United States
Environmental Protection
Agency

Office of Water
Regulations and Standards
Washington, DC 20460

Water

June, 1985

EPA

Environmental Profiles and Hazard Indices for Constituents of Municipal Sludge: Chlorinated Dioxins

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.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

SECTION 1

INTRODUCTION

This preliminary data profile is one of a series of profiles dealing with chemical pollutants potentially of concern in municipal sewage sludges. Tetrachlorodibenzodioxins (TCDDs) were initially identified as being of potential concern when sludge is incinerated or ocean disposed.* This profile is a compilation of information that may be useful in determining whether TCDDs pose an actual hazard to human health or the environment when sludge is disposed of by these methods.

The focus of this document is the calculation of "preliminary hazard indices" for selected potential exposure pathways, as shown in Section 3. Each index illustrates the hazard that could result from movement of a pollutant by a given pathway to cause a given effect (e.g., sludge → air → 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 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.

---

* 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 TETRACHLORODIBENZODIOXINS IN MUNICIPAL SEWAGE SLUDGE

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

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

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

II. LANDFILLING

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

III. INCINERATION

Conclusions were not drawn because index values could not be calculated due to lack of data.

IV. OCEAN DISPOSAL

Conclusions were not drawn because index values could not be calculated due to lack of data.

SECTION 3

PRELIMINARY HAZARD INDICES FOR TETRACHLORODIBENZODIOXINS IN MUNICIPAL SEWAGE SLUDGE

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

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

II. LANDFILLING

Based on the recommendations of the experts at the OWRS meetings (April-May, 1984), an assessment of this reuse/disposal option is not being conducted at this time. 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 (Camp Dresser and McKee, Inc. (CDM), 1984a). 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) - Data not immediately available.

TCDDs were not analyzed in a study (U.S. EPA, 1982) of sludges from 50 publicly-owned treatment works (POTWs) nor were they reported in a summary of sludge data from POTWs throughout the United States (CDM, 1984b).

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)** - Data not immediately available.

4. **Index 1 Values** - Values were not calculated due to lack of data.

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

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

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)** - Values were not calculated due to lack of data.

b. **Background concentration of pollutant in urban air (BA)** - Data not immediately available.

c. **Cancer potency** = 1.56×10^5 $(mg/kg/day)^{-1}$

Cancer potency is based on data generated during a two-year evaluation of the carcinogenicity of 2,3,7,8-TCDD in rats (U.S. EPA, 1984b). (See Section 4, p. 4-4.)

d. **Exposure criterion (EC) = 2.2 x 10^{-8} µg/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** - Values were not calculated due to lack of data.

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.

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

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 7.5×10^6 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)** - Data not immediately available.

See Section 3, p. 3-2.

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)** - Values cannot be calculated due to lack of data on detection limits for TCDDs in sludge. If this information were available, all null values would be 0 and all other values would be expressed in the form of "less than".

6. **Value Interpretation** - Values would equal the expected increase in concentration of TCDDs in seawater around a disposal site as a result of sludge disposal after initial mixing.

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

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. 3-5 to 3-7.

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

   See Section 3, p. 3-8.

5. **Index 2 Values (μg/L)** - Values cannot be calculated due to lack of data on detection limits for TCDDs in sludge. If this information were available, all null values would be 0 and all other values would be expressed in the form of "less than".

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

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

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 TCDDs, 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)** - Values were not calculated due to lack of data.

   b. **Ambient water quality criterion (AWQC) =** 0.00001 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 TCDDs.

   The 0.00001 μg/L value chosen as the criterion to protect saltwater organisms is expressed as a 24-hour average concentration (Federal Register, 1984). Estimated bioconcentration factors (BCFs) for 2,3,7,8-TCDD range from 3,000 to 900,000, but the available measured BCFs range from 390 to 13,000. If the BCF is 5,000, concentrations above 0.00001 μg/L should result in concentrations in edible freshwater and saltwater fish and shellfish that exceed levels identified in an FDA health advisory. If the BCF is greater than 5,000 or if uptake in a field situation is greater than that in laboratory tests, concentrations of less than 0.00001 μg/L could result in exceedence of level in the FDA health advisory. (See Section 4, p. 4-6.)

