food	Fraction of positive composites	Average (μg/g)	Range (μg/g)
Dairy products	26/30	0.002	T-0.005
Meat, fish, poultry	29/30	0.004	0.001-0.010
Potatoes	11/30	0.001	T-0.007
Leafy vegetables	5/30	T	T
Legume vegetables	2/30	T	T
Garden fruit	22/30	0.003	T-0.012
Fruit	1/30	T	T
Oils, fats, shortening	8/30	T	T-0.004

Dieldrin Content (μg/g) of Milk Products (ca 1972 data):

Ang and Dugan, 1973 (p. 791)

Whole milk - 0.034 ± 0.004
Skim milk - 0.005 ± 0.001
Butter - 0.714 ± 0.125
Cream - 0.445 ± 0.011

Dieldrin residues in milk products (μg/g) in Illinois

Wedberg et al., 1978 (p. 164)

	No. Pos.	% Pos.	Avg. ppm	% Samples 0.01-0.10	% Samples 0.11-0.20	% Samples 0.21-0.30
Summary 1971-76 (1,169 samples)	1126	96	0.09	69	29	2

Dieldrin has the highest retention time of all pesticides in milk, approximately 100 days	NAS, 1977 (p. 559)
Occurrence of dieldrin by food class - FY 78	FDA, no date (Attachment E)

Food Class	Fraction of Positive Composites
Dairy	10/20
Meat, fish, poultry	17/20
Potatoes	3/20
Leafy vegetables	1/20
Garden fruit	14/20
Fruit	2/20
Oils, fats, shortening	5/20

Total # Residues: 52
Total Range: T-0.008 µg/g

II. HUMAN EFFECTS

A. Ingestion

1. Carcinogenicity

a. Qualitative Assessment

Aldrin/dieldrin has been shown to cause tumors in laboratory animals.	NAS, 1977 (p. 565)
In mice, the effects range from benign liver tumors to hepatocarcinomas.	U.S. EPA, 1980 (p. C-45)
The induction of liver tumors in mice of both sexes by aldrin and dieldrin is sufficient evidence that they are likely to be human carcinogens.	U.S. EPA, 1980 (p. C-82)

b. Potency

Cancer potency $(mg/kg/day)^{-1}$ Aldrin 11.5 Dieldrin 30.4	U.S. EPA, 1980 (pp. C-83, C-86)

c. **Effects**

Both aldrin and dieldrin have induced hepatocellular carcinomas in mice	U.S. EPA, 1980 (p. C-83, 86)

2. **Chronic Toxicity**

a. **ADI**

For aldrin and dieldrin = 0.0001 mg/kg/day	NAS, 1977 (p. 559)

b. **Effects**

Shortened life span, increased liver-to-body weight ratio, various changes in liver histology and induction of hepatic enzymes.	U.S. EPA, 1980 (p. C-34)

3. **Absorption Factor**

Absorption is reported to vary with the solvent used. No information is available on the absorption factor.	U.S. EPA, 1980 (p. C-11)

4. **Existing Regulations**

Ambient Water Quality Criteria	U.S. EPA, 1980 (p. C-64)

Exposure Assumptions	Risk Levels and Corresponding Criteria			
	0 ng/L	10^{-7} ng/L	10^{-6} ng/L	10^{-5} ng/L
2 liters of drinking water and consumption of 6.5 grams of fish and shellfish (2)				
Aldrin	0	0.0074	0.074	0.74
Dieldrin	0	0.0071	0.071	0.71
Consumption of fish and shellfish only				
Aldrin	0	0.0079	0.079	0.79
Dieldrin	0	0.0076	0.076	0.76

Drinking water standards (1968) — NAS, 1977 (p. 559)

Aldrin 17 ppb
Dieldrin 17 ppb

B. Inhalation

1. Carcinogenicity

a. Qualitative Assessment

Not tested for carcinogenicity via the inhalation route. Presumption of potential carcinogenicity based on ingestion studies.

b. Potency

Cancer potency $(mg/kg/day)^{-1}$: — U.S. EPA, 1980 (p. C-83, 86)

Aldrin 11.5
Dieldrin 30.4

Values based on ingestion potency, assuming 100% absorption by both routes.

c. Effects

Not tested via inhalation route.

2. Chronic toxicity

See below, "Existing Regulations."

3. Absorption Factor

Assumption of 100% absorption.

4. Existing Regulations

Aldrin/Dieldrin - 0.25 mg/m^3 TWA — ACGIH, 1982 (p. 9)

III. PLANT EFFECTS

A. Phytotoxicity

See Table 4-1.

