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Environmental Profiles and Hazard Indices for Constituents of Municipal Sludge: Tricresyl Phosphate

PREFACE

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

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

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SECTION 1

INTRODUCTION

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

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

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

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

The preliminary hazard indices for selected exposure routes pertinent to landspreading and distribution and marketing 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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* Listing was 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 TRICRESYL PHOSPHATE 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 Tricresyl Phosphate

Assuming a soil background concentration of 0 μg/g DW, the concentration of TCP in sludge-amended soil may be expected to increase. The greatest increases in the TCP concentration are indicated by the index values obtained when the worst-case concentration in sludge is assumed (2 orders of magnitude greater than the values obtained for the typical sludge concentration) (see Index 1).

B. Effect on Soil Biota or Predators of Soil Biota

Conclusions were not drawn because index values could not be calculated.

C. Effect on Plants and Plant Tissue Concentration

Conclusions were not drawn because index values could not be calculated.

D. Effect on Herbivorous Animals

Conclusions were not drawn because index values could not be calculated.

E. Effect on Humans

Conclusions were not drawn because index values could not be calculated.

II. LANDFILLING

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

III. INCINERATION

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

IV. OCEAN DISPOSAL

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.

SECTION 3

PRELIMINARY HAZARD INDICES FOR TRICRESYL PHOSPHATE IN MUNICIPAL SEWAGE SLUDGE

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

A. Effect on Soil Concentration of Tricresyl Phosphate

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	6.85	µg/g DW
Worst	1650	µg/g DW

The typical and worst sludge concentrations are the median and maximum concentrations reported

for TCP sludges containing detectable concentrations from publicly-owned treatment works in Michigan (Jacobs and Zabik, 1983). (See Section 4, p. 4-1.)

ii. **Background concentration of pollutant in soil (BS)** = 0 µg/g DW

Data were not immediately available concerning background concentration of TCP in soil. For the purpose of calculating Index 1, the background concentration of TCP in soil is assumed to be 0 µg/g DW.

iii. **Soil half-life of pollutant ($t_{\frac{1}{2}}$)** = 82 years

Under conditions of neutral pH, the half-life of TCP is reported to be ~82 years (Brown et al., 1975). The persistence of TCP in soils of neutral pH appears to be related to the relative absence of available OH groups to which TCP is reactive. At conditions of elevated pH (10), the half-life of TCP is reported to be 30 days (Brown et al., 1975). (See Section 4, p. 4-3.)

d. **Index 1 Values (µg/g DW)**

Sludge Concentration	Sludge Application Rate (mt/ha) 0	5	50	500
Typical	0.0	0.017	0.17	1.2
Worst	0.0	4.1	40	280

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

f. **Preliminary Conclusion** - Assuming a soil background concentration of 0 µg/g DW, the concentration of TCP in sludge-amended soil may be expected to increase. The greatest increases in the TCP concentration are indicated by the index values obtained when the worst-case concentration in sludge is assumed (2 orders of magnitude greater than the values obtained for the typical sludge concentration).

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

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

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

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

   c. **Data Used and Rationale**

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

         See Section 3, p. 3-2.

      ii. **Soil concentration toxic to soil biota (TB)** - Data not immediately available.

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

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

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

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

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

   c. **Data Used and Rationale**

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

         See Section 3, p. 3-2.

ii. **Uptake factor of pollutant in soil biota (UB)** - Data not immediately available.

iii. **Feed concentration toxic to predator (TR)** - Data not immediately available.

d. **Index 3 Values** - Values were not calculated due to lack of data.

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

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

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

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

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

c. **Data Used and Rationale**

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

See Section 3, p. 3-2.

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

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

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

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

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

a. **Explanation** - Calculates expected tissue concentrations, in μg/g DW, in plants grown in

sludge-amended soil, using uptake data for the most responsive plant species in the following categories: (1) plants included in the U.S. human diet; and (2) plants serving as animal feed. Plants used vary according to availability of data.

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

c. **Data Used and Rationale**

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

See Section 3, p. 3-2.

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

d. **Index 5 Values** - Values were not calculated due to lack of data.