4. **Index 3 Values** - Values could not be calculated due to lack of Index 2 values.

5. **Value Interpretation** - Value would equal the factor by which the expected seawater concentration increase in TCDDs exceeds the marine water quality criterion. A value >1 would indicate that a tissue residue hazard might exist for aquatic life. Even for values approaching 1, a TCDD residue in tissue hazard might exist thus jeopardizing the marketability of edible saltwater organisms. The criterion value of 0.00001 µg/L is probably too high because if the assumed BCF of 5,000 is actually greater or if uptake in a field situation is greater than in laboratory tests upon which the 5,000 BCF is based, ambient water concentrations of less than 0.00001 µg/L could result in exceedence of the FDA health advisory tissue TCDDs residue level.

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

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 (Index 2) by a bioconcentration factor. It also assumes that, over the long term, the seafood catch from the disposal site vicinity will be diluted to some extent by the catch from uncontaminated areas.

3. **Data Used and Rationale**

a. **Concentration of pollutant in seawater around a disposal site (Index 2)** - Values were not calculated due to lack of data.

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:

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

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

For the worst (near shore) site:

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

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

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

For the typical (deep water) site:

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

For the worst (near shore) site:

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

d. **Bioconcentration factor of pollutant (BCF)** = 1975 L/kg

The value chosen is the weighted average BCF of TCDDs for the edible portion of all freshwater and estuarine aquatic organisms consumed by U.S. citizens (U.S. EPA, 1984a,b). 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 TCDDs 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 appropriate percent lipid content of consumed fish and shellfish. It should be noted that lipids of marine species differ in both structure and quantity from those of freshwater species. Although a BCF value calculated entirely from marine data would be more appropriate for this assessment, no such data are presently available.

e. **Average daily human dietary intake of pollutant (DI)** - Data not immediately available.

f. **Cancer potency** = 1.56×10^5 $(mg/kg/day)^{-1}$

See Section 3, p. 3-3.

g. **Cancer risk-specific intake (RSI)** = 4.49×10^{-7} 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:

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

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

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

SECTION 4

PRELIMINARY DATA PROFILE FOR TETRACHLORODIBENZODIOXIN IN MUNICIPAL SEWAGE SLUDGE

I. OCCURRENCE

Polychlorinated dibenzodioxins (PCDDs), including 2,3,7,8-TCDD, are not commercially produced. They are found as trace amounts and unwanted impurities in the manufacture of other chemicals, primarily chlorophenols and their derivatives. There is no known technical use for PCDDs. — U.S. EPA, 1984b (p. 4-1)

Despite the large scale application of TCDD contaminated herbicides, and extensive TCDD analysis and monitoring, there is little evidence of widespread occurrence of TCDDs in the environment. — Crosby and Wong, 1977 (p. 1337)

A. Sludge

Data not immediately available on concentrations of TCDDs in sludge.

TCDDs were not detected in sludge from 50 POTWs. — U.S. EPA, 1982 (p. 41)

TCDDs not detected in comparison study of surveys of toxic substances in sludges from POTWs throughout the United States. — CDM, 1984b (p. 7)

B. Soil - Unpolluted

1. Frequency of Detection

Data not immediately available.

2. Concentration

Dioxin in soils of U.S. cities (1978 data): — Long and Hanson, 1983 (p. 32)

Midland, MI - 0.0016-0.0072 ng/g
Chicago, IL - 0.0010-0.0042 ng/g
Lansing, MI - ND-0.0030 ng/g
Detroit, MI - 0.0021-0.0036 ng/g

<0.020 to 2.9 ng/g in soils in contaminated areas — U.S. EPA, 1984b (p. 4-25)

C. Water - Unpolluted

1. Frequency of Detection

A National Academy of Sciences document (NAS, 1977) states that 2,3,7,8-TCDD has never been detected in drinking water in the parts per trillion range. The two most likely sources of 2,3,7,8-TCDD contamination are discharge of contaminated effluents and washouts from contaminated disposal sites. However, even after contamination 2,3,7,8-TCDD should remain strongly sorbed to sediments and biota.	U.S. EPA, 1984a (p. C-1)
No PCDD contamination of any U.S. water supply has been reported.	U.S. EPA, 1984b (p. 4-31)

2. Concentration

Data not immediately available.

