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ENVIRONMENTAL ASSESSMENT FOR THE PROPOSED EFFLUENT GUIDELINES FOR THE LANDFILLS POINT SOURCE CATEGORY

Volume I

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EXECUTIVE SUMMARY

This environmental assessment quantifies the water quality-related benefits associated with achievement of the proposed BAT (Best Available Technology) and PSES (Pretreatment Standards for Existing Sources) controls for hazardous and nonhazardous landfills. Based on site-specific analyses of current conditions and changes in discharges associated with the proposal, the U.S. Environmental Protection Agency (EPA) estimated in-stream pollutant concentrations for 65 priority and nonconventional pollutants from direct and indirect discharges using stream dilution modeling. EPA assessed the potential impacts and benefits to aquatic life by comparing the modeled in-stream pollutant concentrations to published EPA aquatic life criteria guidance or to toxic effect levels. EPA projected potential adverse human health effects and benefits by: (1) comparing estimated in-stream concentrations to health-based water quality toxic effect levels or criteria; and (2) estimating the potential reduction of carcinogenic risk and noncarcinogenic hazard (systemic) from consuming contaminated fish or drinking water. Estimates of upper-bound individual cancer risks, population risks, and systemic hazards result from modeled in-stream pollutant concentrations and standard EPA assumptions. The assessment evaluates modeled pollutant concentrations in fish and drinking water to estimate cancer risk and systemic hazards among the general population, sport anglers and their families, and subsistence anglers and their families. Due to the hydrophobic nature of the two chlorinated dibenzo-p-dioxin (CDD) congeners and one chlorinated dibenzofuran (CDF) congener under evaluation, EPA projected human health benefits for only these pollutants by using the Office of Research and Development's Dioxin Reassessment Evaluation (DRE) model to estimate the potential reduction of carcinogenic risk and noncarcinogenic hazard from consuming contaminated fish. EPA used the findings from the analyses of reduced occurrence of in-stream pollutant concentrations in excess of both aquatic life and human health criteria or toxic effect levels to assess improvements in recreational fishing habitats that are impacted by hazardous and nonhazardous landfill wastewater discharges (ecological benefits). These improvements in aquatic habitats are expected to improve the quality and value of recreational fishing opportunities.

The report presents evaluations of the effect of the discharges on potential inhibition of operations at publicly owned treatment works (POTW) and on concentrations of pollutants in sewage sludge (thereby limiting its use for land application) based on current and proposed pretreatment levels. Estimations of the inhibition of POTW operations are made by comparing modeled POTW influent concentrations to available inhibition levels and estimations of contamination of sewage sludge are made by comparing projected pollutant concentrations in sewage sludge to available EPA regulatory standards. The report also presents economic productivity benefits estimations based on the incremental quantity of sludge that, as a result of reduced pollutant discharges to POTWs, meet criteria for the generally less expensive disposal method, namely land application and surface disposal.

In addition, the report presents the potential fate and toxicity of pollutants of concern associated with hazardous and nonhazardous landfill wastewater based on known characteristics of each chemical. The report includes reviews of recent literature and studies, as well as State environmental agencies contacted, for evidence of documented environmental impacts on aquatic life human health, POTW operations, and on the quality of receiving water.

Performed analyses include discharges from a representative sample set of 43 direct nonhazardous landfills, 3 indirect hazardous landfills, and 85 indirect nonhazardous landfills. EPA extrapolated results for only direct nonhazardous landfills, to the national level (approximately 158 landfills), based on the statistical methodology used for estimated costs, loads, and economic impacts. In this report, EPA provides the results of these analyses, organized by the type of discharge (direct and indirect) and type of landfill (hazardous and nonhazardous).

Comparison of In-stream Concentrations with Ambient Water Quality Criteria (AWQC)/Impacts at POTWs

Direct Discharges

(a) Nonhazardous Landfills (Sample Set)

The water quality modeling results for 43 direct nonhazardous landfills discharging 32 pollutants to 41 receiving streams indicate that at **current** discharge levels, in-stream concentrations of 1 pollutant will likely exceed **acute aquatic life criteria** or toxic effect levels in 1 of the 41 receiving streams. In-stream concentrations of 3 pollutants will likely exceed **chronic aquatic life criteria** or toxic effect levels in 12 percent (5 of the total 41) of the receiving streams. The **proposed BAT** regulatory option will eliminate **acute aquatic life** excursions. The regulatory option will also reduce the **chronic aquatic life** excursions to 2 pollutants in 3 receiving streams. Additionally, at **current** discharge levels, the modeling results project that in-stream concentrations of 1 pollutant (using a target risk of 10^{-6} (1E-6) for carcinogens) will exceed **human health criteria** or toxic effect levels (developed for consumption of water and organisms) in 5 percent (2 of the total 41) receiving streams. EPA projects no excursions of **human health criteria** or toxic effect levels (developed for organisms consumption only). The **proposed BAT** regulatory option will not reduce **human health criteria** or toxic effect levels (developed for consumption of water and organisms) excursions. The **proposed BAT** regulatory option reduces pollutant loadings by 52 percent.

(b) Nonhazardous Landfills (National Extrapolation)

Extrapolations of modeling results of the sample set include 158 nonhazardous landfills, discharging 32 pollutants to 154 receiving streams. From the extrapolated in-stream pollutant concentrations, 1 pollutant is projected to exceed **human health criteria** or toxic effect levels (developed for water and organisms consumption) in 3 percent (4 of the total 154) receiving streams at both **current** and **proposed BAT** discharge levels. The proposed regulation will reduce excursions of **chronic aquatic life criteria** or toxic effect levels due to the discharge of 3 pollutants in 4 receiving streams. **Proposed BAT** discharge levels will reduce the number of excursions from 97 excursions in 38 receiving streams at **current** conditions to 44 excursions in 34 receiving streams.

Indirect Dischargers

(a) Hazardous Landfills (Sample Set)

EPA expects compliance of all the hazardous landfills included in the sample set with the baseline treatment standards established for indirect dischargers. EPA did, however, evaluate the effects of hazardous landfill discharges to POTWs and their receiving streams.

Water quality modeling results for 3 indirect hazardous landfills that discharge 60 pollutants to 3 POTWs with outfalls on 3 receiving streams indicate that at **current** discharge levels, no in-stream pollutant concentrations will likely exceed **aquatic life criteria** (acute or chronic) or toxic effect levels. Additionally, at **current** and **proposed pretreatment** discharge levels, projections indicate that the in-stream concentration of 1 pollutant (using a target risk of 10^{-6} (1E-6) for carcinogens) will exceed **human health criteria** or toxic effect levels (developed for consumption of water and organisms) in 1 receiving stream with the magnitude of the excursion at only twofold or less. Projections show no excursions of **human health criteria** or toxic effect levels (developed for organisms consumption only). Pollutant loadings show a 42 percent reduction.

In addition, this report includes an evaluation of the potential impact of the three hazardous landfills, which discharge to three POTWs, on the inhibition of POTW operation and contamination of sludge. Projections show no inhibition or sludge contamination problems at the three POTWs receiving wastewater.

(b) Nonhazardous Landfills (Sample Set)

EPA evaluated the potential effects of POTW wastewater discharges on receiving stream water quality at only **current** discharge levels for a representative sample of 85 indirect discharging nonhazardous landfills. EPA is not proposing pretreatment standards for these indirect discharges from nonhazardous landfills based on preliminary data analyses, which show no documented persistent problems with POTW upsets or with inhibition or sludge contamination. Pollutant loadings for the 85 landfills at **current** discharge levels are 506,335 pounds-per-year.

Modeling results for the 85 indirect nonhazardous landfills that discharge 32 pollutants to 80 POTWs with outfalls on 80 receiving streams indicate that at **current** discharge levels no in-stream pollutant concentrations will likely exceed **human health criteria** or toxic effect levels (developed for water and organisms consumption/organisms consumption only). Projections indicate that in-stream concentrations of 3 pollutants will exceed **chronic aquatic life criteria** or toxic effect levels in 2 of the receiving streams, with a twofold or less magnitude of the excursions. Projections show no excursions of **acute aquatic life criteria** or toxic effect levels. Nor do projections show inhibition or sludge problems at the 80 POTWs receiving discharges from the 85 nonhazardous landfills.

Human Health Risks and Benefits

Projections for both direct and indirect landfill (hazardous and nonhazardous) wastewater discharges, show the excess annual cancer cases at **current** discharge levels and, therefore, at

proposed BAT and **proposed pretreatment** discharge levels to be far less than 0.5 for all populations evaluated from the ingestion of contaminated fish and drinking water. This benefit, therefore, projects no monetary value to society. Projections indicate systemic toxicant effects from fish consumption for both direct and indirect nonhazardous landfill discharges. For direct discharges (sample set), projections indicate that systemic effects will result from the discharge of 1 pollutant to 1 receiving stream at both **current** and **proposed BAT** discharge levels. Estimates indicate an affected population of 328 subsistence anglers and their families. Results, extrapolated to the national level, project an estimated population of 643 subsistence anglers and their families affected from the discharge of 1 pollutant to 2 receiving streams. For indirect discharges, projections show systemic toxicant effects at only **current** discharge levels due to the discharge of 1 pollutant to 1 receiving stream. Projected estimates indicate a population of 52 subsistence anglers and their families to be affected. Evaluations do not include systemic toxicant effects at **proposed pretreatment** levels. Currently, the reduction of systemic toxic effects does not include estimation of monetary values.

Ecological Benefits

Projections show potential ecological benefits of the proposed regulation, based on improvements in recreational fishing habitats, for only direct nonhazardous landfills wastewater discharges. Projections indicate that the proposed regulation will not completely eliminate in-stream concentrations in excess of aquatic life and human health ambient water quality criteria (AWQC) in any stream receiving wastewater discharges from indirect hazardous landfills (evaluations include indirect nonhazardous landfills at only **current** discharge levels; therefore, the analysis excludes them). For direct nonhazardous landfill discharges, the **proposed BAT** regulatory option eliminates concentrations in excess of AWQC at 1 receiving stream. Estimation of the monetary value of improved recreational fishing opportunity involves first calculating the baseline value of the receiving stream using a value per person day of recreational fishing, and the number of person-days fished on the receiving stream. Calculations then show the value of improving water quality in this fishery, based on the increase in value to anglers of achieving contaminant-free fishing. The resulting estimate of the increase in value of recreational fishing to anglers on the improved receiving stream is $64,300 to $230,000 (1992 dollars). Based on extrapolated data to the national level, projections indicate that the proposed regulation completely eliminates in-stream concentrations in excess of AWQC at 2 receiving streams. The resulting estimate of the increase in value of recreational fishing to anglers ranges from $126,000 to $450,000.

The estimated benefit of improved recreational fishery opportunities is only a limited measure of the value to society of the improvements in aquatic habitats expected to result from the proposed regulation. Additional benefits, which could not be quantified in this assessment, include increased assimilation capacity of the receiving stream, protection of terrestrial wildlife and birds that consume aquatic organisms, maintenance of an aesthetically pleasing environment, and improvements to other recreational activities such as swimming, water skiing, boating, and wildlife observation. Such activities contribute to the support of local and State economies.

Economic Productivity Benefits

This report also presents an evaluation of potential economic productivity benefits, based on reduced sewage sludge contamination and sewage sludge disposal costs, at POTWs receiving the discharges from indirect hazardous and nonhazardous landfills. Because projections do not show sludge contamination problems at the 3 POTWs receiving wastewater from 3 hazardous landfills, or at the 80 POTWs receiving wastewater from 85 nonhazardous landfills, projections do not include economic productivity benefits.

Pollutant Fate and Toxicity

EPA identified 68 pollutants of concern (priority, nonconventional, and conventional) in wastestreams from hazardous landfills. EPA evaluated 60 of these pollutants to assess their potential fate and toxicity based on known characteristics of each chemical.

Most of the 60 pollutants have at least one known toxic effect. Based on available physical-chemical properties and aquatic life and human health toxicity data for these pollutants, 13 exhibit moderate to high toxicity to aquatic life, 16 are classified by EPA as known or probable human carcinogens, and 43 are human systemic toxicants. In addition, 23 have EPA drinking water values (MCLs or action levels), and 20 are designated by EPA as priority pollutants. In terms of projected partitioning, 18 of the evaluated pollutants are moderately to highly volatile (potentially causing risk to exposed populations via inhalation). In the same terms, 12 have a moderate to high potential to bioaccumulate in aquatic biota (potentially accumulating in the food chain and causing increased risk to higher trophic level organisms and to exposed human populations via consumption of fish and shellfish). Also, 3 are moderately to highly adsorptive to solids. Twelve (12) are resistant to biodegradation or slowly biodegraded.

EPA also identified 38 pollutants of concern (priority, nonconventional, and conventional) in wastestreams from nonhazardous landfills. Evaluations included 32 of these pollutants to assess their potential fate and toxicity, based on known characteristics of each chemical.

Most of the 32 pollutants have at least one known toxic effect. Based on available physical-chemical properties and aquatic life and human health toxicity data for these pollutants, 5 exhibit moderate to high toxicity to aquatic life, 24 are human systemic toxicants, and 8 are classified as known or probable carcinogens by EPA. Eight (8) of the pollutants have EPA drinking water values (MCLs) and EPA designated 7 as priority pollutants. In terms of projected environmental partitioning among media, 7 of the evaluated pollutants are moderately to highly volatile. Also, 2 have a moderate to high potential to bioaccumulate in aquatic biota, 2 are moderately to highly adsorptive to solids, and 2 are slowly biodegraded.

Evaluations did not include the impacts of the 2 conventional and 5 nonconventional pollutants (one additional pollutant, amenable cyanide, is evaluated as cyanide) when modeling the effect of the proposed regulation on receiving stream water quality and POTW operations or when evaluating the potential fate and toxicity of discharged pollutants. These pollutants are total suspended solids (TSS), 5-day biological oxygen demand (BOD_5), chemical oxygen demand (COD), total dissolved solids (TDS), total organic carbon (TOC), hexane extractable material, and total phenolic compounds. The discharge of these pollutants may adversely affect human health and the environment. For example, habitat degradation may result from increased suspended particulate matter that reduces light penetration, and thus primary productivity, or from accumulation of sludge particles that alter benthic spawning grounds and feeding habitats. High COD and BOD_5 levels may deplete oxygen concentrations, which can result in mortality or other adverse effects on fish. High TOC levels may interfere with water quality by causing taste and odor problems and mortality in fish.