B. Uptake

Carrots - 0.41 μg/g aldrin
Peanuts - 1.27 μg/g dieldrin

Finlayson and MacCarthy, 1973 (pp. 72 to 73)

Dieldrin residues (μg/g DW) in crops from 37 states (1971 data)

Carey et al., 1978 (pp. 133 to 136)

Crop	Range	Arithmetic Mean	Geometric Mean
Alfalfa	0.01-0.05	<0.01	0.0[illegible]
Field corn kernels	0.01-0.07	<0.01	0.001
Milo	0.11	0.05	-
Peanuts	0.02-0.03	0.01	0.004
Sorghum	0.01-0.28	0.02	0.004
Soybeans	0.01-0.05	<0.01	0.003

Dieldrin residues (μg/g DW) in crops from 37 states (1972 data)

Carey et al., 1979b (pp. 222 to 225)

Crop	Range	Arithmetic Mean	Geometric Mean
Alfalfa	0.01-0.09	0.01	0.007
Field corn kernels	0.01-0.21	<0.01	0.001
Sorghum	0.01	<0.01	0.001
Soybeans	0.01-0.04	<0.01	0.002

Dieldrin residues (μg/g) in sugar beet pulp and soybean oil (1971) from 16 states

Yang, 1976 (p. 43)

	Range	Mean
Sugarbeet pulp	ND - 0.01	<0.01
Soybean oil	ND - 0.05	0.02

See Table 4-2.

Residues in crops following application of aldrin/dieldrin to soil — Muns et al., 1960 (p. 833)

Crop	Application Rate	Residues (μg/g)
Lima beans	4 lbs/acre-aldrin	ND
Sweet potatoes	4 lbs/acre-aldrin	Aldrin:0.03 Dieldrin:0.03
Sugar beets	4 lbs/acre-dieldrin	0.11
Radishes	4 lbs/acre-dieldrin	T

IV. DOMESTIC ANIMAL AND WILDLIFE EFFECTS

A. Toxicity

See Table 4-3.

Aldrin and dieldrin at "very low" dosages affect the central nervous system producing encephalographic changes and altering behavior. The "no-adverse-effect dosage" has never been determined. — NAS, 1977 (p. 565)

B. Uptake

1. Observed range of tissue concentrations

Dieldrin residues, in carcasses of 168 bald eagles from 29 states, 1975-77 (μg/g) — Kaiser, 1980 (p. 147)

Year	# Specimens	Median	Range
1975	44	0.60	0.06-12.0
1976	40	0.66	0.05-12.0
1977	53	0.22	0.05- 4.0

Dieldrin in swine raised for 2 years in sludge-amended soil — Hansen et al., 1981 (p. 1015)

Back fat: 11±8 ng/g fresh wt. dieldrin

Marrow: 6±4 ng/g fresh wt. dieldrin

Selected dieldrin residues in wild mammals:	Stickel, 1973 (pp. 290 to 295)

Mammals	Dieldrin
Shrews - 1969	0.35 µg/g
Grnd. squirrels-1969	0.06, 0.08 µg/g
Jumping mice - 1969	0.04 µg/g
Meadow voles - 1969	0.01 µg/g
Mountain goat - 1968	0.07-max
Mule deer - 1964	0.02-max
Mule deer - 1966	0.05-max
White-tailed deer-1964	0.09-max

2. Tissue concentration where intake is elevated

0.04 µg/g in soil resulted in 3.68 µg/g in vole (whole body) — Gile et al., 1982 (pp. 298 to 299)

3. Bioconcentration factor for tissue concentration versus feed concentration

See Table 4-4.

Concentration of dieldrin in fat tissue of LBR cattle = 10 µg/kg WW — Baxter et al., 1983b

V. AQUATIC LIFE EFFECTS

A. Toxicity

1. Freshwater

Dieldrin - 0.0019 µg/L as 24-hour average, not to exceed 2.5 µg/L at any time. — U.S. EPA, 1980 (p. B-12)

Aldrin - concentration should not exceed 3.0 µg/L at any time. No chronic toxicity data presently available. — U.S. EPA, 1980 (p. B-12)

2. Saltwater

Aldrin - concentration should not exceed 1.3 µg/L at any time. No chronic toxicity data presently available. — U.S. EPA, 1980 (p. B-12)

Dieldrin - 0.0019 μg/L as 24 hour average, not to exceed 0.71 μg/L a any time. — U.S. EPA, 1980 (p. B-12)

B. Uptake

Weighted average dieldrin BCF of 4670 for edible portion of all freshwater and estuarine aquatic organisms consumed by U.S. citizens — U.S. EPA, 1980 (p. B-8)

VI. SOIL BIOTA EFFECTS

A. Toxicity

See Table 4-5.