D. Air

1. Frequency of Detection

Data not immediately available.

2. Concentration

<9 to 20 pg of 2,3,7,8-TCDD in air of Elizabeth, NJ, following industrial fire, based on air filter analysis	U.S. EPA, 1984a (p. C-15)
No 2,3,7,8-TCDD detected in air above Love Canal, NY area (Detection limit: 1 to 20 ppt; 13.17 to 263.31 ng/m^3)	U.S. EPA, 1984a (p. C-16)
1,100 ppt (14.48 $\mu g/m^3$) detected in air above hazardous waste disposal site near Jacksonville, AR	U.S. EPA, 1984a (p. C-16)
Emissions from incinerators are a potential source of dioxins which are formed during burning of organic materials. 2,3,7,8-TCDD detected in incinerator emissions at a "low level" and at 0.4 ng/g in fly ash.	U.S. EPA, 1984a (p. C-16)

E. Food

1. Total Average Intake

Data not immediately available.

2. Concentration

Dioxin has not been detected in U.S. grains and cereals, even in areas where contaminated 2,5,4-trichlorophenoxy acetic acid (2,4,5-T) has been sprayed.	U.S. EPA, 1984a (p. C-6)
4 to 70 pg/g 2,3,7,8-TCDD has been observed in fatty tissues of cattle grazing on 2,4,5-T treated grazing land. Other studies show no dioxin in fat of cattle (Detection limit 1 pg/g) grazing in 2,4,5-T treated land.	U.S. EPA, 1984a (p. C-7)
No dioxin observed in charcoal broiled steak; study conducted to determine dioxin formation during cooking (Detection limit: 1 to 10 pg/g)	
<7 to 480 pg/g in fish from the lower Arkansas River drainage	U.S. EPA, 1984a
1.0 to 162 pg/g in fish from Great Lakes region	
28 to 695 pg/g in fish from Tittabawassee, Saginaw, and Grand Rivers (all values result of industrial contamination)	

II. HUMAN EFFECTS

A. Ingestion

1. Carcinogenicity

a. Qualitative Assessment

The evidence for human carcinogenicity of 2,3,7,8-TCDD is regarded as "inadequate" in the IARC classification. Based on the overall evidence, including animal studies, 2,3,7,8-TCDD is given an IARC rating of 2B, or "probably carcinogenic in humans".	U.S. EPA, 1984b (p. 11-133)

b. Potency

The cancer potency for 2,3,7,8-TCDD is 1.56 x 10^5 $(mg/kg/day)^{-1}$ based on statistical analyses of tumors occurring in female Sprague-Dawley rats during a lifetime feeding study. — U.S. EPA, 1984b (p. 11-113)

c. Effects

Taken together, epidemiological studies of workers exposed to phenoxy acids and/or chlorophenols (and consequently with other impurities including TCDDs) suggest an association with the occurrence of soft tissue sarcomas (STS) in exposed individuals. These studies are only suggestive of a relationship between TCDDs and STS due to the presence of the confounding effects of phenoxy acids and/or chlorophenols. — U.S. EPA, 1984b

2. Chronic Toxicity

Data not assessed since evaluation is based on carcinogenicity.

3. Absorption Factor

Data not immediately available.

4. Existing Regulations

a. Ambient Water

The U.S. EPA has set criteria of 1.3 x 10^{-7}, 1.3 x 10^{-8} or 1.3 x 10^{-9} µg/L based on lifetime cancer risks of 10^{-5}, 10^{-6}, and 10^{-7}, respectively. — U.S. EPA, 1984b (p. 13-1)

b. Fish

$\geq$50 ng/g 2,3,7,8-TCDD in fish should not be consumed, based on FDA Health advisory. — U.S. EPA, 1984a (p. C-176)

B. Inhalation

1. Carcinogenicity

a. Qualitative Assessment

See Section 4, p. 4-3.

b. Potency

The cancer potency for 2,3,7,8-TCDD is 1.56×10^5 $(mg/kg/day)^{-1}$. This potency estimate has been derived from that for ingestion, assuming 100% absorption for both ingestion and inhalation routes. (See Section 4, p. 4-4.)

c. Effects

Data not immediately available.