Documented Environmental Impacts

This assessment also includes summaries of documented environmental impacts on aquatic life, human health, POTW operations, and receiving stream water quality, based on a review of published literature abstracts, State 304(l) Short Lists, State Fishing Advisories, and contact with State environmental agencies. States identified two (2) direct discharging landfills and 10 POTWs receiving the discharges from 12 landfills as point sources that cause water quality problems and are included on their 304(l) Short List. State contacts indicate that of the two direct facilities, one is no longer a direct discharger and the other is currently in compliance with its permit limits and is no longer a source of impairment. All POTWs listed report no problems with landfill wastewater discharges. In addition, States issued fish consumption advisories for waterbodies which receive the discharge from 4 direct discharging landfills and 13 POTWs receiving the discharge from landfills. However, the majority of advisories are based on chemicals that are not pollutants of concern for the landfill industry.

1. INTRODUCTION

The purpose of this report is to present an assessment of the water quality benefits of controlling the discharge of wastewater from hazardous and nonhazardous landfills to surface waters and publicly-owned treatment works (POTWs). Potential aquatic life and human health impacts of direct nonhazardous discharges on receiving stream water quality and of indirect hazardous and nonhazardous discharges on POTWs and their receiving streams are projected at current, proposed BAT (Best Available Technology), and proposed PSES (Pretreatment Standards for Existing Sources) levels by quantifying pollutant releases and by using stream modeling techniques. The potential benefits to human health are evaluated by: (1) comparing estimated in-stream concentrations to health-based water quality toxic effect levels or U.S. Environmental Protection Agency (EPA) published water quality criteria; and (2) estimating the potential reduction of carcinogenic risk and noncarcinogenic hazard (systemic) from consuming contaminated fish or drinking water. Reduction in carcinogenic risks is monetized, if applicable, using estimated willingness-to-pay values for avoiding premature mortality. Due to the hydrophobic nature of the two chlorinated dibenzo-p-dioxin (CDD) congeners and one chlorinated dibenzofuran (CDF) congener being evaluated, human health benefits are projected for only these pollutants by using the Office of Research and Development's Dioxin Reassessment Evaluation (DRE) model to estimate the potential reduction of carcinogenic risk and noncarcinogenic hazard from consuming contaminated fish. Potential ecological benefits are projected by estimating improvements in recreational fishing habitats and, in turn, by projecting, if applicable, a monetary value for enhanced recreational fishing opportunities. Economic productivity benefits are estimated based on reduced POTW sewage sludge contamination (thereby increasing the number of allowable sludge uses or disposal options). In addition, the potential fate and toxicity of pollutants of concern associated with landfill wastewater are evaluated based on known characteristics of each chemical. Recent literature and studies are also reviewed for evidence of documented environmental impacts (e.g., case studies) on aquatic life, human health, and POTW operations and for impacts on the quality of receiving water.

While this report does not evaluate impacts associated with reduced releases of 2 conventional pollutants (total suspended solids [TSS] and 5-day biological oxygen demand

[BOD_5]) and 5 classical pollutant parameters (chemical oxygen demand [COD], total dissolved solids [TDS], total organic carbon [TOC], hexane extractable material, and total phenolic compounds), the discharge of these pollutants may have adverse effects on human health and the environment (one additional pollutant, amenable cyanide, is evaluated as cyanide). For example, habitat degradation may result from increased suspended particulate matter that reduces light penetration and primary productivity, or from accumulation of sludge particles that alter benthic spawning grounds and feeding habitats. High COD and BOD_5 levels may deplete oxygen levels, which may result in mortality or other adverse effects in fish. High TOC levels may interfere with water quality by causing taste and odor problems and mortality in fish.

The following sections of this report describe: (1) the methodology used in the evaluation of projected water quality impacts and projected impacts on POTW operations for direct and indirect discharging landfills (including potential human health risks and benefits, ecological benefits, and economic productivity benefits) in the evaluation of the potential fate and toxicity of pollutants of concern, and in the evaluation of documented environmental impacts; (2) data sources used to evaluate water quality impacts such as plant-specific data, information used to evaluate POTW operations, water quality criteria, and information used to evaluate human health risks and benefits, ecological benefits, economic productivity benefits, pollutant fate and toxicity, and documented environmental impacts; (3) a summary of the results of this analysis; and (4) a complete list of references cited in this report. The various appendices presented in Volume II provide additional detail on the specific information addressed in the main report. These appendices are available in the administrative record.

2. METHODOLOGY

2.1 Projected Water Quality Impacts

The water quality impacts and associated risks/benefits of landfill discharges at various treatment levels are evaluated by: (1) comparing projected in-stream concentrations with ambient water quality criteria,[1] (2) estimating the human health risks and benefits associated with the consumption of fish and drinking water from waterbodies impacted by the landfills industry, (3) estimating the ecological benefits associated with improved recreational fishing habitats on impacted waterbodies, and (4) estimating the economic productivity benefits based on reduced sewage sludge contamination at POTWs receiving the wastewater of landfill facilities. These analyses are performed for a representative sample set of 43 direct nonhazardous landfills, 3 indirect hazardous landfills, and 85 indirect nonhazardous landfills. Results are extrapolated, for only the direct nonhazardous landfills, to the national level (approximately 158 landfills) based on the statistical methodology used for estimated costs, loads, and economic impacts. The methodologies used in this evaluation are described in detail below.

2.1.1 Comparison of In-stream Concentrations with Ambient Water Quality Criteria

Current and proposed pollutant releases are quantified and compared, and potential aquatic life and human health impacts resulting from current and proposed pollutant releases are evaluated using stream modeling techniques. Projected in-stream concentrations for each pollutant are compared to EPA water quality criteria or, for pollutants for which no water quality criteria have been developed, to toxic effect levels (i.e., lowest reported or estimated toxic concentration). Inhibition of POTW operation and sludge contamination are also evaluated. The following three

[1] *In performing this analysis, EPA used guidance documents published by EPA that recommend numeric human health and aquatic life water quality criteria for numerous pollutants. States often consult these guidance documents when adopting water quality criteria as part of their water-quality standards. However, because those State-adopted criteria may vary, EPA used the nationwide criteria guidance as the most representative values. EPA also recognizes that currently there is no scientific consensus on the most appropriate approach for extrapolating the dose-response relationship to the low-dose associated with drinking water exposure for arsenic. EPA's National Center for Environmental Assessment and EPA's Office of Water sponsored an Expert Panel Workshop, May 21-22, 1997, to review and discuss the relevant scientific literature for evaluating the possible modes of action underlying the carcinogenic action of arsenic.*

sections (i.e., Section 2.1.1.1 through Section 2.1.1.3) describe the methodology and assumptions used for evaluating the impact of direct and indirect discharging facilities.

2.1.1.1 *Direct Discharging Facilities*

Using a stream dilution model that does not account for fate processes other than complete immediate mixing, projected in-stream concentrations are calculated at current and proposed BAT treatment levels for stream segments with direct nonhazardous discharging landfills. For stream segments with multiple landfills, pollutant loadings are summed, if applicable, before concentrations are calculated. The dilution model used for estimating in-stream concentrations is as follows.

$$C_{is} = \frac{L/OD}{FF + SF} \; x \; CF \qquad \text{(Eq. 1)}$$

where:

C_{is}	=	in-stream pollutant concentration (micrograms per liter [μg/L])
L	=	landfill pollutant loading (pounds/year [lbs/year])
OD	=	landfill operation (days/year)
FF	=	landfill flow (million gallons/day [gal/day])
SF	=	receiving stream flow (million gal/day)
CF	=	conversion factors for units

The landfill-specific data (i.e., pollutant loading, operating days, landfill flow, and stream flow) used in Eq. 1 are derived from various sources as described in Section 3.1.1 of this report. One of three receiving stream flow conditions (1Q10 low flow, 7Q10 low flow, and harmonic mean flow) is used for the two treatment levels; use depends on the type of criterion or toxic effect level intended for comparison. The 1Q10 and 7Q10 flows are the lowest 1-day and the lowest consecutive 7-day average flow during any 10-year period, respectively, and are used to estimate potential acute and chronic aquatic life impacts, respectively, as recommended in the *Technical Support Document for Water Quality-based Toxics Control* (U.S. EPA, 1991a). The harmonic mean flow is defined as the inverse mean of reciprocal daily arithmetic mean flow values and is used to estimate potential human health impacts. EPA recommends the long-term harmonic mean flow as the design flow for assessing potential human health impacts, because it provides a more conservative estimate than the arithmetic mean flow. 7Q10 flows are not appropriate for assessing potential human health impacts, because they have no consistent relationship with the long-term mean dilution.

For assessing impacts on aquatic life, the landfill operating days are used to represent the exposure duration; the calculated in-stream concentration is thus the average concentration *on days the landfill is discharging wastewater.* For assuming long-term human health impacts, the operating days (exposure duration) are set at 365 days; the calculated in-stream concentration is thus the average concentration *on all days of the year.* Although this calculation for human health impacts leads to a lower calculated concentration because of the additional dilution from days when the landfill is not in operation, it is consistent with the conservative assumption that the target population is present to consume drinking water and contaminated fish every day for an entire lifetime.

Because stream flows are not available for hydrologically complex waters such as bays, estuaries, and oceans, site-specific critical dilution factors (CDFs) or estuarine dissolved concentration potentials (DCPs) are used to predict pollutant concentrations for landfills discharging to estuaries and bays, if applicable, as follows:

$$C_{es} = \left[\left(\frac{L/OD}{FF} \right) x\ CF \right] / \ CDF \qquad \text{(Eq. 2)}$$

where:

C_{es} = estuary pollutant concentration (μg/L)

L	=	landfill pollutant loading (lbs/year)
OD	=	landfill operation (days/year)
FF	=	landfill flow (million gal/day)
CDF	=	critical dilution factor
CF	=	conversion factors for units

$$C_{es} = L \ x \ DCP \ x \ CF \qquad \text{(Eq. 3)}$$

where:

C_{es}	=	estuary pollutant concentration (μg/L)
L	=	landfill pollutant loading (lbs/year)
DCP	=	dissolved concentration potential (milligrams per liter [mg/L])
CF	=	conversion factor for units

Site-specific critical dilution factors are obtained from a survey of States and Regions conducted by EPA's Office of Pollution Prevention and Toxics (OPPT) *Mixing Zone Dilution Factors for New Chemical Exposure Assessments*, Draft Report, (U.S. EPA, 1992a). Acute CDFs are used to evaluate acute aquatic life effects; whereas, chronic CDFs are used to evaluate chronic aquatic life or adverse human health effects. It is assumed that the drinking water intake and fishing location are at the edge of the chronic mixing zone.

The Strategic Assessment Branch of the National Oceanic and Atmospheric Administration's (NOAA) Ocean Assessments Division has developed DCPs based on freshwater inflow and salinity gradients to predict pollutant concentrations in each estuary in the National Estuarine Inventory (NEI) Data Atlas. These DCPs are applied to predict concentrations. They also do not consider pollutant fate and are designed strictly to simulate concentrations of nonreactive dissolved substances. In addition, the DCPs reflect the predicted estuary-wide response and may not be indicative of site-specific locations.

Water quality excursions are determined by dividing the projected in-stream (Eq. 1) or estuary (Eq. 2 and Eq. 3) pollutant concentrations by EPA ambient water quality criteria or toxic effect levels. A value greater than 1.0 indicates an excursion.

CDD/CDF Congeners

Although hydrophobic chemicals like CDD and CDF congeners will become associated primarily with suspended particulates and sediments, concentrations will be found in the water column near the discharge point. This is particularly true if discharges are assumed to be continuous. Therefore, although the stream dilution approach is conservative, it provides a reasonable estimate of dioxin-related water quality impacts on aquatic life. However, use of the stream dilution model to assess human health impacts (water quality excursions) due to the discharge of CDD/CDF congeners is inappropriate. The Office of Research and Development's Dioxin Reassessment Evaluation (DRE) model, which provides more reliable information regarding the partitioning of CDD/CDF between sediment and the water column, and thus their bioavailability to fish, is used to estimate the carcinogenic and noncarcinogenic risks from these contaminants. (See Section 2.1.2.)

2.1.1.2 *Indirect Discharging Facilities*

Assessing the impacts of indirect hazardous and nonhazardous discharging landfills is a two-stage process. First, water quality impacts are evaluated as described in Section (a) below. Next, impacts on POTWs are considered as described in Section (b) that follows.

(a) Water Quality Impacts

A stream dilution model is used to project receiving stream impacts resulting from releases by indirect discharging landfills as shown in Eq. 4. For stream segments with multiple landfills, pollutant loadings are summed, if applicable, before concentrations are calculated. The landfill-specific data used in Eq. 4 are derived from various sources as described in Section 3.1.1 of this report. Three receiving stream flow conditions (1Q10 low flow, 7Q10 low flow, and harmonic mean flow) are used for the current and proposed pretreatment options. Pollutant concentrations are predicted for POTWs located on bays and estuaries using site-specific CDFs or NOAA's DCP calculations (Eq. 5 and Eq. 6).

$$C_{is} = (L/OD)\ x\ \frac{(1-TMT)\ x\ CF}{PF + SF} \qquad \text{(Eq. 4)}$$

where:

C_{is}	=	in-stream pollutant concentration (μg/L)
L	=	landfill pollutant loading (lbs/year)
OD	=	landfill operation (days/year)
TMT	=	POTW treatment removal efficiency
PF	=	POTW flow (million gal/day)
SF	=	receiving stream flow (million gal/day)
CF	=	conversion factors for units

$$C_{es} = \left[\left(\frac{L/OD\ x\ (1-TMT)}{PF} \right) x\ CF \right] / \ CDF \qquad \text{(Eq. 5)}$$

where:

C_{es}	=	estuary pollutant concentration (μg/L)
L	=	landfill pollutant loading (lbs/year)
OD	=	landfill operation (days/year)
TMT	=	POTW treatment removal efficiency
PF	=	POTW flow (million gal/day)
CDF	=	critical dilution factor
CF	=	conversion factors for units

$$C_{es} = L\ x\ (1-TMT)\ x\ DCP\ x\ CF \qquad \text{(Eq. 6)}$$

where:

C_{es}	=	estuary pollutant concentration (μg/L)
L	=	landfill pollutant loading (lbs/year)
TMT	=	POTW treatment removal efficiency
DCP	=	dissolved concentration potential (mg/L)
CF	=	conversion factors for units

Potential impacts on freshwater quality are determined by comparing projected in-stream pollutant concentrations (Eq. 4) at reported POTW flows and at 1Q10 low, 7Q10 low, and harmonic mean receiving stream flows with EPA water quality criteria or toxic effect levels for the protection of aquatic life and human health; projected estuary pollutant concentrations (Eq. 5 and Eq. 6), based on CDFs or DCPs, are compared to EPA water quality criteria or toxic effect levels to determine impacts. Water quality criteria excursions are determined by dividing the projected in-stream or estuary pollutant concentration by the EPA water quality criteria or toxic effect levels. (See Section 2.1.1.1 for discussion of streamflow conditions, application of CDFs or DCPs, assignment of exposure duration, comparison with criteria or toxic effect levels, and assessment of CDD and CDF congeners.) A value greater than 1.0 indicates an excursion.