Aldrin and dieldrin may kill or reduce numbers of soil saprophagus mites, and dipterous and coleopterous larvae in soil, while nematodes, earthworms, and other soil animals are not harmed. — Martin, 1972 (p. 744)

"The most important sublethal effect of organochlorine insecticides on soil invertebrates is the development of resistance to organochlorine insecticides by exposed species." — Edwards, 1973 (p. 431)

0.1 μg/g aldrin in soil, lowest concentration exhibiting bioactivity to cricket larvae — Harris, 1970 (p. 784)

B. Uptake

See Table 4-6.

VII. PHYSICOCHEMICAL DATA FOR ESTIMATING FATE AND TRANSPORT

Aldrin:

Chemical name: 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo 1,4-5,8-dimethanonapthalene

Molecular weight: 364.93
Molecular formula: $C_{12}H_8Cl_6$

Dieldrin:

Chemical name: 6,7-epoxy aldrin

Molecular weight: 380.93
Molecular formula: $C_{12}H_8Cl_6O$

Vapor pressure of aldrin and dieldrin at 20°C (mm Hg)
aldrin: 2.3×10^{-5} (volatile)
dieldrin: 1.8×10^{-7} (slightly volatile)

Edwards, 1973 (p. 433)

Insecticide	Water Solubility at 20-30°C (ppm)
Aldrin	0.027
Dieldrin	0.186

Edwards, 1973 (p. 4447)

Dieldrin is lipophilic.

Ackerman, 1980 (p. 65)

Half-life of dieldrin residues in soil is 2.8 years or 8 years for 95% disappearance.

Ackerman, 1980 (p. 64)

Aldrin is immobile in soils (R_f = 0.09-0.00)

Lawless et al., 1975 (p. 51)

Half-lives:
aldrin - 3.1 months
aldrin and dieldrin - 8.5 months
dieldrin - 29.7 months (~2.5 years)

Onsager et al., 1970 (p. 1143)

TABLE 4-1. PHYTOTOXICITY OF ALDRIN/DIELDRIN

Plant/Tissue	Chemical Form Applied (study type)	Soil Type	Control Tissue Concentration (µg/g DW)	Experimental Soil Concentration (µg/g DW)	Experimental Application Rate (kg/ha)	Experimental Tissue Concentration (µg/g DW)	Effects	References
Cucumber, tomato beans, beets, cereals	Aldrin (field)	agricultural	NR[b]	4.45-8.95[c]	8.9-17.9	NR	"Damage"	Edwards, 1973 (p. 432)
Lima bean, sweet potato, sugar beet, radish	Aldrin/ dieldrin (field)	sandy loam	NR	2.25[c]	4.5	NR	No effect	Muns et al., 1960 (p. 833)
Sugar beet	Aldrin/ dieldrin (field)	loam	NR	5.5[c]	11	NR	No effect	Onsager et al., 1966 (p. 1114)
Tomato, cucumber	Aldrin/ dieldrin (field)	compost	NR	11.2[c]	22.4	NR	Reduced growth 10-24%	Dennis and Edwards, 1964 (p. 173-77)
Carrot	Aldrin (pot)	compost	NR	56[c]	112	NR	27% reduced growth	Dennis and Edwards, 1964 (p. 173-77)
Strawberry	Aldrin (pot)	compost	NR	56[c]	112	NR	No effect	Dennis and Edwards, 1964 (p. 173-77)
Black Valentine bean/seed	Aldrin (pot)	loamy sand	NR	12.5	NR	NR	6% increased germination	Eno and Everett, 1958 (p. 236)
bean/seed	Aldrin (pot)	loamy sand	NR	50	NR	NR	3% increased germination	Eno and Everett, 1958 (p. 236)
bean/seed	Aldrin (pot)	loamy sand	NR	100	NR	NR	5% decreased germination	Eno and Everett, 1958 (p. 236)
bean/root	Aldrin (pot)	loamy sand	NR	12.5	NR	NR	24% decreased growth	Eno and Everett, 1958 (p. 236)
bean/root	Aldrin (pot)	loamy sand	NR	50	NR	NR	30% decreased growth	Eno and Everett, 1958 (p. 236)
bean/root	Aldrin (pot)	loamy sand	NR	100	NR	NR	48% decreased growth	Eno and Everett, 1958 (p. 236)