2. Chronic Toxicity

Data not assessed since evaluation based on carcinogenicity.

3. Absorption Factor

Data not assessed since evaluation based on carcinogenicity.

4. Existing Regulations

No current regulations in effect.	U.S. EPA, 1984b

III. PLANT EFFECTS

A. Phytotoxicity

Data not immediately available.

B. Uptake

2,3,7,8-TCDD adsorbs strongly onto soils, reducing its bioavailability	U.S. EPA, 1984b (p. 5-9)
Two researchers failed to detect any uptake of TCDDs in plants. It was concluded that 2,3,7,8-TCDD is not likely to concentrate in plants grown in contaminated soils.	U.S. EPA, 1984b (p. 5-11)

See Table 4-1.

IV. DOMESTIC ANIMAL AND WILDLIFE EFFECTS

A. Toxicity

See Table 4-2.

B. Uptake

See Table 4-3.

V. AQUATIC LIFE EFFECTS

A. Toxicity

1. Freshwater

Concentrations of 0.001 to 0.0001 μg/L of 2,3,7,8-TCDD resulted in sublethal effects when tested on rainbow trout and northern pike early life stages.	U.S. EPA, 1984a (p. B-7)

2. Saltwater

Data not immediately available.

B. Uptake

Weighted average BCF for edible portion of all freshwater and estuarine aquatic organisms consumed by U.S. citizens = 1975	U.S. EPA, 1984b (p. 4-33)
Estimated BCF for 2,3,7,8-TCDD is from 3,000 to 900,000. If BCF is 5,000, concentrations above 0.00001 μg/L should cause concentrations in edible fish and shellfish to exceed levels identified in an FDA health advisory.	Federal Register, 1984

VI. SOIL BIOTA EFFECTS

A. Toxicity

Forest soil exposed to dioxin contaminated 2,4,5-T with dioxin concentration of 0.1 μg/g: No effect on CO_2 evolution at application rates of 4.48×10^{-3} to 44.8 kg/ha of 2,4,5-T	Bollen and Norris, 1979 (p. 649-50)

See Table 4-4.

B. Uptake

Data not immediately available.

VII. PHYSICOCHEMICAL DATA FOR ESTIMATING FATE AND TRANSPORT

2,3,7,8-TCDD: Melting point: 305°C	Worthy, 1983 (p. 51)
Quite stable, thermal destruction requires temperatures >700°C	
Lipophilic, binding strongly to soils and other organic matter	
Sparingly soluble in water and most organic liquids	
Degraded rather quickly when directly exposed to sunlight or artifical ultraviolet light. Once in soil, however, degradation is not significant.	Worthy, 1983 (p. 53)
Water solubility: 0.2 µg/L immobile in soil 1 year half-life in laboratory soil	Bollen and Norris, 1979 (p. 648)
Emperical formula: $C_{12}H_4Cl_4O_2$ Molecular weight: 321.9	U.S. EPA, 1984a (p. A-1)
Vapor pressure: 10^{-6} mm of Hg at 25°C	U.S. EPA, 1984a (p. A-1)
Henry's law constant: 2.1×10^{-3} atmosphere m^3 mol^{-1}	
Half-life of 6 minutes from water 1 cm deep Half-life of 10 hours from water 1 m deep	
Only 5 of approximately 100 microbial strains that have the ability to degrade persistent pesticides show a slight ability to degrade 2,3,7,8-TCDD.	U.S. EPA, 1984b (p. 5-1)
4.8×10^4 soil/water partition coefficient for soil with 10% organic matter	U.S. EPA, 1984b (p. 5-7)
1 to 3 year half-life in soils	U.S. EPA, 1984b (p. 5-10)
Sunlight is the principal factor in dioxin disappearance from inert surfaces, plants, and soils treated with TCDD-contaminated pesticides	Crosby and Wong, 1976 (p. 1338)
56% recovery of TCDDs in Hagerstown silty clay loam after 1 year 63% recovery of TCDDs in Lakeland loamy sand after 1 year	Kearney et al., 1972 (p. 1017)