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

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

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

a. **Explanation** - The index value is the maximum tissue concentration, in μg/g DW, associated with phytotoxicity in the same or similar plant species used in Index 5. The purpose is to determine whether the plant tissue concentrations determined in Index 5 for high applications are realistic, or whether such concentrations would be precluded by phytotoxicity. The maximum concentration should be the highest at which some plant growth still occurs (and thus consumption of tissue by animals is possible) but above which consumption by animals is unlikely.

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

c. **Data Used and Rationale**

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

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

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

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

D. **Effect on Herbivorous Animals**

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

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

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

c. **Data Used and Rationale**

i. **Concentration of pollutant in plant grown in sludge-amended soil (Index 5)** - Values were not calculated due to lack of data (see Section 3, p. 3-5).

ii. **Feed concentration toxic to herbivorous animal (TA)** - Data not immediately available.

d. **Index 7 Values** - Values were not calculated due to lack of data.

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

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	6.85	µg/g DW
Worst	1650	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)** - Data not immediately available.

d. **Index 8 Values** - Values were not calculated due to lack of data.

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

E. **Effect on Humans**

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

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

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

c. Data Used and Rationale

i. **Concentration of pollutant in plant grown in sludge-amended soil (Index 5)** - Values were not calculated due to lack of data (see Section 3, p. 3-5).

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)** - Data not immediately available.

iv. **Acceptable daily intake of pollutant (ADI)** - Data not immediately available.

d. **Index 9 Values** - Values were not calculated due to lack of data.

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

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

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

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

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

c. **Data Used and Rationale**

i. **Concentration of pollutant in plant grown in sludge-amended soil (Index 5)** - Values were not calculated due to lack of data (see Section 3, p. 3-5).

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

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)** - Data not immediately available.

v. **Acceptable daily intake of pollutant (ADI)** - Data not immediately available.

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

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

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

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

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

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

c. **Data Used and Rationale**

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

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

Typical 6.85 µg/g DW
Worst 1650 µg/g DW

See Section 3, p. 3-1.

iii. **Background concentration of pollutant in soil (BS)** = 0 µg/g DW

See Section 3, p. 3-2.

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

See Section 3, p. 3-7.

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

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

Toddler 39.4 g/day
Adult 82.4 g/day

The affected tissue intake value is assumed to be from the fat component of meat only (beef, pork, lamb, veal) and milk products

(Pennington, 1983). This is a slightly more limited choice than for Index 10. Adult intake of meats is based on males 25 to 30 years of age and the intake for milk products on males 14 to 16 years of age, the age-sex groups with the highest daily intake. Toddler intake of milk products is actually based on infants, since infant milk consumption is the highest among that age group (Pennington, 1983).

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

viii. **Acceptable daily intake of pollutant (ADI)** - Data not immediately available.

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

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

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

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

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

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

c. **Data Used and Rationale**

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

See Section 3, p. 3-2.

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

Pica child	5	g/day
Adult	0.02	g/day

The value of 5 g/day for a pica child is a worst-case estimate employed by U.S. EPA's

Exposure Assessment Group (U.S. EPA, 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)** - Data not immediately available.

iv. **Acceptable daily intake of pollutant (ADI)** - Data not immediately available.

d. **Index 12 Values** - Values were not calculated due to lack of data.

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

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

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

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

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

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

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

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

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

II. LANDFILLING

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

III. INCINERATION

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

IV. OCEAN DISPOSAL

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.

SECTION 4

PRELIMINARY DATA PROFILE FOR TRICRESYL PHOSPHATE IN MUNICIPAL SEWAGE SLUDGE

I. OCCURRENCE

A. Sludge

1. Frequency of Detection

Found in 162 of 235 sludges from more than 200 Michigan POTWs (69%)	Jacobs and Zabik, 1983 (p. 425)

2. Concentration

Minimum:	0.069 µg/g DW	Jacobs and Zabik, 1983 (p. 425)
Median of all detected values:	6.85 µg/g DW	
Mean:	39.9 µg/g DW	
Maximum	1650 µg/g DW	

B. Soil - Unpolluted

Data not immediately available.

C. Water - Unpolluted

1. Frequency of Detection

Data not immediately available.