TABLE 4-1. (continued)

Plant/Tissue	Chemical Form Applied (study type)	Soil Type	Control Tissue Concentration (μg/g DW)	Experimental Soil Concentration (μg/g DW)	Experimental Application Rate (kg/ha)	Experimental Tissue Concentration (μg/g DW)	Effects	References
bean/top	Aldrin (pot)	loamy sand	NR	12.5	-	NR	10% decreased growth	Eno and Everett, 1958 (p. 236)
bean/top	Aldrin (pot)	loamy sand	NR	50	-	NR	6% decreased growth	Eno and Everett, 1958 (p. 236)
bean/top	Aldrin (pot)	loamy sand	NR	100	-	NR	16% decreased growth	Eno and Everett, 1958 (p. 236)

[a] N = Number of application rates (if applicable).
[b] NR = Not reported.
[c] Estimated soil concentration assuming the insecticide is incorporated into the upper 15 cm of soil which has an approximate (dry matter) mass of 2×10^3 mt/ha.

TABLE 4-2. UPTAKE OF ALDRIN/DIELDRIN BY PLANTS

Plant	Tissue	Soil Type	Chemical Form Applied (Study Type)	Soil Concentration (µg/g)	Range of Tissue (WW) Concentration (µg/g)	Uptake Factor[a]	References
Wheat	grain	loess	Dieldrin (field)	0.52	<0.01	<0.01	Weisgerber, 1974 (p. 610)
Corn	grain	loess	Dieldrin (field)	0.55	<0.01	<0.01	Weisgerber, 1974 (p. 610)
Wheat	grain	loess	Aldrin (field)	1.09	<0.01	<0.01	Weisgerber, 1974 (p. 610)
Corn	grain	loess	Aldrin (field)	0.78	<0.01	<0.01	Weisgerber, 1974 (p. 610)
Corn	seed	clay loam	Aldrin/ dieldrin (field)	0.4-3.0	0.003-0.008	<0.01	Bruce et al., 1966 (p. 180)
Oats	seed	clay loam	Aldrin/ dieldrin (field)	0.4-3.0	0.005-0.09	0.01-0.03	Bruce et al., 1966 (p. 180)
Peanuts	seed	clay loam	Aldrin/ dieldrin (field)	0.4-3.0	0.1-1.0	0.25-0.33	Bruce et al., 1966 (p. 180)
Sugar beet	plant	loam	Aldrin/ dieldrin (field)	0.01-0.97	<0.01-0.96	0.33-<1.0	Onsager et al., 1966 (p. 1144)
Alfalfa	plant	clay	Dieldrin (field)	1.2	0.02	0.02	Harris and Sans, 1969 (p. 184)
Oats	plant	clay	Dieldrin (field)	1.2	0.02	0.02	Harris and Sans, 1969 (p. 184)
Corn	plant	clay	Dieldrin (field)	1.2	0.023[b]	0.020	Harris and Sans, 1969 (p. 184)
Sugar beet	top	clay	Dieldrin (field)	1.2	0.03	0.03	Harris and Sans, 1969 (p. 184)
Potato	plant	clay	Dieldrin (field)	1.2	0.03	0.03	Harris and Sans, 1969 (p. 184)
Carrot	plant	clay	Dieldrin (field)	1.2	0.04	0.03	Harris and Sans, 1969 (p. 184)
Sugar beet	root	clay	Dieldrin (field)	1.2	0.55[b]	0.46	Harris and Sans, 1969 (p. 184)
Alfalfa, oats corn, beet, potato, carrot	as above	clay	Aldrin (field)	0.14-0.37	<0.01	0	Harris and Sans, 1969 (p. 184)
Alfalfa	plant	sandy loam	Dieldrin (field)	0.57	<0.01	0	Harris and Sans, 1969 (p. 184)
Alfalfa	plant	sandy loam	Aldrin (field)	0.06	0	0	Harris and Sans, 1969 (p. 184)
Carrot	plant	sandy loam	Dieldrin (field)	0.57	0.03	0.05	Harris and Sans, 1969 (p. 184)
Carrot	plant	sandy loam	Aldrin (field)	0.06	0	0	Harris and Sans, 1969 (p. 184)
Carrot	NR	NR	Aldrin/dieldrin (field)	0.05-0.26	0.01-0.14	0.48[c]	Nash, 1974 (p. 272)
Peanut	meats	NR	Aldrin/dieldrin (field)	0.08-0.20	0.08-0.13	0.75[c]	

[a] UF = tissue conc./soil conc.