(b) Impacts on POTWs

The impacts of landfill discharges on POTW operations are evaluated for the potential to inhibit POTW processes (i.e., inhibition of microbial degradation) and to limit land use or disposal of POTW sludges. Inhibition of POTW operations is determined by dividing calculated POTW influent levels (Eq. 7) with chemical-specific inhibition threshold levels. Excursions are indicated by a value greater than 1.0.

$$C_{pi} = \frac{L/OD}{PF} \times CF \qquad \text{(Eq. 7)}$$

where:

C_{pi}	=	POTW influent concentration (μg/L)
L	=	landfill pollutant loading (lbs/year)
OD	=	landfill operation (days)
PF	=	POTW flow (million gal/day)
CF	=	conversion factors for units

Limitations on sludge use (for land application) is evaluated by dividing projected pollutant concentrations in sludge (Eq. 8) by available EPA-developed criteria values for sludge. A value greater than 1.0 indicates an excursion.

$$C_{SP} = C_{pi} \times TMT \times PART \times SGF \qquad \text{(Eq. 8)}$$

where:

C_{sp}	=	sludge pollutant concentration (milligrams per kilogram [mg/kg])
C_{pi}	=	POTW influent concentration (μg/L)
TMT	=	POTW treatment removal efficiency
PART	=	chemical-specific sludge partition factor
SGF	=	sludge generation factor (5.96 parts per million [ppm])

Landfill-specific data and information used to evaluate POTWs are derived from the sources described in Sections 3.1.1 and 3.1.2. For landfills that discharge to the same POTW, their individual loadings are summed, if applicable, before the POTW influent and sludge concentrations are calculated.

The partition factor is a measure of the tendency for the pollutant to partition in sludge when it is removed from wastewater. For predicting sludge generation, the model assumes that 1,400 pounds of sludge are generated for each million gallons of wastewater processed (Metcalf & Eddy, 1972). This results in a sludge generation factor of 5.96 mg/kg per μg/L (that is, for every 1 μg/L of pollutant removed from wastewater and partitioned to sludge, the concentration in sludge is 5.96 mg/kg dry weight).

2.1.1.3 *Assumptions and Caveats*

The following major assumptions are used in this analysis:

- Background concentrations of each pollutant, both in the receiving stream and in the POTW influent, are equal to zero; therefore, only the impacts of discharging landfills are evaluated.
- Landfills are assumed to operate 365 days per year.
- An exposure duration of 365 days is used to determine the likelihood of actual excursions of human health criteria or toxic effect levels.

- Complete mixing of discharge flow and stream flow occurs across the stream at the discharge point. This mixing results in the calculation of an "average stream" concentration, even though the actual concentration may vary across the width and depth of the stream.

- The process water at each landfill and the water discharged to a POTW are obtained from a source other than the receiving stream.

- The pollutant load to the receiving stream is assumed to be continuous and is assumed to be representative of long-term landfill operations. These assumptions may overestimate risks to human health and aquatic life, but may underestimate potential short-term effects.

- 1Q10 and 7Q10 receiving stream flow rates are used to estimate aquatic life impacts, and harmonic mean flow rates are used to estimate human health impacts. 1Q10 low flows are estimated using the results of a regression analysis conducted by Versar, Inc. for EPA's Office of Pollution Prevention and Toxics (OPPT) of 1Q10 and 7Q10 flows from representative U.S. rivers and streams taken from *Upgrade of Flow Statistics Used to Estimate Surface Water Chemical Concentrations for Aquatic and Human Exposure Assessment* (Versar, 1992a). Harmonic mean flows are estimated from the mean and 7Q10 flows as recommended in the *Technical Support Document for Water-Quality-based Toxics Control* (U.S. EPA, 1991a). These flows may not be the same as those used by specific States to assess impacts.

- Pollutant fate processes, such as sediment adsorption, volatilization, and hydrolysis, are not considered. This may result in estimated in-stream concentrations that are environmentally conservative (higher).

- Pollutants without a specific POTW treatment removal efficiency provided by EPA or found in the literature are assigned a removal efficiency of zero; pollutants without a specific partition factor are assigned a value of zero.

- Sludge criteria levels are only available for seven pollutants--arsenic, cadmium, copper, lead, mercury, selenium, and zinc.

- Water quality criteria or toxic effect levels developed for freshwater organisms are used in the analysis of landfills discharging to estuaries or bays.

2.1.2 Estimation of Human Health Risks and Benefits

The potential benefits to human health are evaluated by estimating the risks (carcinogenic and noncarcinogenic hazard [systemic]) associated with reducing pollutant levels in fish tissue and drinking water from current to proposed treatment levels. Reduction in carcinogenic risks is monetized, if applicable, using estimated willingness-to-pay values for avoiding premature mortality. The following three sections (i.e., Section 2.1.2.1 through Section 2.1.2.3) describe the methodology and assumptions used to evaluate the human health risks and benefits from the consumption of fish tissue and drinking water derived from waterbodies impacted by direct nonhazardous landfills and indirect hazardous and nonhazardous discharging landfills.

2.1.2.1 *Fish Tissue*

To determine the potential benefits, in terms of reduced cancer cases, associated with reducing pollutant levels in fish tissue, lifetime average daily doses (LADDs) and individual risk levels are estimated for each pollutant discharged from a landfill based on the in-stream pollutant concentrations calculated at current and proposed treatment levels in the site-specific stream dilution analysis. (See Section 2.1.1.) Estimates are presented for sport anglers, subsistence anglers, and the general population. LADDs are calculated as follows:

$$LADD = (C \times IR \times BCF \times F \times D) \; / \; (BW \times LT) \qquad \text{(Eq. 9)}$$

where:

LADD	=	potential lifetime average daily dose (milligrams per kilogram per day [mg/kg/day])
C	=	exposure concentration (mg/L)
IR	=	ingestion rate (See Section 2.1.2.3 - Assumptions)
BCF	=	bioconcentration factor, (liters per kilogram [L/kg] (whole body x 0.5)
F	=	frequency duration (365 days/year)
D	=	exposure duration (70 years)
BW	=	body weight (70 kg)
LT	=	lifetime (70 years x 365 days/year)

Individual risks are calculated as follows:

$$R = LADD \times SF \qquad \text{(Eq. 10)}$$

where:

R	=	individual risk level
LADD	=	potential lifetime average daily dose (mg/kg/day)
SF	=	potency slope factor $(mg/kg\text{-}day)^{-1}$

The estimated individual pollutant risk levels are then applied to the potentially exposed populations of sport anglers, subsistence anglers, and the general population to estimate the potential number of excess annual cancer cases occurring over the life of the population. The number of excess cancer cases is then summed on a pollutant, landfill, and overall industry basis. The number of reduced cancer cases are assumed to be the difference between the estimated risks at current and proposed treatment levels.

Due to the hydrophobic nature of the two CDD congeners and the one CDF congener, LADDs and individual risk levels are estimated for these pollutants based on the pollutant fish tissue concentrations calculated at current and proposed treatment levels using the DRE model. The DRE model calculates the fish tissue concentration by calculating the equilibrium between CDD/CDF congeners in fish tissue and CDD/CDF congeners adsorbed to the organic fraction of sediments suspended in the water column (Appendix A). LADDs are calculated as follows:

$$LADD = \frac{(CFT \times IR \times F \times D \times CF)}{(BW \times LT)} \qquad \text{(Eq. 11)}$$

where:

LADD	=	potential lifetime average daily dose (mg/kg/day)
CFT	=	fish tissue concentration (mg/kg)
IR	=	ingestion rate (See Section 2.1.2.3 - Assumptions)
F	=	frequency duration (365 days/year)
D	=	exposure duration (70 years)
BW	=	body weight (70 kg)

LT	=	lifetime (70 years x 365 days/year)
CF	=	conversion factor

Individual risks are then calculated as shown in Eq. 10.

A monetary value of benefits to society from avoided cancer cases is estimated if current wastewater discharges result in excess annual cancer cases greater than 0.5. The valuation of benefits is based on estimates of society's willingness-to-pay to avoid the risk of cancer-related premature mortality. Although it is not certain that all cancer cases will result in death, to develop a worst case estimate for this analysis, avoided cancer cases are valued on the basis of avoided *mortality*. To value mortality, a range of values recommended by an EPA, Office of Policy Analysis (OPA) review of studies quantifying individuals' willingness-to-pay to avoid risks to life is used (Fisher, Chestnut, and Violette, 1989; and Violette and Chestnut, 1986). The reviewed studies used hedonic wage and contingent valuation analyses in labor markets to estimate the amounts that individuals are willing to pay to avoid slight increases in risk of mortality or will need to be compensated to accept a slight increase in risk of mortality. The willingness-to-pay values estimated in these studies are associated with small changes in the probability of mortality. To estimate a willingness-to-pay for avoiding certain or high probability mortality events, they are extrapolated to the value for a 100 percent probability event.[2] The resulting estimates of the value of a "statistical life saved" are used to value regulatory effects that are expected to reduce the incidence of mortality.

From this review of willingness-to-pay studies, OPA recommends a range of $1.6 to $8.5 million (1986 dollars) for valuing an avoided event of premature mortality or a statistical life saved. A more recent survey of value of life studies by Viscusi (1992) also supports this range with the finding that value of life estimates are clustered in the range of $3 to $7 million (1990 dollars). For this analysis, the figures recommended in the OPA study are adjusted to 1992 using the relative change in the Employment Cost Index of Total Compensation for All Civilian Workers from 1986 to 1992 (29 percent). Basing the adjustment in the willingness-to-pay values on change in nominal Gross Domestic Product (GDP) instead of change in inflation, accounts for the

[2] *These estimates, however, do not represent the willingness-to-pay to avoid the certainty of death.*

expectation that willingness-to-pay to avoid risk is a normal economic good, and, accordingly, society's willingness-to-pay to avoid risk will increase as national income increases. Updating to 1992 yields a range of $2.1 to $11.0 million.

Potential reductions in risks due to reproductive, developmental, or other chronic and subchronic toxic effects are estimated by comparing the estimated lifetime average daily dose and the oral reference dose (RfD) for a given chemical pollutant as follows:

$$HQ = ORI/RfD \qquad \text{(Eq. 12)}$$

where:

HQ	=	hazard quotient
ORI	=	oral intake (LADD x BW, mg/day)
RfD	=	reference dose (mg/day assuming a body weight of 70 kg)

A hazard index (i.e., sum of individual pollutant hazard quotients) is then calculated for each landfill or receiving stream. A hazard index greater than 1.0 indicates that toxic effects may occur in exposed populations. The size of the subpopulations affected are summed and compared at the various treatment levels to assess benefits in terms of reduced systemic toxicity. While a monetary value of benefits to society associated with a reduction in the number of individuals exposed to pollutant levels likely to result in systemic health effects could not be estimated, any reduction in risk is expected to yield human health related benefits.

The noncarcinogenic hazard of the CDD/CDF congeners is not estimated based on the oral intake and RfD because the establishment of an RfD for these pollutants, using the standard conventions of uncertainty, will likely be one or two orders of magnitude below average background population exposures. This situation precludes using an RfD for determining an acceptable level of CDD/CDF exposure, because at ambient background levels, effects are not readily apparent (Personal Communication from William Farland, Director of the National Center for Environmental Assessment to Andrew Smith, State Toxicologist, Maine Bureau of Health, January 24, 1997 - Appendix A). Therefore, potential systemic effects of the CDD/CDF congeners are evaluated by comparing the estimated LADD (converted to units of toxic equivalent [TEQ] by multiplying by the congener-specific toxic equivalent factor [TEF]) to ambient background levels of 120 picograms (pg) TEQ/day as estimated by EPA in the 1994 Review Draft Document *Health Assessment Document for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds* (U.S. EPA, 1994a). EPA (1994a) estimates that adverse impacts associated with dioxin exposures may occur at or within one order of magnitude of average background exposures. As exposures increase within and above this range, the probability and severity of systemic effects most likely increase. For this assessment, fish tissue exposures greater than one order of magnitude above ambient background concentration indicate that toxic effects may occur in exposed populations. The sizes of the subpopulation affected are then summed and compared at the various treatment levels to assess benefits in terms of reduced systemic toxicity.

2.1.2.2 *Drinking Water*

Potential benefits associated with reducing pollutant levels in drinking water are determined in a similar manner. LADDs for drinking water consumption are calculated as follows:

$$LADD = (C \times IR \times F \times D) \; / \; (BW \times LT) \qquad \text{(Eq. 13)}$$

where:

LADD	=	potential lifetime average daily dose (mg/kg/day)
C	=	exposure concentration (mg/L)
IR	=	ingestion rate (2L/day)
F	=	frequency duration (365 days/year)
D	=	exposure duration (70 years)
BW	=	body weight (70 kg)
LT	=	lifetime (70 years x 365 days/year)

Estimated individual pollutant risk levels greater than 10^{-6} (1E-6) are applied to the population served downstream by any drinking water utilities within 50 miles from each discharge site to determine the number of excess annual cancer cases that may occur during the life of the population. Systemic toxicant effects are evaluated by estimating the sizes of populations exposed to pollutants from a given landfill, the sum of whose individual hazard quotients yields a hazard index (HI) greater than 1.0. A monetary value of benefits to society from avoided cancer cases is estimated, if applicable, as described in Section 2.1.2.1.

2.1.2.3 *Assumptions and Caveats*

The following assumptions are used in the human health risks and benefits analyses:

- A linear relationship is assumed between pollutant loading reductions and benefits attributed to the cleanup of surface waters.
- Synergistic effects of multiple chemicals on aquatic ecosystems are not assessed; therefore, the total benefit of reducing toxics may be underestimated.
- The total number of persons who might consume recreationally caught fish and the number who rely upon fish on a subsistence basis in each State are estimated, in part, by assuming that these anglers regularly share their catch with family members. Therefore, the number of anglers in each State are multiplied by the average household size in each State. The remainder of the population of these States is assumed to be the "general population" consuming commercially caught fish.
- Five percent of the resident anglers in a given State are assumed to be subsistence anglers; the other 95 percent are assumed to be sport anglers.
- Commercially or recreationally valuable species are assumed to occur or to be taken in the vicinity of the discharges included in the evaluation.
- Ingestion rates of 6.5 grams per day for the general population, 30 grams per day (30 years) + 6.5 grams per day (40 years) for sport anglers, and 140 grams per day for subsistence anglers are used in the analysis of fish tissue (*Exposure Factors Handbook*, U.S. EPA, 1989a)
- All rivers or estuaries within a State are equally fished by any of that State's resident anglers, and the fish are consumed only by the population within that State.
- Populations potentially exposed to discharges to rivers or estuaries that border more than one State are estimated based only on populations within the State in which the landfill is located.