TABLE 4-1. UPTAKE OF TCDDS BY PLANTS

Plant/Tissue	Chemical Form Applied	Soil Type	Experimental Soil Concentration (μg/g)	Range of Tissue Concentration (μg/g)	Bioconcentration Factor[a]	References
Oats/seed	TCDDs	Sandy loam	0.06	<0.001	<0.02	Isensee and Jones, 1971 (p. 1212)
Soybean/seed	TCDDs	Sandy loam	0.06	0.006	0.1	Isensee and Jones, 1971 (p. 1212)
Oats/plant	TCDDs	Sandy loam	0.06	<0.001-0.132	2.2	Isensee and Jones, 1971 (p. 1212)
Soybean/plant	TCDDs	Sandy loam	0.06	0.005-0.059	0.98	Isensee and Jones, 1971 (p. 1212)
Soybean/root	TCDDs	Nutrient solution	0.18	0.080-20.2	252.5	Isensee and Jones, 1971 (p. 1212)
Soybean/top	TCDDs	Nutrient solution	0.18	0.020-0.77	4.28	Isensee and Jones, 1971 (p. 1212)
Oats/root	TCDDs	Nutrient solution	0.18	0.090-27.1	150.5	Isensee and Jones, 1971 (p. 1212)
Oats/top	TCDDs	Nutrient solution	0.18	0.020-1.50	8.33	Isensee and Jones, 1971 (p. 1212)

[a] BF = tissue concentration/soil concentration.

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

Species (N)[a]	Chemical Form Fed	Feed Concentration (ng/g)	Water Concentration (mg/L)	Daily Intake (µg/kg)	Duration of Study	Effects	References
Guinea pig	TCDDs in gavage	-	-	0.6-2.1	2-8 weeks	LD_{50}	U.S. EPA, 1984a (p. C-37)
Rat (5-10)	TCDDs in gavage	-	-	22	2-8 weeks	LD_{50}	
Mouse (14)	TCDDs in gavage	-	-	144	-	LD_{50}	
Rabbit	TCDDs in gavage	-	-	115	-	LD_{50}	
Dog (2)	TCDDs in gavage	-	-	30-100	2-8 weeks	Not lethal	U.S. EPA, 1984a (p. C-39)
Dog (2)	TCDDs in gavage	-	-	3,000	2-8 weeks	All animals died	
Rat	TCDDs	7	-	-	42 days	Increased liver weight	Fries and Marrow, 1975 (p. 267)
Rat	TCDDs	20	-	-	42 days	Increased liver weight, less than 7 ng/g feed rate	
Rat	TCDDs	-	-	0.01-0.1	Lifetime	Effects on liver, thymus, and reproduction	U.S. EPA, 1984a (p. C-54)
Rat (10)	TCDDs	0.001	-	0.0003	95 weeks	80% survival, first death at week 6	Van Miller et al., 1977 (p. 539)
Rat (10)	TCDDs	0.005	-	0.001	95 weeks	60% survival, first death at week 33	
Rat (10)	TCDDs	0.050	-	0.01	95 weeks	60% survival, first death at week 69	
Rat (10)	TCDDs	0.500	-	0.1	95 weeks	50% survival, first death at week 17	
Rat (10)	TCDDs	1-5	-	0.4-2.0	95 weeks	0% survival to 95 weeks, first death at 31 weeks	
Rat (100)	TCDDs	2.2	-	0.1	2 years	Increased mortality; decreased body weight gain, adverse hemoglobin effect	Kociba et al., 1978 (p. 279)
Rat (100)	TCDDs	0.210	-	0.01	2 years	Extensive histopathologic and hemopathologic changes	
Rat (100)	TCDDs	0.022	-	0.001	2 years	No effect	

TABLE 4-2. (continued)