[b] Tissue concentration in dry weight; conversion based on an assumed water content of 87.3 percent for sugar beets which holds for the root of the common red beet, and 13.8 percent for corn (kernels) which is taken as typical of the entire plant.

[c] Based on midpoint of soil and tissue concentration ranges.

TABLE 4-3. TOXICITY OF ALDRIN/DIELDRIN TO DOMESTIC ANIMALS AND WILDLIFE

Species (N)[a]	Chemical Form Fed	Feed Concentration (μg/g DW)	Water Concentration (mg/L)	Daily Intake (mg/kg DW)	Duration of Study	Effects	References
Sheep	Dieldrin	NR[b]	NR	20	3-4 days	Reduced vigilence behavior	Sandler et al., 1969 (p. 261)
Sheep	Dieldrin	NR	NR	15	NR	Impaired visual discrimination	Pimentel, 1974 (p. 40)
Deer	Dieldrin	5-25	NR	NR	3 years	Slow growth	Pimentel, 1974 (p. 37)
Rat	Aldrin	40-60	NR	NR	NR	LD_{50}	Lawless et al., 1975 (p. 37)
Rat	Dieldrin	40	NR	NR	NR	LD_{50}	Lawless et al., 1975 (p. 37)
Raccoon	Dieldrin	2	NR	NR	NR	Impaired reproduction	Menzie, 1972 (p. 488)
Hungarian Partridge	Dieldrin	1	NR	NR	NR	Affected reproduction	U.S. EPA, 1976
Mallard	Dieldrin	NR	NR	1.25	30 days	Chronic lethal dose	Matsumura, 1972 (p. 536)
Mice	Dieldrin	2.5	NR	NR	23 months	Tumor appearance	U.S. EPA, 1976 (p. 128)
Mice	Dieldrin	5.0	NR	NR	10 months	Tumor appearance	U.S. EPA, 1976 (p. 128)
Mice	Dieldrin	10	NR	NR	9 months	Tumor appearance	U.S. EPA , 1976 (p. 128)
Mallard	Dieldrin	3	NR	NR	NR	Slight eggshell thinning	U.S. EPA, 1976 (p. 130)

TABLE 4-3. (continued)

Species (N)[a]	Chemical Form Fed	Feed Concentration (μg/g DW)	Water Concentration (mg/L)	Daily Intake (mg/kg DW)	Duration of Study	Effects	References
Mice	Aldrin	10	NR	NR	2 years	Lifespan shortened by 2 months	U.S. EPA, 1976 (p. C-45)
Mice	Dieldrin	10	NR	NR	2 years	Lifespan shortened by 2 months	U.S. EPA, 1976 (p. C-45)
Rats (12)	Aldrin	NR	NR	>50	2 years	Reduced growth rate and survival	U.S. EPA, 1980 (p. C-51)
Rats (12)	Dieldrin	NR	NR	>50	2 years	Reduced growth rate and survival	U.S. EPA, 1980 (p. C-51)
Dogs (10)	Dieldrin	NR	NR	0.005-0.05	2 years	No effect	U.S. EPA, 1980 (p. C-57)
Rhesus monkeys (30)	Dieldrin	NR	NR	0-5.0	6 years	0.1, 1.0, and 5.0 mg/kg proved lethal to 4 animals	U.S. EPA, 1980 (p. C-58)
Raccoon	Dieldrin	2-6	NR	NR	NR	Affected reproduction	NAS, 1977 (p. 567)