- The size of the population potentially exposed to fish caught in an impacted water body in a given State is estimated based on the ratio of impacted river miles to total river miles in that State or impacted estuary square miles to total estuary square miles in that State. The number of miles potentially impacted by a landfill's discharge is assumed to be 50 miles for rivers and the total surface area of the various estuarine zones for estuaries.

- Pollutant fate processes (e.g., sediment adsorption, volatilization, hydrolysis) are not considered in estimating the concentration in drinking water or fish; consequently, estimated concentrations are environmentally conservative (higher).

2.1.3 Estimation of Ecological Benefits

The potential ecological benefits of the proposed regulation are evaluated by estimating improvements in the recreational fishing habitats that are impacted by landfill wastewater discharges. Stream segments are first identified for which the proposed regulation is expected to eliminate all occurrences of pollutant concentrations in excess of both aquatic life and human health ambient water quality criteria (AWQC) or toxic effect levels. (See Section 2.1.1.) The elimination of pollutant concentrations in excess of AWQC is expected to result in significant improvements in aquatic habitats. These improvements in aquatic habitats are then expected to improve the quality and value of recreational fishing opportunities. The estimation of the monetary value to society of improved recreational fishing opportunities is based on the concept of a "contaminant-free fishery" as presented by Lyke (1993).

Research by Lyke (1993) shows that anglers may place a significantly higher value on a contaminant-free fishery than a fishery with some level of contamination. Specifically, Lyke estimates the consumer surplus[3] associated with Wisconsin's recreational Lake Michigan trout and salmon fishery, and the additional value of the fishery if it was completely free of contaminants affecting aquatic life and human health. Lyke's results are based on two analyses:

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[3] *Consumer surplus is generally recognized as the best measure from a theoretical basis for valuing the net economic welfare or benefit to consumers from consuming a particular good or service. An increase or decrease in consumer surplus for particular goods or services as the result of regulation is a primary measure of the gain or loss in consumer welfare resulting from the regulation.*

1. A multiple site, trip generation, travel cost model was used to estimate net benefits associated with the fishery under baseline (i.e., contaminated) conditions.

2. A contingent valuation model was used to estimate willingness-to-pay values for the fishery if it was free of contaminants.

Both analyses used data collected from licensed anglers before the 1990 season. The estimated incremental benefit values associated with freeing the fishery of contaminants range from 11.1 percent to 31.3 percent of the value of the fishery under current conditions.

To estimate the gain in value of stream segments identified as showing improvements in aquatic habitats as a result of the proposed regulation, the baseline recreational fishery value of the stream segments are estimated on the basis of estimated annual person-days of fishing per segment and estimated values per person-day of fishing. Annual person-days of fishing per segment are calculated using estimates of the affected (exposed) recreational fishing populations. (See Section 2.1.2.) The number of anglers are multiplied by estimates of the average number of fishing days per angler in each State to estimate the total number of fishing days for each segment. The baseline value for each fishery is then calculated by multiplying the estimated total number of fishing days by an estimate of the net benefit that anglers receive from a day of fishing where net benefit represents the total value of the fishing day exclusive of any fishing-related costs (license fee, travel costs, bait, etc.) incurred by the angler. In this analysis, a range of median net benefit values for warm water and cold water fishing days, $27.75 and $35.14, respectively, in 1992 dollars is used. Summing over all benefiting stream segments provides a total baseline recreational fishing value of landfill stream segments that are expected to benefit by elimination of pollutant concentrations in excess of AWQC.

To estimate the increase in value resulting from elimination of pollutant concentrations in excess of AWQC, the baseline value for benefiting stream segments are multiplied by the incremental gain in value associated with achievement of the "contaminant-free" condition. As noted above, Lyke's estimate of the increase in value ranged from 11.1 percent to 31.3 percent. Multiplying by these values yields a range of expected increase in value for the landfill stream segments expected to benefit by elimination of pollutant concentrations in excess of AWQC.

2.1.3.1 *Assumptions and Caveats*

The following major assumptions are used in the ecological benefits analysis:

- Background concentrations of the landfill pollutants of concern in the receiving stream are not considered.

- The estimated benefit of improved recreational fishing opportunities is only a limited measure of the value to society of the improvements in aquatic habitats expected to result from the proposed regulation; increased assimilation capacity of the receiving stream, improvements in taste and odor, or improvements to other recreational activities, such as swimming and wildlife observation, are not addressed.

- Significant simplifications and uncertainties are included in the assessment. This may overestimate or underestimate the monetary value to society of improved recreational fishing opportunities. (See Sections 2.1.1.3 and 2.1.2.3.)

- Potential overlap in valuation of improved recreational fishing opportunities and avoided cancer cases from fish consumption may exist. This potential is considered to be minor in terms of numerical significance.

2.1.4 Estimation of Economic Productivity Benefits

Potential economic productivity benefits are estimated based on reduced sewage sludge contamination due to the proposed regulation. The treatment of wastewaters generated by landfills produces a sludge that contains pollutants removed from the wastewaters. As required by law, POTWs must use environmentally sound practices in managing and disposing of this sludge. The proposed pretreatment levels are expected to generate sewage sludges with reduced pollutant concentrations. As a result, the POTWs may be able to use or dispose of the sewage sludges with reduced pollutant concentrations at lower costs.

To determine the potential benefits, in terms of reduced sewage sludge disposal costs, sewage sludge pollutant concentrations are calculated at current and proposed pretreatment levels. (See Section 2.1.1.2.) Pollutant concentrations are then compared to sewage sludge pollutant limits for surface disposal and land application (minimum ceiling limits and pollutant concentration limits). If, as a result of the proposed pretreatment, a POTW meets all pollutant limits for a sewage sludge use or disposal practice, that POTW is assumed to benefit from the increase in sewage sludge use or disposal options. The amount of the benefit deriving from changes in sewage sludge use or disposal practices depends on the sewage sludge use or disposal practices employed under current levels. This analysis assumes that POTWs choose the least expensive sewage sludge use or disposal practice for which their sewage sludge meets pollutant limits. POTWs with sewage sludge that qualifies for land application in the baseline are assumed to dispose of their sewage sludge by land application; likewise, POTWs with sewage sludge that meets surface disposal limits (but not land application ceiling or pollutant limits) are assumed to dispose of their sewage sludge at surface disposal sites.

The economic benefit for POTWs receiving wastewater from a landfill is calculated by multiplying the cost differential between baseline and post-compliance sludge use or disposal practices by the quantity of sewage sludge that shifts into meeting land application (minimum ceiling limits and pollutant concentration limits) or surface disposal limits. Using these cost differentials, reductions in sewage sludge use or disposal costs are calculated for each POTW (Eq. 14):

$$SCR = PF \times S \times CD \times PD \times CF \qquad \text{(Eq. 14)}$$

where:

SCR = estimated POTW sewage sludge use or disposal cost reductions resulting from the proposed regulation (1992 dollars)
PF = POTW flow (million gal/year)
S = sewage sludge to wastewater ratio (1,400 lbs (dry weight) per million gallons of water)
CD = estimated cost differential between least costly composite baseline use or disposal method for which POTW qualifies and least costly use or disposal method for which POTW qualifies post-compliance ($1992/dry metric ton)
PD = percent of sewage sludge disposed
CF = conversion factor for units

2.1.4.1 *Assumptions and Caveats*

The following major assumptions are used in the economic productivity benefits analysis:

- 13.4 percent of the POTW sewage sludge generated in the United States is generated at POTWs that are located too far from agricultural land and surface disposal sites for these use or disposal practices to be economical. This percentage of sewage sludge is not associated with benefits from shifts to surface disposal or land application.

- Benefits expected from reduced record-keeping requirements and exemption from certain sewage sludge management practices are not estimated.

- No definitive source of cost-saving differential exists. Analysis may overestimate or underestimate the cost differentials.

- Sewage sludge use or disposal costs vary by POTW. Actual costs incurred by POTWs affected by the landfill regulation may differ from those estimates.

- Due to the unavailability of such data, baseline pollutant loadings from all industrial sources are not included in the analysis.

2.2 Pollutant Fate and Toxicity

Human and ecological exposure and risk from environmental releases of toxic chemicals depend largely on toxic potency, inter-media partitioning, and chemical persistence. These factors are dependant on chemical-specific properties relating to toxicological effects on living organisms, physical state, hydrophobicity/lipophilicity, and reactivity, as well as the mechanism and media of release and site-specific environmental conditions.

The methodology used in assessing the fate and toxicity of pollutants associated with landfill wastewaters is comprised of three steps: (1) identification of pollutants of concern; (2) compilation of physical-chemical and toxicity data; and (3) categorization assessment. These steps are described in detail below. A summary of the major assumptions and limitations associated with this methodology is also presented.

2.2.1 Pollutants of Concern Identification

From 1992 to 1995, EPA conducted sampling and site visits at hazardous and nonhazardous landfills to determine the presence or absence of priority, conventional, and nonconventional pollutants at landfills located nationwide. Raw wastewater samples were collected at 5 hazardous landfills, and raw wastewater samples were collected at 13 nonhazardous landfills. Over 400 pollutants were characterized from the sampling including: (1) 233 priority and nonconventinal organic compounds; (2) 69 priority and nonconventional metals; (3) 4 conventional pollutants; and (5) 123 priority and nonconventional pollutants (pesticides, herbicides, dioxins, and furans). From this characterization sampling data, EPA identified pollutants of interest, by subcategory, based on their detection at treatable levels in raw wastewaters. Pollutants further eliminated from this list included treatment chemicals and non-toxic parameters. The remaining pollutants of concern (68 discharged by hazardous landfills and 38 discharged by nonhazardous landfills) are evaluated (with the exception of 2 conventional, 5 nonconventional, and amenable cyanide) to assess their potential fate and toxicity based on known characteristics of each chemical.

2.2.2 Compilation of Physical-Chemical and Toxicity Data

The chemical specific data needed to conduct the fate and toxicity evaluation for this study include aquatic life criteria or toxic effect data for native aquatic species, human health reference doses (RfDs) and cancer potency slope factors (SFs), EPA maximum contaminant levels (MCLs) for drinking water protection, Henry's Law constants, soil/sediment adsorption coefficients (K_{oc}), bioconcentration factors (BCFs) for native aquatic species, and aqueous aerobic biodegradation half-lives (BD).

Sources of the above data include EPA ambient water quality criteria documents and updates, EPA's ASsessment Tools for the Evaluation of Risk (ASTER) and the associated AQUatic Information REtrieval System (AQUIRE) and Environmental Research Laboratory-Duluth fathead minnow data base, EPA's Integrated Risk Information System (IRIS), EPA's 1993-1995 Health Effects Assessment Summary Tables (HEAST), EPA's 1991-1996 Superfund Chemical Data Matrix (SCDM), EPA's 1989 Toxic Chemical Release Inventory Screening Guide, Syracuse Research Corporation's CHEMFATE data base, EPA and other government reports, scientific literature, and other primary and secondary data sources. To ensure that the examination is as comprehensive as possible, alternative measures are taken to compile data for chemicals for which physical-chemical property and/or toxicity data are not presented in the sources listed above. To the extent possible, values are estimated for the chemicals using the quantitative structure-activity relationship (QSAR) model incorporated in ASTER, or for some physical-chemical properties, utilizing published linear regression correlation equations.

(a) Aquatic Life Data

Ambient criteria or toxic effect concentration levels for the protection of aquatic life are obtained primarily from EPA ambient water quality criteria documents and EPA's ASTER. For several pollutants, EPA has published ambient water quality criteria for the protection of freshwater aquatic life from acute effects. The acute value represents a maximum allowable 1-hour average concentration of a pollutant at any time that protects aquatic life from lethality. For pollutants for which no acute water quality criteria have been developed by EPA, an acute value from published aquatic toxicity test data or an estimated acute value from the ASTER QSAR model is used. In selecting values from the literature, measured concentrations from flow-through studies under typical pH and temperature conditions are preferred. In addition, the test organism must be a North American resident species of fish or invertebrate. The hierarchy used to select the appropriate acute value is listed below in descending order of priority.

- National acute freshwater quality criteria;
- Lowest reported acute test values (96-hour LC_{50} for fish and 48-hour EC_{50}/LC_{50} for daphnids);
- Lowest reported LC_{50} test value of shorter duration, adjusted to estimate a 96-hour exposure period;
- Lowest reported LC_{50} test value of longer duration, up to a maximum of 2 weeks exposure; and
- Estimated 96-hour LC_{50} from the ASTER QSAR model.

BCF data are available from numerous data sources, including EPA ambient water quality criteria documents and EPA's ASTER. Because measured BCF values are not available for several chemicals, methods are used to estimate this parameter based on the octanol/water partition coefficient or solubility of the chemical. Such methods are detailed in Lyman et al. (1982). Multiple values are reviewed, and a representative value is selected according to the following guidelines:

- Resident U.S. fish species are preferred over invertebrates or estimated values.
- Edible tissue or whole fish values are preferred over nonedible or viscera values.
- Estimates derived from octanol/water partition coefficients are preferred over estimates based on solubility or other estimates, unless the estimate comes from EPA Criteria Documents.

The most conservative value (i.e., the highest BCF) is selected among comparable candidate values.

(b) Human Health Data

Human health toxicity data include chemical-specific RfD for noncarcinogenic effects and potency SF for carcinogenic effects. RfDs and SFs are obtained first from EPA's IRIS, and secondarily from EPA's HEAST. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious noncarcinogenic health effects over a lifetime (U.S. EPA, 1989b). A chemical with a low RfD is more toxic than a chemical with a high RfD. Noncarcinogenic effects include systemic effects (e.g., reproductive, immunological, neurological, circulatory, or respiratory toxicity), organ-specific toxicity, developmental toxicity, mutagenesis, and lethality. EPA recommends a threshold level assessment approach for these systemic and other effects, because several protective mechanisms must be overcome prior to the appearance of an adverse noncarcinogenic effect. In contrast, EPA assumes that cancer growth can be initiated from a single cellular event and, therefore, should not be subject to a threshold level assessment approach. The SF is an upper bound estimate of the probability of cancer per unit intake of a chemical over a lifetime (U.S. EPA, 1989b). A chemical with a large SF has greater potential to cause cancer than a chemical with a small SF.