Species (N)[a]	Chemical Form Fed	Feed Concentration (ng/g)	Water Concentration (mg/L)	Daily Intake (µg/kg)	Duration of Study	Effects	References
Rat	TCDDs by gavage	-	-	0.007/wk	1 year	Increased tumor incidence	U.S. EPA, 1984a (p. C-159)
Rat	TCDDs	0.001	-	-	NR[b]	0% tumor incidence	U.S. EPA, 1984b (p. 11-5)
Rat	TCDDs	0.005-1	-	-	NR	30-50% tumor incidence	
Rat	TCDDs	5	-	-	NR	70% tumor incidence	
Rat	TCDDs	50	-	-	NR	Lethal within 4 weeks	
Rat (7)	TCDDs	-	-	25	Day 7-16 of gestation	6% fetal mortality/litter; 42% abnormal fetuses	Courtney, 1976 (p. 677, 679)
Rat (7)	TCDDs	-	-	50	Day 7-16 of gestation	13% fetal mortality/litter; 74% abnormal fetuses	
Rat (6)	TCDDs	-	-	100	Day 7-16 of gestation	14% fetal mortality/litter; 86% abnormal fetuses	
Rat (6)	TCDDs	-	-	200	Day 7-16 of gestation	87% fetal mortality/litter; 100% abnormal fetuses	
Rat (5)	TCDDs	-	-	400	Day 7-16 of gestation	97% fetal mortality/litter; 100% abnormal fetuses	
Monkey (9)	TCDDs	0.5	-	-	9 months	Lethal to 5 of 9 animals	Van Miller et al., 1977 (p. 537)

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

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

Species (N)[a]	Chemical Form Fed	Range (and N) of Feed Concentration (ng/g DW)	Tissue Analyzed	Range of Tissue Concentration (ng/g WW)	Bioconcentration Factor[b]	References
Rat (60)	TCDDs	0-20(3)	Fat	0-6.20	0.17-0.31	Fries and Marrow, 1975 (p. 267)
Rat (60)	TCDDs	0-20(3)	Liver	0-0.33	<0.01-0.03	Fries and Marrow, 1975 (p. 267)
Rat	TCDDs	0.22-2.2(3)	Fat	0.54-8.1	3.68-24.54	Kociba et al., 1978, (p. 301)
Rat	TCDDs	0.022-2.2(3)	Liver	0.54-24.0	10.9-24.54	Kociba et al., 1978, (p. 301)

[a] N = Number of experimental animals or feed rates when reported.
[b] BF = Tissue concentration/feed concentration.

TABLE 4-4. TOXICITY OF TCDDS TO SOIL BIOTA

Species	Chemical Form Applied	Soil Type	Soil Concentration (ug/g DW)	Application Rate (kg/ha)	Duration of Study	Effects	References
Soil bacteria	TCCD contaminated 2,4,5-T	Forest Soil	5.2×10^{-5} 5.2×10^{-9} of TCDDs	- -	4 weeks	No effect on CO_2 evolution	Bollen and Norris, 1979 (p. 649-50)

SECTION 5

REFERENCES

Bollen, W. B., and L. A. Norris. 1979. Influence of 2,3,7,8-Tetrachlorodibenzo-p-dioxin on Respiration in a Forest Floor and Soil. Bull. Environ. Contam. Toxicol. 22:648-652.

Camp Dresser and McKee, Inc. 1984a. Development of Methodologies for Evaluating Permissible Contaminant Levels in Municipal Wastewater Sludges. Draft. Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington, D.C.

Camp Dresser and McKee, Inc. 1984b. A Comparison of Studies of Toxic Substances in POTW Sludges. Prepared for the U.S. EPA under Contract No. 68-01-6403. Annandale, VA. August.

Camp Dresser and McKee, Inc. 1984c. Technical Review of the 106-Mile Ocean Disposal Site. Prepared for the U.S. EPA under Contract No. 68-01-6403. Annandale, VA. January.

Camp Dresser and McKee, Inc. 1984d. Technical Review of the 12-Mile Sewage Sludge Disposal Site. Prepared for the U.S. EPA under Contract No. 68-01-6403. Annandale, VA. May.

City of New York Department of Environmental Protection. 1983. A Special Permit Application for the Disposal of Sewage Sludge from Twelve New York City Water Pollution Control Plants at the 12-Mile Site. New York, NY. December.