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

TABLE 4-4. UPTAKE OF ALDRIN/DIELDRIN BY DOMESTIC ANIMALS AND WILDLIFE

Species	Chemical Form Fed	Range of Feed Concentrations (N)[a] (µg/g)	Tissue Analyzed	Range of Tissue Concentrations (µg/g)	Uptake[b] Factor	References
Cattle	Dieldrin	3.25 (1)	Milk fat	18.0	5.54	Fries, 1982 (p. 15)
Cattle	Aldrin	50 (1)	Body fat	31.0 36.99[c]	0.62 0.74	Fries, 1982 (p. 15)
Sheep	Dieldrin	25-50 (1)	Body fat	126-191 162-245[c]	4.78-5.04 4.9-6.48	Fries, 1982 (p. 15)
Pheasant	Dieldrin	50	Muscle	2.7	0.05	Edwards, 1970 (p. 45)
Barn owl	Dieldrin	0.5	Carcass	9.2-9.6	18.4-19.2	Mendenhall et al., 1983 (p. 237)
Rat	Dieldrin	10.0	Fat	15.85	1.6	Edwards, 1970 (p. 45)
Hen	Dieldrin	0.25-0.75 (2)	Fat	10.2-35.7	40.8-47.6	Edwards, 1970 (p. 45)
Steer	Dieldrin	0.25-2.25 (3)	Fat	0.8-8.7 0.96-10.4[c]	3.2-4.7	Edwards, 1970 (p. 45)
Hog	Dieldrin	0.25-2.25 (3)	Fat	0.4-4.3 0.46-4.91[c]	1.6-3.7 0.91-3.84	Edwards, 1970 (p. 45)
Lamb	Dieldrin	0.25-2.25 (3)	Fat	0.4-1.7 0.51-2.18[c]	0.7-1.6 0.96-2.04	Edwards, 1970 (p. 45)
Chickens	Dieldrin	0.1-0.75 (2)	Fat	4.1-35.7	41-47.6	NAS, 1977 (p. 561)
Rat	Dieldrin	0-10	Fat	0.0059-1.476	0.26-8.9	U.S. EPA, 1980 (p. C-14)

[a] N = Number of feed concentrations.
[b] Uptake factor = Tissue concentration/feed concentration.
[c] Tissue concentration in dry weight; conversion is based on a mean water content of 16.2% in cattle and steer fat, 12.4% in hog fat, and 22% in sheep fat.

TABLE 4-5. TOXICITY OF ALDRIN/DIELDRIN TO SOIL BIOTA

Biota/Tissue	Chem. Form Applied	Soil Type	Control Tissue Concentration (μg/g)	Experimental Soil Concentration (μg/g)	Experimental Application Rate (kg/ha)	Experimental Tissue Concentration (μg/g)	Effect	References
Soil fungi	Aldrin	loamy sand	NR[a]	12.5	NR	NR	12% increase in fungus weight	Eno and Everett, 1958 (p. 328)
Soil fungi	Aldrin	loamy sand	NR	50	NR	NR	16% increase in fungus weight	Eno and Everett, 1958 (p. 328)
Soil fungi	Aldrin	loamy sand	NR	100	NR	NR	22% increase in fungus weight	Eno and Everett, 1958 (p. 328)
Soil bacteria	Dieldrin	sandy sand	NR	NR	11.2	NR	21% decrase in total count	Martin, 1972 (p. 745)
Soil fungi	Dieldrin	sandy laom	NR	NR	11.2	NR	8% increase in total count	Martin, 1972 (p. 745)
Earthworm	Aldrin	bedding	NR	15	NR	NR	20% mortality after 6 weeks	Cathey, 1982 (p. 75-76)
Earthworm	Aldrin	bedding	NR	30	NR	NR	37.5% mortality after 6 weeks	Cathey, 1982 (p. 75-76)
Earthworm	Aldrin	bedding	NR	60	NR	NR	47.5% mortality after 6 weeks	Cathey, 1982 (p. 75-76)
Earthworm	Aldrin	bedding	NR	150	NR	NR	90.0% mortality after 6 weeks	Cathey, 1982 (p. 75-76)
Earthworm	Aldrin	bedding	NR	3	NR	NR	"skin blisters"	Cathey, 1982 (p. 75-76)
Cricket larvae	Aldrin	bedding	NR	0.1	NR	NR	"bioactivity" threshold	Harris, 1970 (p. 784)

[a] NR = Not reported.