Other chemical designations related to potential adverse human health effects include EPA assignment of a concentration limit for protection of drinking water, and EPA designation as a priority pollutant. EPA establishes drinking water criteria and standards, such as the MCL, under authority of the Safe Drinking Water Act (SDWA). Current MCLs are available from IRIS. EPA has designated 126 chemicals and compounds as priority pollutants under the authority of the Clean Water Act (CWA).

(c) Physical-Chemical Property Data

Three measures of physical-chemical properties are used to evaluate environmental fate: Henry's Law constant (HLC), an organic carbon-water partition coefficient (K_{oc}), and aqueous aerobic biodegradation half-life (BD).

HLC is the ratio of vapor pressure to solubility and is indicative of the propensity of a chemical to volatilize from surface water (Lyman et al., 1982). The larger the HLC, the more likely the chemical will volatilize. Most HLCs are obtained from EPA's Office of Toxic Substances' (OTS) 1989 Toxic Chemical Release Inventory Screening Guide (U.S. EPA, 1989c), the Office of Solid Waste's (OSW) Superfund Chemical Data Matrix (U.S. EPA, 1994b), or the quantitative structure activity relationship (QSAR) system (U.S. EPA, 1993), maintained by EPA's Environmental Research Laboratory (ERL) in Duluth, Minnesota.

K_{oc} is indicative of the propensity of an organic compound to adsorb to soil or sediment particles and, therefore, partition to such media. The larger the K_{oc}, the more likely the chemical will adsorb to solid material. Most K_{oc}s are obtained from Syracuse Research Corporation's CHEMFATE data base and EPA's 1989 Toxic Chemical Release Inventory Screening Guide.

BD is an empirically-derived time period when half of the chemical amount in water is degraded by microbial action in the presence of oxygen. BD is indicative of the environmental persistence of a chemical released into the water column. Most BDs are obtained from Howard et al. (1991) and ERL-Duluth's QSAR.

2.2.3 Categorization Assessment

The objective of this generalized evaluation of fate and toxicity potential is to place chemicals into groups with qualitative descriptors of potential environmental behavior and impact. These groups are based on categorization schemes derived for:

- Acute aquatic toxicity (high, moderate, or slight);
- Volatility from water (high, moderate, slight, or nonvolatile);
- Adsorption to soil/sediment (high, moderate, slight, or nonadsorptive);
- Bioaccumulation potential (high, moderate, slight, or nonbioaccumulative); and
- Biodegradation potential (fast, moderate, slow or resistant)l

Using appropriate key parameters, and where sufficient data exist, these categorization schemes identify the relative aquatic and human toxicity and bioaccumulation potential for each chemical associated with landfill wastewater. In addition, the potential to partition to various media (air, sediment/sludge, or water) and to persist in the environment is identified for each chemical. These schemes are intended for screening purposes only and do not take the place of detailed pollutant assessments analyzing all fate and transport mechanisms.

This evaluation also identifies chemicals that: (1) are known, probable, or possible human carcinogens; (2) are systemic human health toxicants; (3) have EPA human health drinking water standards; and (4) are designated as priority pollutants by EPA. The results of this analysis can provide a qualitative indication of potential risk posed by the release of these chemicals. Actual risk depends on the magnitude, frequency, and duration of pollutant loading; site-specific environmental conditions; proximity and number of human and ecological receptors; and relevant exposure pathways. The following discussion outlines the categorization schemes. Ranges of parameter values defining the categories are also presented.

(a) Acute Aquatic Toxicity

Key Parameter: Acute aquatic life criteria/LC_{50} or other benchmark (AT) (μg/L)

Using acute criteria or lowest reported acute test results (generally 96-hour and 48-hour durations for fish and invertebrates, respectively), chemicals are grouped according to their relative short-term effects on aquatic life.

Categorization Scheme:

$AT < 100$	Highly toxic
$1{,}000 \geq AT \geq 100$	Moderately toxic
$AT > 1{,}000$	Slightly toxic

This scheme, used as a rule-of-thumb guidance by EPA's OPPT for Premanufacture Notice (PMN) evaluations, is used to indicate chemicals that could potentially cause lethality to aquatic life downstream of discharges.

(b) Volatility from Water

Key Parameter: Henry's Law constant (HLC) (atm-m^3/mol)

$$HLC = \frac{Vapor\ Pressure\ (atm)}{Solubility\ (mol/m^3)} \qquad \text{(Eq. 15)}$$

HLC is the measured or calculated ratio between vapor pressure and solubility at ambient conditions. This parameter is used to indicate the potential for organic substances to partition to air in a two-phase (air and water) system. A chemical's potential to volatilize from surface water can be inferred from HLC.

Categorization Scheme:

$HLC > 10^{-3}$	Highly volatile
$10^{-3} \geq HLC \geq 10^{-5}$	Moderately volatile
$10^{-5} > HLC \geq 3 \times 10^{-7}$	Slightly volatile
$HLC < 3 \times 10^{-7}$	Essentially nonvolatile

This scheme, adopted from Lyman et al. (1982), gives an indication of chemical potential to volatilize from process wastewater and surface water, thereby reducing the threat to aquatic life and human health via contaminated fish consumption and drinking water, yet potentially causing risk to exposed populations via inhalation.

(c) Adsorption to Soil/Sediments

Key Parameter: Soil/sediment adsorption coefficient (K_{oc})

K_{oc} is a chemical-specific adsorption parameter for organic substances that is largely independent of the properties of soil or sediment and can be used as a relative indicator of adsorption to such media. K_{oc} is highly inversely correlated with solubility, well correlated with octanol-water partition coefficient, and fairly well correlated with BCF.

Categorization Scheme:

$K_{oc} > 10{,}000$	Highly adsorptive
$10{,}000 \geq K_{oc} \geq 1{,}000$	Moderately adsorptive
$1{,}000 > K_{oc} \geq 10$	Slightly adsorptive
$K_{oc} < 10$	Essentially nonadsorptive

This scheme is devised to evaluate substances that may partition to solids and potentially contaminate sediment underlying surface water or land receiving sewage sludge applications. Although a high K_{oc} value indicates that a chemical is more likely to partition to sediment, it also indicates that a chemical may be less bioavailable.

(d) Bioaccumulation Potential

Key Parameter: Bioconcentration Factor (BCF)

$$BCF = \frac{\text{Equilibrium chemical concentration in organism (wet weight)}}{\text{Mean chemical concentration in water}} \qquad \text{(Eq. 16)}$$

BCF is a good indicator of potential to accumulate in aquatic biota through uptake across an external surface membrane.

Categorization Scheme:

BCF > 500	High potential
500 $\geq$ BCF $\geq$ 50	Moderate potential
50 > BCF $\geq$ 5	Slight potential
BCF < 5	Nonbioaccumulative

This scheme is used to identify chemicals that may be present in fish or shellfish tissues at higher levels than in surrounding water. These chemicals may accumulate in the food chain and increase exposure to higher trophic level populations, including people consuming their sport catch or commercial seafood.

(e) Biodegradation Potential

Key Parameter: Aqueous Aerobic Biodegradation Half-life (BD) (days)

Biodegradation, photolysis, and hydrolysis are three potential mechanisms of organic chemical transformation in the environment. A BD is selected to represent chemical persistence because of its importance and the abundance of measured or estimated data relative to other transformation mechanisms.

Categorization Scheme:

BD ≤ 7	Fast
7 < BD ≤ 28	Moderate
28 < BD ≤ 180	Slow
180 < BD	Resistant

This scheme is based on classification ranges given in a recent compilation of environmental fate data (Howard et al., 1991). This scheme gives an indication of chemicals that are likely to biodegrade in surface water, and therefore, not persist in the environment. However, biodegradation products can be less toxic, equally as toxic, or even more toxic than the parent compound.

2.2.4 Assumptions and Limitations

The major assumptions and limitations associated with the data compilation and categorization schemes are summarized in the following two sections.

(a) Data Compilation

- If data are readily available from electronic data bases, other primary and secondary sources are not searched.
- Much of the data are estimated and, therefore, can have a high degree of associated uncertainty.

- For some chemicals, neither measured nor estimated data are available for key categorization parameters. In addition, chemicals identified for this study do not represent a complete set of wastewater constituents. As a result, this study does not completely assess landfill wastewater.

(b) Categorization Schemes

- Receiving waterbody characteristics, pollutant loading amounts, exposed populations, and potential exposure routes are not considered.

- Placement into groups is based on arbitrary order of magnitude data breaks for several categorization schemes. Combined with data uncertainty, this may lead to an overstatement or understatement of the characteristics of a chemical.

- Data derived from laboratory tests may not accurately reflect conditions in the field.

- Available aquatic toxicity and bioconcentration test data may not represent the most sensitive species.

- The biodegradation potential may not be a good indicator of persistence for organic chemicals that rapidly photoxidize or hydrolyze, since these degradation mechanisms are not considered.

2.3 Documented Environmental Impacts

State environmental agencies are contacted, and State 304(l) Short Lists, State Fishing Advisories, and published literature are reviewed for evidence of documented environmental impacts on aquatic life, human health, POTW operations, and the quality of receiving water due to discharges of pollutants from landfills. Reported impacts are compiled and summarized by study site and landfill.

3. DATA SOURCES

3.1 Water Quality Impacts

Readily available EPA and other agency data bases, models, and reports are used in the evaluation of water quality impacts. The following six sections describe the various data sources used in the analysis.

3.1.1 Landfill-Specific Data

EPA's Engineering and Analysis Division (EAD) provided projected landfill effluent process flows, landfill operating days, and pollutant loadings (Appendix B) in October 1996-January 1997 (U.S. EPA, 1996-1997). For each option, the long-term averages (LTAs) were calculated for each pollutant of concern based on EPA sampling data and industry-supplied data. Landfills reported in the 1994 *Waste Treatment Industry: Landfills Questionnaire* the annual quantity discharged to surface water and POTWs (U.S. EPA, 1994c). The annual quantity discharged (landfill flow) was multiplied by the LTA for each pollutant and converted to the proper units to calculate the loading (in pounds per year) for each pollutant at each facility.

The locations of landfills on receiving streams are identified using the U.S. Geological Survey (USGS) cataloging and stream segment (reach) numbers contained in EPA's Industrial Facilities Discharge (IFD) data base (U.S. EPA, 1994-1996a). Latitude/longitude coordinates, if available, are used to locate those facilities and POTWs that have not been assigned a reach number in IFD. The names, locations, and the flow data for the POTWs to which the indirect landfills discharge are obtained from the 1994 *Waste Treatment Industry: Landfills Questionaire* (U.S. EPA, 1994c), EPA's 1992 NEEDS Survey (U.S. EPA, 1992b), IFD, and EPA's Permit Compliance System (PCS) (U.S. EPA, 1993-1996). If these sources did not yield information for a landfill, alternative measures are taken to obtain a complete set of receiving streams and POTWs.

The receiving stream flow data are obtained from either the W.E. Gates study data or from measured streamflow data, both of which are contained in EPA's GAGE file (U.S. EPA, 1994-1996b). The W.E. Gates study contains calculated average and low flow statistics based on the best available flow data and on drainage areas for reaches throughout the United States. The GAGE file also includes average and low flow statistics based on measured data from USGS gaging stations. "Dissolved Concentration Potentials (DCPs)" for estuaries and bays are obtained from the Strategic Assessment Branch of NOAA's Ocean Assessments Division (NOAA/U.S. EPA, 1989-1991) (Appendix C). Critical Dilution Factors are obtained from the *Mixing Zone Dilution Factors for New Chemical Exposure Assessments* (U.S. EPA, 1992a).

3.1.2 Information Used to Evaluate POTW Operations

POTW treatment efficiency removal rates are obtained from a study of 50 well-operated POTWs entitled, *Fate of Priority Pollutants in Publicly-Owned Treatment Works,* commonly referred to as the "50 POTW Study," September 1982 (U.S. EPA, 1982) (Appendix D). Due to the large number of pollutants applicable for this industry, additional data from the Risk Reduction Engineering Laboratory (RREL) data base (now renamed the National Risk Management Research Laboratory data base) are used to augment the POTW data base for the pollutants for which the 50 POTW Study did not cover (U.S. EPA, 1995a). When data are not available, the removal rate is based on the removal rate of a similar pollutant. More detailed information on the removal rates is found in Chapter 7 of the *Technical Development Document for Proposed Effluent Limitations Guidelines and Standards for the Landfills Category* (U.S. EPA, 1997).

Inhibition values are obtained from *Guidance Manual for Preventing Interference at POTWs* (U.S. EPA, 1987) and from *CERCLA Site Discharges to POTWs: Guidance Manual* (U.S. EPA, 1990a). The most conservative values for activated sludge are used. For pollutants with no specific inhibition value, a value based on compound type (e.g., aromatics) is used (Appendix D).

Sewage sludge regulatory levels, if available for the pollutants of concern, are obtained from the Federal Register 40 CFR Part 503, Standards for the Use or Disposal of Sewage Sludge, Final Rule (October 25, 1995) (U.S. EPA, 1995b). Pollutant limits established for the final use or disposal of sewage sludge when the sewage sludge is applied to agricultural and non-agricultural land are used (Appendix D). Sludge partition factors are obtained from the *Report to Congress on the Discharge of Hazardous Wastes to Publicly-Owned Treatment Works (Domestic Sewage Study)* (U.S. EPA, 1986) (Appendix D).

3.1.3 Water Quality Criteria (WQC)

The ambient criteria (or toxic effect levels) for the protection of aquatic life and human health are obtained from a variety of sources including EPA criteria documents, EPA's ASTER, and EPA's IRIS (Appendix D). Ecological toxicity estimations are used when published values are not available. The hierarchies used to select the appropriate aquatic life and human health values are described in the following sections.

3.1.3.1 *Aquatic Life*

Water quality criteria for many pollutants are established by EPA for the protection of freshwater aquatic life (acute and chronic criteria). The acute value represents a maximum allowable 1-hour average concentration of a pollutant at any time and can be related to acute toxic effects on aquatic life. The chronic value represents the average allowable concentration of a toxic pollutant over a 4-day period at which a diverse genera of aquatic organisms and their uses should not be unacceptably affected, provided that these levels are not exceeded more than once every 3 years.

For pollutants for which no water quality criteria are developed, specific toxicity values (acute and chronic effect concentrations reported in published literature or estimated using various application techniques) are used. In selecting values from the literature, measured concentrations from flow-through studies under typical pH and temperature conditions are preferred. The test organism must be a North American resident species of fish or invertebrate. The hierarchies used to select the appropriate acute and chronic values are listed below in descending order of priority.