2. Concentration

a. Freshwater

Data not immediately available.

b. Seawater

Data not immediately available.

c. Drinking water

Survey of 29 Canadian municipalities:	Williams and LeBel, 1981 (pp. 452-454)
Frequency of detection - 23% Range 0.7 to 4.3 µg/L	

D. Air

Data not immediately available.

E. Food

Data not immediately avaialble.

II. HUMAN EFFECTS

A. Ingestion

1. Carcinogenicity

Data not immediately available.

2. Chronic Toxicity

a. ADI

Data not immediately available.

b. Effects

Lowest lethal dose observed for humans by oral ingestion = 1.0 g/kg	NIOSH/OSHA, 1978 (p. 2)
Ingestion of 6 to 7 mg/kg TCP has resulted in severe delayed paralysis presumably resulting from demyelination of nerve cells.	NIOSH/OSHA, 1978 (p. 1)

3. Absorption Factor

Data not immediately available.

4. Existing Regulations

Data not immediately available.

B. Inhalation

1. Carcinogenicity

Data not immediately available.

2. Chronic Toxicity

a. Inhalation Threshold or MPIH

See below, "Existing Regulations."

2. **Chronic Toxicity**

a. **Inhalation Threshold or MPIH**

See below, "Existing Regulations."

b. **Effects**

Data not immediately available.

3. **Absorption Factor**

Data not immediately available.

4. **Existing Regulations**

OSHA Standard 100 μg TCP/m^3/day (averaged over 8 hours)	NIOSH/OSHA, 1978 (p. 1)

III. PLANT EFFECTS

Data not immediately available.

IV. DOMESTIC ANIMAL AND WILDLIFE EFFECTS

A. **Toxicity**

LC_{50} 1 mg/kg subcutaneous (rat) LC_{50} 1900 to 2000 μg/kg oral (mouse) LC_{50} 12.1 g/kg oral (rat) Tolerated dose 0 to 200 μg/kg oral (cat)	Brown et al., 1975 (p. 138)

B. **Uptake**

Data not immediately available.

V. AQUATIC LIFE EFFECTS

Data not immediately available.

VI. SOIL BIOTA EFFECTS

Data not immediately available.

VII. PHYSICOCHEMICAL DATA FOR ESTIMATING FATE AND TRANSPORT

Formula:	$(CH_3C_6H_4)_3\ PO_4$	Hodgman et al.,
Molecular wt.:	368.36 1960	
Melting pt.:	77-78°C	
Boiling pt.:	410°C	
Solubility		
water:	insoluble	
alcohol:	very soluble	
ether:	very soluble	
Soil half-life:	82 years	Brown et al., 1975 (p. 139)

SECTION 5

REFERENCES

Bertrand, J. E., M. C. Lutrick, G. T. Edds and R. L. West. 1981. Metal Residue in Tissues, Animal Performance and Carcass Quality with Beef Steers Grazing Pensacola Bahiagrass Pastures Treated with Liquid Digested Sludge. J. Ani. Sci. 53:1.

Boswell, F. C. 1975. Municipal Sewage Sludge and Selected Element Applications to Soil: Effect on Soil and Fescue. J. Environ. Qual. 4(2):267-273.

Brown, S. L., F. Y. Chan, and J. L. Jones, et al. 1975. Research Program on Hazard Priority Ranking of Manufactured Chemicals, Phase II. National Science Foundation, Washington, D.C. PB-263-162, NTIS.

Chaney, R. L., and C. A. Lloyd. 1979. Adherence of Spray-Applied Liquid Digested Sewage Sludge to Tall Fescue. J. Environ. Qual. 8(3): 407-411.

Hodgman, C. D., R. C. Weast, and S. M. Selby (eds.). 1960. Handbook of Chemistry and Physics, 42nd ed. Chemical Rubber Publishing Co., Cleveland, OH. 3481 pp.

Jacobs, L. W., and M. J. Zabik. 1983. The Importance of Sludge-Borne Organic Chemicals for Land Application Programs. Proc. 6th Ann. Madison Conf. of Applied Research and Practice on Municipal and Industrial Waste, Madison, WI. September.