TABLE 4-6. UPTAKE OF ALDRIN/DIELDRIN BY SOIL BIOTA

Biota/Tissue	Chemical Form Applied	Soil Type	Range of Soil Concentrations (μg/g WW)	Range of Tissue Concentration (μg/g WW)	Uptake[a,d] Factor	References
Earthworm/whole	Aldrin	Agricultural	0.06	0.07	1.2	Korschgen, 1970 (p. 190-192)
Ground beetle (<u>Harpalus</u>)/whole	Aldrin	Agricultural	0.06	0.11	1.8	Korschgen, 1970 (p. 190-192)
Cricket/whole	Aldrin	Agricultural	0.06	0.01	0.17	Korschgen, 1970 (p. 190-192)
Ground beetle (<u>Poecilus</u>)/whole	Aldrin	Agricultural	0.06	0.34	5.80	Korschgen, 1970 (p. 190-192)
Cricket/whole	Dieldrin	Agricultural	0.13-1.46	0.63-11.79	12.0	Gile et al., 1982 (p. 298-299)
Snail/whole	Dieldrin	Agricultural	0.13-1.46	0.79-7.53	10.4	Gile et al., 1982 (p. 298-299)
Earthworm/whole	Dieldrin	Agricultural	0.10[c]	0.99[c]	9.9	Gish, 1970 (p. 241-252)
Earthworm/whole	Dieldrin	Agricultural	0.25	1.42	5.7	Korschgen, 1970 (p. 190-192)
Cricket/whole	Dieldrin	Agricultural	0.25	0.22	0.88	Korschgen, 1970 (p. 190-192)
Ground beetle (<u>Harpalus</u>)/whole	Dieldrin	Agricultural	0.25	0.99	3.9	Korschgen, 1970 (p. 190-192
Earthworm/whole	Dieldrin	Agricultural	0.13-1.46	3.7	9.2[b]	Gile et al., 1982 (p. 298)
Earthworm/whole	Aldrin plus dieldrin	Agricultural	0.31	0.56-5.65	4.8	Thompson, 1973 (p. 101)
Ground beetle (<u>Poecilus</u>)/whole	Dieldrin	Agricultural	0.25	9.33	37.33	Korschgen, 1970 (p. 190-192)
Slug	Dieldrin	Agricultural	0.0034-0.024[c]	0.21-2.84[c]	74.4[d]	Gish, 1970 (p. 249-250)

[a] UF = tissue conc./soil conc.
[b] Based on a weighted average of the soil concentration in a 38 x 50 x 10 cm area, i.e., 0.40 μg/g.
[c] Dry weight.
[d] Based on arithmetic means for biota and soil concentrations.

SECTION 5

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APPENDIX

PRELIMINARY HAZARD INDEX CALCULATIONS FOR ALDR. N/DIELDRIN IN MUNICIPAL SEWAGE SLUDGE

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

A. Effect on Soil Concentration of Aldrin/Dieldrin

1. Index of Soil Concentration (Index 1)

a. Formula

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

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

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

$$0.001177 \ \mu g/g \ DW = \frac{(0.22 \ \mu g/g \ DW \times 5 \ mt/ha) + (0.00063 \ \mu g/g \ DW \times 2000 \ mt/ha)}{(5 \ mt/ha \ DW + 2000 \ mt/ha \ DW)}$$

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

$$0.005367 \ \mu g/g \ DW = 0.001177 \ \mu g/g \ DW \, [1 + 0.5^{(1/2.8)} + 0.5^{(2/2.8)} + \ldots + 0.5^{(99/2.8)}]$$

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

$$0.000039 = \frac{0.001177 \ \mu g/g \ DW}{30 \ \mu g/g \ DW}$$

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 $[\mu g/g \text{ soil DW}]^{-1}$)
TR = Feed concentration toxic to predator (μg/g DW)

b. Sample calculation

$$0.087573 = \frac{0.001177 \ \mu g/g \ DW \times 74.4 \ \mu g/g \text{ tissue DW } (\mu g/g \text{ soil DW})^{-1}}{1.0 \ \mu g/g \ DW}$$

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**

$$0.000094 = \frac{0.001177 \ \mu g/g \ DW}{12.5 \ \mu g/g \ DW}$$

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

a. **Formula**

$$\text{Index 5} = I_1 \times UP$$

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**

$$0.000023 \ \mu g/g \ DW = 0.001177 \ \mu g/g \ DW \times 0.02 \ \mu g/g \text{ tissue DW } (\mu g/g \text{ soil DW})^{-1}$$

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

a. **Formula**

$$\text{Index 6} = PP$$

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

$$0.000023 = \frac{0.000023 \ \mu g/g \ DW}{1 \ \mu g/g \ DW}$$

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

a. Formula

If AR = 0; Index 8 = 0

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

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

$$\text{If } AR \neq 0; \ 0.011 = \frac{0.22 \ \mu g/g \ DW \times 0.05}{1 \ \mu g/g \ DW}$$

E. Effect on Humans

1. Index of Human Cancer Risk Resulting from Plant Consumption (Index 9)

a. Formula

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

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)
RSI = Cancer risk-specific intake (μg/day)

b. Sample calculation (toddler)

$$157.7252 = \frac{(0.000882\ \mu g/g\ DW \times 74.5\ g/day) + 0.297\ \mu g/day}{0.0023\ \mu g/day}$$

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

a. Formula

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

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)
RSI = Cancer risk-specific intake (μg/day)

b. Sample calculation (toddler)