Acute Aquatic Life Values:

- National acute freshwater quality criteria;
- Lowest reported acute test values (96-hour LC_{50} for fish and 48-hour EC_{50}/LC_{50} for daphnids);
- Lowest reported LC_{50} test value of shorter duration, adjusted to estimate a 96-hour exposure period;
- Lowest reported LC_{50} test value of longer duration, up to a maximum of 2 weeks exposure; and
- Estimated 96-hour LC_{50} from the ASTER QSAR model.

Chronic Aquatic Life Values:

- National chronic freshwater quality criteria;
- Lowest reported maximum allowable toxic concentration (MATC), lowest observable effect concentration (LOEC), or no observable effect concentration (NOEC);
- Lowest reported chronic growth or reproductive toxicity test concentration; and
- Estimated chronic toxicity concentration from a measured acute chronic ratio for a less sensitive species, QSAR model, or default acute:chronic ratio of 10:1.

3.1.3.2 *Human Health*

Water quality criteria for the protection of human health are established in terms of a pollutant's toxic effects, including carcinogenic potential. These human health criteria values are developed for two exposure routes: (1) ingesting the pollutant via contaminated aquatic organisms only, and (2) ingesting the pollutant via both water and contaminated aquatic organisms as follows.

For Toxicity Protection (ingestion of organisms only)

$$HH_{oo} = \frac{RfD \times CF}{IR_f \times BCF} \qquad \text{(Eq. 17)}$$

where:

HH_{oo}	=	human health value (µg/L)
RfD	=	reference dose for a 70-kg individual (mg/day)
IR_f	=	fish ingestion rate (0.0065 kg/day)
BCF	=	bioconcentration factor (liters/kg)
CF	=	conversion factor for units (1,000 µg/mg)

For Carcinogenic Protection (ingestion of organisms only)

$$HH_{oo} = \frac{BW \times RL \times CF}{SF \times IR_f \times BCF} \qquad \text{(Eq. 18)}$$

where:

HH_{oo}	=	human health value (µg/L)
BW	=	body weight (70 kg)
RL	=	risk level (10^{-6})
SF	=	cancer slope factor $(mg/kg/day)^{-1}$
IR_f	=	fish ingestion rate (0.0065 kg/day)
BCF	=	bioconcentration factor (liters/kg)
CF	=	conversion factor for units (1,000 µg/mg)

For Toxicity Protection (ingestion of water and organisms)

$$HH_{wo} = \frac{RfD \times CF}{IR_w + (IR_f \times BCF)} \qquad \text{(Eq. 19)}$$

where:

HH_{wo}	=	human health value (µg/L)
RfD	=	reference dose for a 70-kg individual (mg/day)
IR_w	=	water ingestion rate (2 liters/day)
IR_f	=	fish ingestion rate (0.0065 kg/day)

BCF	=	bioconcentration factor (liters/kg)
CF	=	conversion factor for units (1000 μg/mg)

For Carcinogenic Protection (ingestion of water and organisms)

$$HH_{wo} = \frac{BW \ x \ RL \ x \ CF}{SF \ x \ (IR_w + (IR_f \ x \ BCF))} \qquad \text{(Eq. 20)}$$

where:

HH_{wo}	=	human health value (μg/L)
BW	=	body weight (70 kg)
RL	=	risk level (10^{-6})
SF	=	cancer slope factor $(\text{mg/kg/day})^{-1}$
IR_w	=	water ingestion rate (2 liters/day)
IR_f	=	fish ingestion rate (0.0065 kg/day)
BCF	=	bioconcentration factor (liters/kg)
CF	=	conversion factor for units (1,000 μg/mg)

The values for ingesting water and organisms are derived by assuming an average daily ingestion of 2 liters of water, an average daily fish consumption rate of 6.5 grams of potentially contaminated fish products, and an average adult body weight of 70 kilograms (U.S. EPA, 1991a). Values protective of carcinogenicity are used to assess the potential effects on human health, if EPA has established a slope factor.

Protective concentration levels for carcinogens are developed in terms of non-threshold lifetime risk level. Criteria at a risk level of 10^{-6} (1E-6) are chosen for this analysis. This risk level indicates a probability of one additional case of cancer for every 1-million persons exposed. Toxic effects criteria for noncarcinogens include systemic effects (e.g., reproductive, immunological, neurological, circulatory, or respiratory toxicity), organ-specific toxicity, developmental toxicity, mutagenesis, and lethality.

The hierarchy used to select the most appropriate human health criteria values is listed below in descending order of priority:

- Calculated human health criteria values using EPA's IRIS RfDs or SFs used in conjunction with adjusted 3 percent lipid BCF values derived from *Ambient Water Quality Criteria Documents* (U.S. EPA, 1980); three percent is the mean lipid content of fish tissue reported in the study from which the average daily fish consumption rate of 6.5 g/day is derived;

- Calculated human health criteria values using current IRIS RfDs or SFs and representative BCF values for common North American species of fish or invertebrates or estimated BCF values;

- Calculated human health criteria values using RfDs or SFs from EPA's HEAST used in conjunction with adjusted 3 percent lipid BCF values derived from *Ambient Water Quality Criteria Documents* (U.S. EPA, 1980);

- Calculated human health criteria values using current RfDs or SFs from HEAST and representative BCF values for common North American species of fish or invertebrates or estimated BCF values;

- Criteria from the *Ambient Water Quality Criteria Documents* (U.S. EPA, 1980); and

- Calculated human health values using RfDs or SFs from data sources other than IRIS or HEAST.

This hierarchy is based on Section 2.4.6 of the *Technical Support Document for Water Quality-based Toxics Control* (U.S. EPA, 1991a), which recommends using the most current risk information from IRIS when estimating human health risks. In cases where chemicals have both RfDs and SFs from the same level of the hierarchy, human health values are calculated using the formulas for carcinogenicity, which always result in the more stringent value of the two given the risk levels employed.

3.1.4 Information Used to Evaluate Human Health Risks and Benefits

Fish ingestion rates for sport anglers, subsistence anglers, and the general population are obtained from the *Exposure Factors Handbook* (U.S. EPA, 1989a). State population data and average household size are obtained from the 1995 *Statistical Abstract of the United States* (U.S. Bureau of the Census, 1995). Data concerning the number of anglers in each State (i.e., resident fishermen) are obtained from the 1991 *National Survey of Fishing, Hunting, and Wildlife Associated Recreation* (U.S. FWS, 1991). The total number of river miles or estuary square miles within a State are obtained from the 1990 *National Water Quality Inventory - Report to Congress* (U.S. EPA, 1990b). Drinking water utilities located within 50 miles downstream from each discharge site are identified using EPA's PATHSCAN (U.S. EPA, 1996a). The population served by a drinking water utility is obtained from EPA's Drinking Water Supply Files (U.S. EPA, 1996b) or Federal Reporting Data System (U.S. EPA, 1996c). Total suspended solids (TSS) concentrations (effluent and receiving stream) used in the DRE model are obtained from EAD and from the *Analysis of STORET Suspended Sediments Data for the United States* (Versar, 1992b), repectively (See Section 3.1.1). Willingness-to-pay values are obtained from OPA's review of a 1989 and a 1986 study *The Value of Reducing Risks of Death: A Note on New Evidence* (Fisher, Chestnut, and Violette, 1989) and *Valuing Risks: New Information on the Willingness to Pay for Changes in Fatal Risks* (Violette and Chestnut, 1986). Values are adjusted to 1992, based on the relative change in the Employment Cost Index of Total Compensation for all Civilian Workers. Information used in the evaluation is presented in Appendix E.

3.1.5 Information Used to Evaluate Ecological Benefits

The concept of a "contaminant-free fishery" and the estimate of an increase in the consumer surplus associated with a contaminant-free fishery are obtained from *Discrete Choice Models to Value Changes in Environmental Quality: A Great Lakes Case Study*, a thesis submitted at the University of Wisconsin-Madison by Audrey Lyke in 1993. Data concerning the number of resident anglers in each State and average number of fishing days per angler in each State are obtained from the 1991 *National Survey of Fishing, Hunting, and Wildlife Associated Recreation* (U.S. FWS, 1991) (Appendix E). Median net benefit values for warm water and cold water fishing days are obtained from *Nonmarket Values from Two Decades of Research on Recreational Demand* (Walsh et al., 1990). Values are adjusted to 1992, based on the change in the Consumer Price Index for all urban consumers, as published by the Bureau of Labor Statistics.

3.1.6 Information Used to Evaluate Economic Productivity Benefits

Sewage sludge pollutant limits for surface disposal and land application (ceiling limits and pollutant concentration limits) are obtained from 40 CFR Part 503 (U.S. EPA, 1995b). Cost savings from shifts in sludge use or disposal practices from composite baseline disposal practices are obtained from the *Regulatory Impact Analysis of Proposed Effluent Limitations Guidelines and Standards for the Metal Products and Machinery Industry (Phase I)* (U.S. EPA, 1995c). Savings are adjusted to 1992 using the Construction Cost Index published in the Engineering News Record. In this report, EPA consulted a wide variety of sources, including:

- 1988 National Sewage Sludge Survey;
- 1985 EPA *Handbook for Estimating Sludge Management Costs*;
- 1989 EPA *Regulatory Impact Analysis of the Proposed Regulations for Sewage Sludge Use and Disposal*;
- Interviews with POTW operators;
- Interviews with State government solid waste and waste pollution control experts;
- Review of trade and technical literature on sewage sludge use or disposal practices and costs; and
- Research organizations with expertise in waste management.

Information used in the evaluation is presented in Appendix E.

3.2 Pollutant Fate and Toxicity

The chemical-specific data needed to conduct the fate and toxicity evaluation are obtained from various sources as discussed in Section 2.2.2 of this report. Aquatic life and human health values are presented in Appendix D. Physical/chemical property data are also presented in Appendix D.

3.3 Documented Environmental Impacts

Data concerning environmental impacts are obtained from State environmental agencies in EPA Regions 3 and 6. Data are also obtained from the 1990 State 304(l) Short Lists (U.S. EPA, 1991b) and the 1995 *National Listing of Fish Consumption Advisories* (U.S. EPA, 1995d). Literature abstracts are obtained through the computerized information system DIALOG (Knight-Ridder Information, 1996), which provides access to Enviroline, Pollution Abstracts, Aquatic Science Abstracts, and Water Resources Abstracts.

4. SUMMARY OF RESULTS

4.1 Projected Water Quality Impacts

4.1.1 Comparison of In-stream Concentrations with Ambient Water Quality Criteria

The results of this analysis indicate the water quality benefits of controlling discharges from hazardous and nonhazardous landfills to surface waters and POTWs. The following two sections summarize potential aquatic life and human health impacts on receiving stream water quality and on POTW operations and their receiving streams for direct and indirect discharges. All tables referred to in these sections are presented at the end of Section 4. Appendices F, G, and H present the results of the stream modeling for each type of discharge and landfill, respectively.

4.1.1.1 *Direct Discharges*

(a) Nonhazardous Landfills - Sample Set

The effects of direct wastewater discharges on receiving stream water quality are evaluated at **current** and **proposed BAT** treatment levels for 43 nonhazardous landfills discharging 32 pollutants to 41 receiving streams (39 rivers and 2 estuaries) (Table 1). At **current** discharge levels, these 43 landfills discharge 131,567 pounds-per-year of priority and nonconventional pollutants (Table 2). These loadings are reduced to 63,728 pounds-per-year at **proposed BAT** levels; a 52 percent reduction.

The assessment shows no change in human health impacts on receiving stream water quality if the proposed regulation is adopted. Modeled in-stream pollutant concentrations are projected to exceed **human health criteria** or toxic effect levels (developed for water and organisms consumption) in 5 percent (2 of the total 41) of the receiving streams at **current** and **proposed BAT** discharge levels (Table 3). One (1) pollutant at both **current** and **proposed BAT** discharge levels is projected to exceed in-stream criteria or toxic effect levels using a target risk of 10^{-6} (1E-6) for carcinogens (Table 4).

In-stream pollutant concentrations are projected to exceed **chronic aquatic life criteria** or toxic effect levels in 12 percent (5 of the total 41) of the receiving streams at **current** discharge levels (Table 3). A total of 3 pollutants at **current** discharge levels are projected to exceed in-stream criteria or toxic effect levels (Table 4). **Proposed BAT** discharge levels reduce projected excursions to 2 pollutants in 7 percent (3 of the total 41) of the receiving streams (Tables 3 and 4).

Excursions of **human health criteria** or toxic effect levels (developed for organisms consumption only) and of **acute aquatic life criteria** or toxic effect levels are also presented in Table 3. No excursions of **human health criteria** or toxic effect levels (developed for organisms consumption only) are projected at **current** or **proposed BAT** discharge levels. The one excursion of **acute aquatic life criteria** or toxic effect levels projected at **current** discharge levels is eliminated at **proposed BAT.**

(b) Nonhazardous Landfills - National Extrapolation

Sample set data are extrapolated to the national level based on the statistical methodology used for estimated costs, loads, and economic impacts. Extrapolated values are based on the sample set of 43 nonhazardous landfills discharging 32 pollutants to 41 receiving streams (Table 1). These values are extrapolated to 158 nonhazardous landfills discharging 32 pollutants to 154 receiving streams.

Extrapolated in-stream pollutant concentrations of 1 pollutant are projected to exceed **human health criteria** or toxic effect levels (developed for water and organisms consumption) in 3 percent (4 of the total 154) receiving streams at both **current** and **proposed BAT** discharge levels (Table 5). The proposed regulation is projected to reduce excursions of **chronic aquatic life criteria** or toxic effect levels due to the discharge of 3 pollutants in 4 receiving streams

(Table 5). A total of 97 excursions in 38 receiving streams at current conditions will be reduced to 44 excursions in 34 streams at proposed BAT (Table 5).

4.1.1.2 *Indirect Discharges*

(a) Hazardous Landfills - Sample Set

All hazardous landfills are expected to be in compliance with the baseline treatment standards established for indirect dischargers. EPA did, however, evaluate the effects of POTW wastewater discharges of 60 pollutants on receiving stream water quality at current and proposed pretreatment discharge levels, for 3 hazardous landfills identified in the 308 Questionnaire, which discharge to 3 POTWs located on 3 receiving streams (2 rivers and 1 estuary) (Table 6). Pollutant loadings for 3 landfills at current discharge levels are 81,534 pounds-per-year (Table 2). The loadings are reduced to 47,532 pounds-per-year after pretreatment; a 42 percent reduction.