Courtney, K. D. 1976. Mouse Teratology Studies with Chlorodibenzo-p-dioxins. Bull. Environ. Contam. Toxicol. 16(6):674-681.

Crosby, D. G., and A. S. Wong. 1977. Environmental Degradation 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD). Science 195:1337-38.

Farrell, J. B. 1984. Personal Communication. Water Engineering Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH. December.

Federal Register. 1984. Water Quality Criteria. Vol. 49(32):5831. U.S. Environmental Protection Agency, Washington, D.C. February 15.

Fries, G. F., and G. S. Marrow. 1975. Retention and Excretion of 2,3,7,8-Tetrachlorodibenzo-p-dioxin by Rats. J. Agr. Food Chem. 23(2):265-269.

Isensee, A. R., and G. E. Jones. 1971. Absorption and Translocation of Root and Foliage Applied 2,4-Dichlorophenol, 2,7-Dichlorodibenzo-p-dioxin, and 2,3,7,8-Tetrachlorodibenzo-p-dioxin. J. Agr. Food Chem. 19(6):1210-1214.

Kearney, P. C., E. A. Woolson, and C. P. Ellington. 1972. Persistence and Metabolism of Chlorodioxins in Soils. Environ. Sci. Technol. 6(12):1017-1019.

Kociba, R. J., D. G. Keyes, and J. E. Beyer et al. 1978. Results for a Two-Year Chronic Toxicity and Oncogenicity Study of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in Rats. Toxicol. & Appl. Pharmacology. 46:29-303.

Long, J. R., and D. J. Hanson. 1983. Dioxin Issue Focuses on Three Major Controversies. Chemical and Engineering News. June 6. pp. 23-36.

National Academy of Sciences. 1977. Drinking Water and Health. NAS, National Research Council Safe Drinking Water Committee, Washington, D.C.

National Oceanic and Atmospheric Administration. 1983. Northeast Monitoring Program 106-Mile Site Characterization Update. NOAA Technical Memorandum NMFS-F/NEC-26. U.S. Department of Commerce National Oceanic and Atmospheric Administration. August.

Stanford Research Institute International. 1980. Seafood Consumption Data Analysis. Final Report, Task 11. Prepared for U.S. EPA under Contract No. 68-01-3887. Menlo Park, CA. September.

U.S. Environmental Agency. 1979. Industrial Source Complex (ISC) Dispersion Model User Guide. EPA 450/4-79-30. Vol. 1. Office of Air Quality Planning and Standards, Research Triangle Park, NC. December.

U.S. Environmental Protection Agency. 1982. Fate of Priority Pollutants in Publicly-Owned Treatment Works. Volume 1. EPA 44/1-82/303. U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency. 1984a. Ambient Water Quality Criteria Document for 2,3,7,8-Tetrachlorodibenzo-p-dioxin. External Review Draft. U.S. Environmental Protection Agency, Cincinnati, OH.

U.S. Environmental Protection Agency. 1984b. Health Assessment Document for Polychlorinated Dibenzo-p-dioxins. External Review Draft. U.S. Environmental Protection Agency, Cincinnati, OH.

Van Miller, J. P., J. J. Lalich, and J. R. Allen. 1977. Increased Incidence of Neoplasms in Rats Exposed to Low Levels of 2,3,7,8-Tetrachlorodibenzo-p-dioxin. Chemosphere 9:537-544.

Worthy. 1983. Both Incidence, Control of Dioxin are Highly Complex. Chemical and Engineering News. June 6. 51-56.

APPENDIX

PRELIMINARY HAZARD INDEX CALCULATIONS FOR TETRACHLORODIBENZODIOXINS IN MUNICIPAL SEWAGE SLUDGE

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

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

II. LANDFILLING

Based on the recommendations of the experts at the OWRS meetings (April-May, 1984), an assessment of this reuse/disposal option is not being conducted at this time. 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 (μg/m^3)
BA = Background concentration of pollutant in urban air (μg/m^3)

2. Sample Calculation - Values were not calculated due to lack of data.

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

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

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

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

1. **Formula**

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

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** - Values were not calculated due to lack of Index 2 values.

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

1. **Formula**

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

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