132.0377 = [(0.000023 μg/g DW x 6.5 μg/g tissue DW

[μg/g feed DW]$^{-1}$ x 43.7 g/day DW) + 0.297 μg/day] ÷

0.0023 μg/day

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

a. Formula

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

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

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)
RSI = Cancer risk-specific intake (μg/day)

b. **Sample calculation (toddler)**

1353.956 = [(0.22 μg/g DW x 0.05 x 6.5 μg/g tissue DW [μg/g feed DW]$^{-1}$ x 39.4 g/day DW) + 0.297 μg/day] ÷ 0.0023 μg/day

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

a. **Formula**

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

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)
RSI = Cancer risk-specific intake (μg/day)

b. **Sample calculation (toddler)**

$$131.6892 = \frac{(0.001177\ \mu g/g\ DW \times 5\ g/day) + 0.297\ \mu g/day}{0.0023\ \mu g/day}$$

5. **Index of Aggregate Human Cancer Risk (Index 13)**

a. **Formula**

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

where:

I_9 = Index 9 = Index of human toxicity/cancer risk resulting from plant consumption (unitless)

I_{10} = Index 10 = Index of human toxicity/cancer risk resulting from consumption of animal products derived from animals feeding on plants (unitless)

I_{11} = Index 11 = Index of human toxicity/cancer risk resulting from consumption of animal products derived from animals ingesting soil (unitless)

I_{12} = Index 12 = Index of human toxicity/cancer risk resulting from soil ingestion (unitless)

DI = Average daily human dietary intake of pollutant (μg/day)

RSI = Cancer risk-specific intake (μg/day)

b. **Sample calculation (toddler)**

$$1388.017 = (157.7252 + 132.0377 + 1353.956 + 131.6892) - \left(\frac{3 \times 0.297\ \mu g/day}{0.0023\ \mu g/day}\right)$$

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

A. **Index of Air Concentration Increment Resulting from Incinerator Emissions (Index 1)**

1. **Formula**

$$\text{Index 1} = \frac{(C \times DS \times SC \times FM \times DP) + BA}{BA}$$

where:

C = Coefficient to correct for mass and time units (hr/sec x g/mg)
DS = Sludge feed rate (kg/hr DW)
SC = Sludge concentration of pollutant (mg/kg DW)
FM = Fraction of pollutant emitted through stack (unitless)
DP = Dispersion parameter for estimating maximum annual ground level concentration ($\mu g/m^3$)
BA = Background concentration of pollutant in urban air ($\mu g/m^3$)

2. Sample Calculation

$$1.127743 = [(2.78 \times 10^{-7} \text{ hr/sec} \times \text{g/mg} \times 2660 \text{ kg/hr DW} \times 0.22 \text{ mg/kg DW} \times 0.05 \times 3.4 \ \mu g/m^3) + 0.000216 \ \mu g/m^3] \div 0.000216 \ \mu g/m^3$$

B. Index of Human Cancer Risk Resulting from Inhalation of Incinerator Emissions (Index 2)

1. Formula

$$\text{Index 2} = \frac{[(I_1 - 1) \times BA] + BA}{EC}$$

where:

I_1 = Index 1 = Index of air concentration increment resulting from incinerator emissions (unitless)
BA = Background concentration of pollutant in urban air ($\mu g/m^3$)
EC = Exposure criterion ($\mu g/m^3$)

2. Sample Calculation

$$2.121255 = \frac{[(1.127743 - 1) \times 0.000216 \ \mu g/m^3] + 0.000216 \ \mu g/m^3}{0.000115 \ \mu g/m^3}$$

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**

$$0.00044\ \mu g/L = \frac{0.22\ mg/kg\ DW \times 1600000\ kg\ WW \times 0.04\ kg\ DW/kg\ WW \times 10^3\ \mu g/mg}{200\ m \times 20\ m \times 8000\ m \times 10^3\ L/m^3}$$

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**

$$0.000119\ \mu g/L = \frac{825000\ kg\ DW/day \times 0.22\ mg/kg\ DW \times 10^3\ \mu g/mg}{9500\ m/day \times 20\ m \times 8000\ m \times 10^3\ L/m^3}$$

C. Index of 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**

$$0.062846 = \frac{0.000119 \ \mu g/L}{0.0019 \ \mu g/L}$$

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

1. **Formula**

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

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)
RSI = Cancer risk-specific intake (μg/day)

2. **Sample Calculation**

903.9131 =

$$\frac{(0.000119 \ \mu g/L \times 4670 \ L/kg \times 10^{-3} \ kg/g \times 0.000021 \times 14.3 \ g \ WW/day) + 2.079 \ \mu g/day}{0.0023 \ \mu g/day}$$