In-stream pollutant concentrations are projected to exceed human health criteria or toxic effect levels (developed for water and organisms consumption) in 33 percent (1 of the total 3) of the receiving streams at current discharge levels (Table 7). One (1) pollutant at current and proposed pretreatment discharge levels is projected to exceed in-stream criteria or toxic effect levels using a target risk of 10^{-6} (1E-6) for the carcinogens (Table 8). No excursions of human health criteria or toxic effect levels (developed for organisms consumption only) or of aquatic life criteria (acute or chronic) or toxic effect levels are projected at current or proposed pretreatment discharge levels (Table 7).

In addition, the potential impact of the 3 hazardous landfills, which discharge to 3 POTWs, are evaluated in terms of inhibition of POTW operation and contamination of sludge. No inhibition or sludge contamination problems are projected at the 3 POTWs receiving wastewater (Table 9).

(b) Nonhazardous Landfills - Sample Set

The potential effects of POTW wastewater discharges of 32 pollutants on receiving stream water quality are also evaluated at only **current** discharge levels for a representative sample of 85 indirect discharging nonhazardous landfills. These indirect discharges from nonhazardous landfills are not being proposed for pretreatment standards based on preliminary data analyses, which show no documented persistent problems with POTW upsets, or with inhibition or sludge contamination. These 85 nonhazardous landfills discharge 32 pollutants to 80 POTWs located on 80 receiving streams (Table 1). Pollutant loadings for the 85 landfills at **current** discharge levels are 506,335 pounds-per-year (Table 2).

In-stream pollutant concentrations are not projected to exceed **human health criteria** or toxic effect levels (developed for water and organisms consumption/organisms consumption only) (Table 10). In-stream concentrations of 3 pollutants are projected to exceed **chronic aquatic life criteria** or toxic effect levels in 2 of the receiving streams, with the magnitude of the excursions being only twofold or less (Tables 10 and 11). No excursions of **acute aquatic life criteria** or toxic effect levels are projected. In addition, no inhibition or sludge problems are projected at the 80 POTWs receiving discharges from the 85 nonhazardous landfills (Table 12).

4.1.2 Estimation of Human Health Risks and Benefits

The results of this analysis indicate the potential benefits to human health by estimating the risks (carcinogenic and systemic effects) associated with current and reduced pollutant levels in fish tissue and drinking water. The following two sections summarize potential human health impacts from the consumption of fish tissue and drinking water derived from waterbodies impacted by direct and indirect discharges. Risks are estimated for recreational (sport) and subsistence anglers and their families, as well as the general population. Appendices I and J present the results of the modeling for each type of discharge and landfill, respectively.

4.1.2.1 *Direct Discharges*

(a) **Nonhazardous Landfills - Sample Set**

The effects of direct wastewater discharges on human health from the consumption of fish tissue and drinking water are evaluated at **current** and **proposed BAT** treatment levels for 43 facilities discharging 32 pollutants to 41 receiving streams (39 rivers and 2 estuaries) (Table 13).

Fish Tissue -- At **current** discharge levels, 13 receiving streams have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) due to the discharge of 3 carcinogens from 13 nonhazardous landfills (Tables 13 and 14). Total estimated risks greater than 10^{-6} (1E-6) are projected for the **general population**, **sport anglers**, and **subsistence anglers**. At **current** discharge levels, total excess annual cancer cases are estimated to be 1.3E-3 (Table 13). At **proposed BAT** discharge levels, 10 receiving streams have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) due to the discharge of 3 carcinogens from 10 nonhazardous landfills. Total estimated risks greater than 10^{-6} (1E-6) are projected for **sport anglers** and **subsistence anglers**. Total excess annual cancer cases are reduced to 3.0E-4 at **proposed BAT** levels (Table 13). Because the number of excess annual cancer cases at current discharge levels is less than 0.5, a monetary value of benefits to society from avoided cancer cases is not estimated.

Systemic toxicant effects (hazard index greater than 1.0) are projected for only subsistence anglers in 1 receiving stream from 1 pollutant at **current** and **proposed BAT** discharge levels (Table 15). An estimated population of 328 subsistence anglers and their families are projected to be affected. A monetary value of benefits to society could not be estimated.

Drinking Water -- At **current** and **proposed BAT** discharge levels, 2 receiving streams have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) due to the discharge of 1 carcinogen (Table 16). Estimated risks range from 2.3E-6 to 2.6E-6 at **current** and at **proposed BAT**. A drinking water utility is located within 50 miles downstream of one discharge site. However, EPA has published a drinking water criterion for that pollutant, and it is assumed that drinking water treatment systems will reduce concentrations to below adverse effect thresholds. Total excess annual cancer cases are, therefore, not projected. In addition, no systemic toxicant effects (hazard index greater than 1.0) are projected at current or proposed pretreatment levels (Table 15).

(b) Nonhazardous Landfills - National Extrapolation

Sample set data are extrapolated to the national level based on the statistical methodology used for estimated costs, loads, and economic impacts. Extrapolated values are based on sample set of 43 nonhazardous landfills discharging 32 pollutants to 41 receiving streams (Table 1). These values are extrapolated to 158 nonhazardous landfills discharging 32 pollutants to 154 receiving streams.

Fish Tissue -- At current discharge levels, 53 receiving streams have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) due to the discharge of 3 carcinogens from 53 nonhazardous landfills (Table 17). Total estimated risks greater than 10^{-6} (1E-6) are projected for the general population, sport anglers, and subsistence anglers. At current discharge levels, total excess annual cancer cases are estimated to be 3.4E-3 (Table 17). At proposed BAT discharge levels, 41 receiving streams have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) due to the discharge of 3 carcinogens from 41 nonhazardous landfills. Total estimated risks greater than 10^{-6} (1E-6) are projected for sport anglers and subsistence anglers. Total excess annual cancer cases are reduced to 7.4E-4 at proposed BAT levels (Table 17). Because the number of excess annual cancer cases at current discharge levels is less than 0.5, a monetary value of benefits to society from avoided cancer cases is not estimated.

Systemic toxicant effects (hazard index greater than 1.0) are projected for only subsistence anglers in 2 receiving streams from 1 pollutant at current and proposed BAT discharge levels (Table 18). An estimated population of 643 subsistence anglers and their families are projected to be affected. A monetary value of benefits to society could not be estimated.

Drinking Water -- At **current** and **proposed BAT** discharge levels, 4 receiving streams have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) due to the discharge of 1 carcinogen (Table 19). However, EPA has published a drinking water criterion for that pollutant, and it is assumed that drinking water treatment systems will reduce concentrations to below adverse effect thresholds. Total excess annual cancer cases are, therefore, not projected.

4.1.2.2 *Indirect Discharges*

(a) Hazardous Landfills - Sample Set

The effects of POTW wastewater discharges on human health from the consumption of fish tissue and drinking water are evaluated at **current** and **proposed pretreatment** discharge levels for 3 landfills that discharge 60 pollutants to 3 POTWs with outfalls on 3 receiving streams (2 rivers and 1 estuary) (Table 6).

Fish Tissue -- At **current** and **proposed pretreatment** discharge levels, 1 stream, receiving the discharge from 1 landfill/POTW, has a total estimated individual pollutant cancer risk greater than 10^{-6} (1E-6) from 1 carcinogen (Tables 20 and 21). Total estimated risks greater than 10^{-6} (1E-6) are projected for only **subsistence anglers**. Total excess annual cancer cases are estimated at 4.6E-5 for **current** discharge levels and at 3.5E-5 for **proposed pretreatment** levels (Table 20). Because the number of excess annual cancer cases at current discharge levels is less than 0.5, a monetary value of benefits to society from avoided cancer cases is not estimated. In addition, no systemic toxicant effects (hazard index greater than 1.0) are projected at **current** or **proposed pretreatment** levels (Table 22).

Drinking Water -- At **current** and **proposed pretreatment** discharge levels, 1 stream has a total estimated individual pollutant cancer risk greater than 10^{-6} (1E-6) due to the discharge of 1 carcinogen (Table 23). The estimated risk is 2.0E-6 and 1.5E-6, respectively. However, no drinking water utility is located within 50 miles downstream of the discharge site (i.e., total excess annual cancer cases are not projected). In addition, no systemic toxicant effects (hazard index greater than 1.0) are projected at **current** or **proposed pretreatment** levels (Table 22).

(b) **Nonhazardous Landfills - Sample Set**

The effects of POTW wastewater discharges on human health from the consumption of fish tissue and drinking water are evaluated at only **current** discharge levels for 85 landfills that discharge 32 pollutants to 80 POTWs with outfalls on 80 receiving streams (70 rivers and 10 estuaries) (Table 1). These indirect discharges from nonhazardous landfills are not proposed for pretreatment standards based on preliminary data analyses, which show no documented persistent problems with POTW upsets, or with inhibition or sludge contamination.

Fish Tissue -- At **current** discharge levels, 8 streams, receiving the discharge from 8 landfills/POTWs, have total estimated individual pollutant cancer risks greater than 10^{-6} (1E-6) from 2 carcinogens (Tables 24 and 25). Total estimated risks greater than 10^{-6} (1E-6) are projected for the **general population**, **sport anglers**, and **subsistence anglers**. Total excess annual cancer cases are estimated at 7.5E-4. Because the number of excess annual cancer cases at current discharge levels is less than 0.5, a monetary value of benefits to society from avoided cancer cases is not projected.

Systemic toxicant effects (hazard index greater than 1.0) are projected at **current** discharge levels for only subsistence anglers due to the discharge of 1 pollutant to 1 receiving stream (Table 26). An estimated population of 52 subsistence anglers and their families are projected to be affected.

Drinking Water -- At **current** discharge levels, no receiving streams are projected to have a total estimated individual pollutant cancer risk greater than 10^{-6} (1E-6) due to the discharge of carcinogens (Table 27). In addition, no systemic toxicant effects (hazard index greater than 1.0) are projected (Table 26).

4.1.3 Estimation of Ecological Benefits

The results of this analysis indicate the potential ecological benefits of the proposed regulation by estimating improvements in the recreational fishing habitats that are impacted by direct and indirect landfill wastewater discharges. Such impacts include acute and chronic toxicity, sublethal effects on metabolic and reproductive functions, physical destruction of spawning and feeding habitats, and loss of prey organisms. These impacts will vary due to the diversity of species with differing sensitivities to impacts. For example, lead exposure can cause spinal deformities in rainbow trout. Copper exposure can affect the growth activity of algae. In addition, copper and cadmium can be acutely toxic to aquatic life, including finfish. The following sections summarize the potential monetary benefits for direct and indirect discharges as well as additional benefits that are not monetized. Appendices I and J present the results of the analyses for each type of discharge, respectively.

4.1.3.1 *Direct Discharges*

(a) Nonhazardous Landfills - Sample Set

The effects of direct wastewater discharges on aquatic habitats are evaluated at current and proposed BAT treatment levels for 43 nonhazardous landfills discharging 32 pollutants to 41 receiving streams (Tables 1 and 3). The proposed regulation is projected to completely eliminate in-stream concentrations in excess of AWQC at 1 receiving stream (Table 3). Benefits to recreational (sport) anglers, based on improved quality and improved value of fishing opportunities, are estimated. The monetary value of improved recreational fishing opportunity is estimated by first calculating the baseline value of the benefiting stream segment. From the estimated total of 20,873 person-days fished on the stream segment, and the value per person-day of recreational fishing ($27.75 and $35.14, 1992 dollars), a baseline value of $579,000 to $733,000 is estimated for the 1 stream segment (Table 28). The value of improving water quality in this fishery, based on the increase in value (11.1 percent to 31.3 percent) to anglers of achieving a contaminant-free fishing (Lyke, 1993), is then calculated. The resulting estimate of the increase in value of recreational fishing to anglers ranges from $64,300 to $230,000.

(b) Nonhazardous Landfills - National Extrapolation

Sample set data are extrapolated to the national level based on the statistical methodology used for estimated costs, loads, and economic impacts. Extrapolated values are based on the sample set of 43 nonhazardous landfills discharging 32 pollutants to 41 receiving streams (Table 1). These values are extrapolated to 158 nonhazardous landfills discharging 32 pollutants to 154 receiving streams (Table 5).

The proposed regulation is projected to completely eliminate in-stream concentrations in excess of AWQC at 2 receiving streams (Table 5). Benefits to recreational (sport) anglers, based on improved quality and improved value of fishing opportunities, are estimated. The resulting estimate of the increase in value of recreational fishing to anglers ranges from $126,000 to $450,000 (Table 28).

4.1.3.2 *Indirect Discharges*

(a) Hazardous Landfills - Sample Set

The effects of indirect wastewater discharges on aquatic habitats are evaluated at **current** and **proposed pretreatment** levels for 3 hazardous landfills that discharge 60 pollutants to 3 POTWs, with outfalls located on 3 receiving streams (Tables 6 and 7). Because the proposed regulation is not estimated to completely eliminate in-stream concentrations in excess of AWQC, no benefits to recreational (sport) anglers, based on improved quality and improved value of fishing opportunities, are estimated.

(b) Nonhazardous Landfills - Sample Set

Because the effects of indirect wastewater discharges on aquatic habitats are evaluated at only **current** discharge levels for the 85 nonhazardous landfills, ecological benefits, based on enhanced recreational fishing opportunities, are not estimated.

4.1.2.3 *Additional Ecological Benefits*

As noted in Section 2.1.3.1, the estimated benefit of improved recreational fishing opportunities is only a limited measure of the value to society of the improvements in aquatic habitats expected to result from the proposed regulation. Additional ecological benefits include protection of terrestrial wildlife and birds that consume aquatic organisms. The proposed regulation will also result in a reduction in the presence and discharge of toxic pollutants, thereby protecting those aquatic organisms currently under stress, providing the opportunity for the re-establishment of productive ecosystems in damaged waterways, and protection of resident endangered species. In addition, recreational activities, such as boating, water skiing, and swimming, will also be preserved along with the maintenance of an aesthetically pleasing environment. Such activities contribute to the support of local and State economies.

4.1.4 Estimation of Economic Productivity Benefits

The results of this analysis indicate the potential productivity benefits of the proposed regulation based on reduced sewage sludge contamination at POTWs receiving the discharges from indirect hazardous and nonhazardous landfills. Because no sludge contamination problems are projected at the 3 POTWs receiving wastewater from 3 hazardous landfills or at the 80 POTWs receiving wastewater from 85 nonhazardous landfills, no economic productivity benefits are projected.