Pennington, J. A. T. 1983. Revision of the Total Diet Study Food Lists and Diets. J. Am. Diet. Assoc. 82:166-173.

Ryan, J. A., H. R. Pahren, and J. B. Lucas. 1982. Controlling Cadmium in the Human Food Chain: A Review and Rationale Based on Health Effects. Environ. Res. 28:251-302.

Thornton, I., and P. Abrams. 1983. Soil Ingestion - A Major Pathway of Heavy Metal into Livestock Grazing Contaminated Land. Sci. Total Environ. 28:287-294.

NIOSH/OSHA. 1978. Occupational Health Guidelines for Chemical Hazards. U.S. Government Printing Office, Washington, D.C.

U.S. Department of Agriculture. 1975. Composition of Foods. Agricultural Handbook No. 8.

U.S. Environmental Protection Agency. 1983. Assessment of Human Exposure to Arsenic: Tacoma, Washington. Internal Document. OHEA-E-075-U. Office of Health and Environmental Assessment. Washington, D.C. July 19.

U.S. Environmental Protection Agency. 1984. Air Quality Criteria for Lead. External Review Draft. EPA 600/8-83-028B. Environmental Criteria and Assessment Office. Research Triangle Park, NC. September.

Williams, D. T., and G. L. LeBel. 1981. A National Survey of Tri(haloalky)-, Trialkyl-, and Triarylphosphates in Canadian Drinking Water. Bull. Environ. Contam. Toxicol. 27:450-457.

APPENDIX

PRELIMINARY HAZARD INDEX CALCULATIONS FOR TRICRESYL PHOSPHATE IN MUNICIPAL SEWAGE SLUDGE

I. LANDSPREADING AND DISTRIBUTION-AND-MARKETING

A. Effect on Soil Concentration of Tricresyl Phosphate

1. Index of Soil Concentration (Index 1)

a. Formula

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

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

where:

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

b. Sample calculation

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

$$0.017\ \mu g/g\ DW = \frac{(6.85\ \mu g/g\ DW \times 5\ mt/ha) + (0\ \mu g/g\ DW \times 2000\ mt/ha)}{(5\ mt/ha\ DW + 2000\ mt/ha\ DW)}$$

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

$$1.16\ \mu g/g\ DW = 6.85\ \mu g/g\ DW \left[1 + 0.5^{(1/82)} + 0.5^{(2/82)} + \ldots + 0.5^{(99/82)}\right]$$

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

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

a. **Formula**

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

where:

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

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

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

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

a. **Formula**

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

where:

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

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

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

a. **Formula**

Index 5 = I_1 x UP

where:

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

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

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

a. **Formula**

Index 6 = PP

where:

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

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

D. **Effect on Herbivorous Animals**

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

a. **Formula**

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

where:

I_5 = Index 5 = Concentration of pollutant in plant grown in sludge-amended soil (µg/g DW)

TA = Feed concentration toxic to herbivorous animal (µg/g DW)

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

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

a. **Formula**

If AR = 0; Index 8 = 0

If AR ≠ 0; 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** - Values were not calculated due to lack of data.

E. **Effect on Humans**

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

a. **Formula**

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

where:

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

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

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

a. **Formula**

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

where:

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

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

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

a. **Formula**

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

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

where:

AR = Sludge application rate (mt DW/ha)
SC = Sludge concentration of pollutant (µg/g DW)
BS = Background concentration of pollutant in soil (µg/g DW)
GS = Fraction of animal diet assumed to be soil
UA = Uptake factor of pollutant in animal tissue (µg/g tissue DW [µg/g feed DW]$^{-1}$)
DA = Daily human dietary intake of affected animal tissue (g/day DW) (milk products and meat only)
DI = Average daily human dietary intake of pollutant (µg/day)
ADI = Acceptable daily intake of pollutant (µg/day)

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

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

a. **Formula**

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

where:

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

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

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

a. **Formula**

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

where:

I_9 = Index 9 = Index of human toxicity/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)
ADI = Acceptable daily intake of pollutant (µg/day)

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

II. LANDFILLING

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

III. INCINERATION

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

IV. OCEAN DISPOSAL

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.