4.2 Pollutant Fate and Toxicity

Human exposure, ecological exposure, and risk from environmental releases of toxic chemicals depend largely on toxic potency, inter-media partitioning, and chemical persistence. These factors are dependent on chemical-specific properties relating to toxicological effects on living organisms, physical state, hydrophobicity/lipophilicity, and reactivity, as well as the mechanism and media of release and site-specific environmental conditions. Based on available physical-chemical properties, and aquatic life and human health toxicity data for the 68 hazardous landfill pollutants of concern, 13 exhibit moderate to high toxicity to aquatic life; 43 are human systemic toxicants; 16 are classified as known or probable human carcinogens; 23 have drinking water values (21 with enforceable health-based MCLs, 1 with a secondary MCL for aesthetics or taste, and 1 with an action level for treatment); and 20 are designated by EPA as priority pollutants (Tables 29, 30, and 31). In terms of projected environmental partitioning among media, 18 of the evaluated pollutants are moderately to highly volatile (potentially causing risk to exposed populations via inhalation); 12 have a moderate to high potential to bioaccumulate in aquatic biota (potentially accumulating in the food chain and causing increased risk to higher trophic level organisms and to exposed human populations via fish and shellfish consumption); 3 are moderately to highly adsorptive to solids; and 12 are resistant to or slowly biodegraded.

Based on available physical-chemical properties, and aquatic life and human health toxicity data for the 38 nonhazardous landfill pollutants of concern, 5 exhibit moderate to high toxicity to aquatic life; 24 are human systemic toxicants; 8 are classified as known or probable carcinogens; 8 have drinking water values (7 with enforceable health-based MCLs and 1 with a secondary MCL); and 7 are designated by EPA as priority pollutants (Tables 32, 33, and 34). In terms of projected environmental partitioning among media, 7 of the evaluated pollutants are moderately to highly volatile; 2 have a moderate to high potential to bioaccumulate in aquatic biota; 2 are moderately to highly adsorptive to solids; and 2 are slowly biodegraded.

4.3 Documented Environmental Impacts

Literature abstracts, State 304(l) Short Lists, and State fishing advisories are reviewed for documented impacts due to discharges from hazardous and nonhazardous landfills. Two (2) direct landfills and 10 POTWs receiving wastewater from 12 landfills are identified by States as being point sources causing water quality problems and are included on their 304(l) Short List (Tables 35 and 36). Section 304(l) of the Water Quality Act of 1987, which requires States to identify waterbodies impaired by the presence of toxic substances, to identify point-source discharges of these toxics, and to develop Individual Control Strategies (ICSs) for these discharges. The Short List is a list of waters for which a State does not expect applicable water quality standards (numeric or narrative) to be achieved after technology-based requirements are met due entirely or substantially to point source discharges of Section 307(a) toxics. State contacts indicate that of the two direct facilities, one is no longer in a direct discharger and the other is currently in compliance with its permit limits and is no longer a source of impairment. All POTWs listed report no problems with landfill wastewater discharges. In addition, 4 landfills and 13 POTWs receiving landfill wastewater discharges are located on waterbodies with State-issued fish consumption advisories (Table 37). However, the majority of advisories are based on chemicals which are not pollutants of concern for the landfill industry.

Table 1. Evaluated Pollutants of Concern (32) Discharged from 43 Direct and 85 Indirect Nonhazardous Landfills

CAS Number	Pollutant
98555	Alpha-Terpineol
7664417	Ammonia as N
7440382	Arsenic
7440393	Barium
65850	Benzoic Acid
7440428	Boron
7440473	Chromium
120365	Dichlorprop
298044	Disulfoton
142621	Hexanoic Acid
18540299	Hexavalent Chromium
75092	Methylene Chloride
7439987	Molybdenum
94746	MCPA
7085190	MCPP
68122	N,N-Dimethylformamide
C-005	Nitrate/Nitrite
95487	o-Cresol
3268879	OCDD
106445	p-Cresol
108952	Phenol
7440213	Silicon
7440246	Strontium

Table 1. Evaluated Pollutants of Concern (32) Discharged from 43 Direct and 85 Indirect Nonhazardous Landfills (cont'd)

CAS Number	Pollutant
7440326	Titanium
108883	Toluene
20324338	Tripropyleneglycol Methyl Ether
7440666	Zinc
123911	1,4-Dioxane
35822469	1,2,3,4,6,7,8-HpCDD
78933	2-Butanone
67641	2-Propanone
108101	4-Methyl-2-Pentanone

Source: Engineering and Analysis Division (EAD), October 1996 - January 1997.

Table 2. Summary of Pollutant Loadings for Evaluated Direct and Indirect Hazardous and Nonhazardous Landfills

	Loadings (Pounds-per-Year)*				Total
	Hazardous		Nonhazardous		
	Direct Dischargers	Indirect Dischargers	Direct Dischargers	Indirect Dischargers	
Current	NA	81,534	131,567	506,335	719,436
Proposed BAT/Pretreatment	NA	47,532	63,728	NA	111,260
No. of Pollutants Evaluated	NA	60	32	32	65**
No. of Landfills Evaluated	NA	3	43	85	131

* Loadings are representative of pollutants evaluated; conventional and nonconventional pollutants such as TSS, BOD_5, COD, TDS, TOC, hexane extractable material, total phenolic compounds, and amenable cyanide are not included.

** The same pollutant may be discharged from a number of direct and indirect landfills; therefore, the total does not equal the sum of pollutants.

NA = Not applicable
NE = Option not evaluated

Table 3. Summary of Projected Criteria Excursions for Direct Nonhazardous Landfill Dischargers (Leachate) (Sample Set)

	Acute Aquatic Life	Chronic Aquatic Life	Human Health Water and Orgs.	Human Health Orgs. Only	Total*
Current					
Stream (No.)	1	5	2**	0	6
Pollutants (No.)	1 (1.6)	3 (1.0 - 30.1)	1 (2.7 - 3.1)	0	4
Total Excursions	**1**	**10**	**2**	**0**	
Proposed BAT					
Stream (No.)	0	3	2**	0	5
Pollutants (No.)	0	2 (1.4 - 22.1)	1 (2.7 - 3.1)	0	3
Total Excursions	**0**	**5**	**2**	**0**	

NOTE: Number in parentheses represents magnitude of excursions.
Number of streams evaluated = 41 (39 rivers and 2 estuaries), number of landfills = 43, and number of pollutants = 32.

* Pollutants may exceed criteria on a number of streams; therefore, total does not equal sum of pollutants exceeding criteria.

** Excursions will be eliminated using state-adopted criteria for arsenic.

Table 4. Summary of Pollutants Projected to Exceed Criteria for Direct Nonhazardous Landfill Dischargers (Leachate)
(Sample Set)

	Number of Excursions							
	Acute Aquatic Life		Chronic Aquatic Life		Human Health Water and Orgs.		Human Health Orgs. Only	
	Current	Proposed BAT	Current	Proposed BAT	Current	Proposed BAT	Current	Proposed BAT
Ammonia as N	1 (1.6)	0	2 (1.2 - 14.6)	0	0	0	0	0
Arsenic	0	0	0	0	2 (2.7 - 3.1)*	2 (2.7 - 3.1)*	0	0
Boron	0	0	4(1.7 - 22.1)	3 (1.4 - 22.1)	0	0	0	0
Disulfoton	0	0	4 (1.0 - 30.1)	2 (3.6 - 20.1)	0	0	0	0

NOTE: Number of pollutants evaluated = 32.

* Excursions will be eliminated using state-adopted criteria for arsenic.

Table 5. Summary of Projected Criteria Excursions for Direct Nonhazardous Landfill Dischargers (Leachate) (National Level)

	Acute Aquatic Life	Chronic Aquatic Life	Human Health Water and Orgs.	Human Health Orgs. Only	Total*
Current					
Stream (No.)	2	38	4**	0	40
Pollutants (No.)	1 (1.6)	3 (1.0 - 30.1)	1(2.7 - 3.1)	0	4
Total Excursions	**2**	**97**	**4**	**0**	
Proposed BAT					
Stream (No.)	0	34	4**	0	38
Pollutants (No.)	0	2 (1.4 - 22.1)	1 (2.7 - 3.1)	0	3
Total Excursions	**0**	**44**	**4**	**0**	

NOTE: Number in parentheses represents magnitude of excursions.
Number of streams = 154, number of landfills = 158, and number of pollutants = 32.

* Pollutants may exceed criteria on a number of streams; therefore, total does not equal sum of pollutants exceeding criteria.

** Excursions will be eliminated using state-adopted criteria for arsenic.

Table 6. Evaluated Pollutants of Concern (60) Discharged from 3 Indirect Hazardous Landfills

CAS Number	Pollutant
319846	Alpha-BHC
98555	Alpha-Terpineol
7664417	Ammonia as N
62533	Aniline
7440382	Arsenic
1912249	Atrazine
71432	Benzene
65850	Benzoic Acid
100516	Benzyl Alcohol
7440428	Boron
7440473	Chromium
7440508	Copper
57125	Cyanide
1918009	Dicamba
120365	Dichlorprop
60297	Diethyl Ether
100414	Ethylbenzene
142621	Hexanoic Acid
78831	Isobutyl Alcohol
7439932	Lithium
108383	m-Xylene
75092	Methylene Chloride
7439987	Molybdenum
94746	MCPA

Table 6. Evaluated Pollutants of Concern (60) Discharged from 3 Indirect Hazardous Landfills (cont'd)

CAS Number	Pollutant
7085190	MCPP
91203	Naphthalene
7440020	Nickel
C-005	Nitrate/Nitrite
95487	O-Cresol
136777612	O&P-Xylene
3268879	OCDD
39001020	OCDF
106445	p-Cresol
108952	Phenol
1918021	Picloram
110861	Pyridine
7782492	Selenium
7440213	Silicon
122349	Simazine
7440246	Strontium
5915413	Terbuthylazine
7440315	Tin
7440326	Titantium
108883	Toluene
156605	Trans-1,2-Dichloroethene
79016	Trichloroethene
20324338	Tripropyleneglycol Methyl Ether

Table 6. Evaluated Pollutants of Concern (60) Discharged from 3 Indirect Hazardous Landfills (cont'd)

CAS Number	Pollutant
75014	Vinyl Chloride
7440666	Zinc
75343	1,1-Dichloroethane
107062	1,2-Dichloroethane
123911	1,4-Dioxane
78933	2-Butanone
67641	2-Propanone
94757	2,4-D
105679	2,4-Dimethylphenol
94826	2,4-DB
93765	2,4,5-T
93721	2,4,5-TP
108101	4-Methyl-2-Pentanone

Source: Engineering and Analysis Divison (EAD), December 1996.

Table 7. Summary of Projected Criteria Excursions for Indirect Hazardous Landfill Dischargers (Leachate)
(Sample Set)

	Acute Aquatic Life	Chronic Aquatic Life	Human Health Water and Orgs.	Human Health Orgs. Only	Total*
<u>Current</u>					
Stream (No.)	0	0	1**	0	1
Pollutants (No.)	0	0	1 (2.3)	0	1
Total Excursions	**0**	**0**	**1**	**0**	
<u>Proposed Pretreatment</u>					
Stream (No.)	0	0	1**	0	1
Pollutants (No.)	0	0	1 (1.7)	0	1
Total Excursions	**0**	**0**	**1**	**0**	

NOTE: Number in parentheses represents magnitude of excursions.
Number of streams evaluated = 3 (2 rivers and 1 estuary), number of landfills = 3, number of POTWs = 3, and number of pollutants = 60.

* Pollutants may exceed criteria on a number of streams; therefore, total does not equal sum of pollutants exceeding criteria.

** Excursions will be eliminated using state-adopted critria for arsenic.

Table 8. Summary of Pollutants Projected to Exceed Criteria for Indirect Hazardous Landfill Dischargers (Leachate) (Sample Set)

	Number of Excursions							
	Acute Aquatic Life		Chronic Aquatic Life		Human Health Water and Orgs.		Human Health Orgs. Only	
	Current	Proposed Pretreatment	Current	Proposed Pretreatment	Current	Proposed Pretreatment	Current	Proposed Pretreatment
Arsenic	0	0	0	0	1 (2.3)*	1 (1.7)*	0	0

NOTE: Number of pollutants evaluated = 60.

* Excursions will be eliminated using state-adopted criteria for arsenic.

Table 9. Summary of Projected POTW Inhibition and Sludge Contamination Problems from Indirect Hazardous Landfill Dischargers (Sample Set)

	Biological Inhibition	Sludge Contamination	Total
Current			
POTWs (No.)	0	0	0
Pollutants (No.)	0	0	0
Total Problems	**0**	**0**	
Proposed Pretreatment			
POTWs (No.)	0	0	0
Pollutants (No.)	0	0	0
Total Problems	**0**	**0**	

NOTE: Number of POTWs evaluated = 3, number of facilities = 3, and number of pollutants = 60.

Table 10. Summary of Projected Criteria Excursions for Indirect Nonhazardous Landfill Dischargers (Leachate) (Sample Set)

	Acute Aquatic Life	Chronic Aquatic Life	Human Health Water and Orgs.	Human Health Orgs. Only	Total*
Current					
Stream (No.)	0	2	0	0	2
Pollutants (No.)	0	3 (1.0 - 2.3)	0	0	3
Total Excursions	**0**	**4**	**0**	**0**	

NOTE: Number in parentheses represents magnitude of excursions.
Number of streams evaluated = 80 (70 rivers and 10 estuaries), number of landfills = 85, number of POTWs = 80, and number of pollutants = 32.

* Pollutants may exceed criteria on a number of streams; therefore, total does not equal sum of pollutants exceeding criteria.

Table 11. Summary of Pollutants Projected to Exceed Criteria for Indirect Nonhazardous Landfill Dischargers (Leachate) (Sample Set)

	Number of Excursions			
	Acute Aquatic Life	Chronic Aquatic Life	Human Health Water and Orgs.	Human Health Orgs. Only
	Current	Current	Current	Current
Ammonia as N	0	2 (1.0 - 2.3)	0	0
Boron	0	1 (1.3)	0	0
Disulfoton	0	1 (1.4)	0	0

NOTE: Number of pollutants evaluated = 32.

Table 12. Summary of Projected POTW Inhibition and Sludge Contamination Problems from Indirect Nonhazardous Landfill Dischargers
(Sample Set)

	Biological Inhibition	Sludge Contamination	Total
Current			
POTWs (No.)	0	0	0
Pollutants (No.)	0	0	0
Total Problems	**0**	**0**	

NOTE: Number of POTWs evaluated = 80, number of landfills = 85, and number of pollutants = 32.

Table 13. Summary of Potential Human Health Impacts for Direct Nonhazardous Landfill Dischargers (Fish Tissue Consumption) (Sample Set)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
Current		
Stream (No.)/Facilities (No.)	13/13	NA/NA
Carcinogens (No.)	3	NA
General Population	1 (2.3E-6)	3.0E-4
Sport Fishermen	2 (1.7E-6 to 6.1E-6)	5.4E-4
Subsistence Fishermen	13 (1.6E-6 to 5.1E-5)	4.4E-4
TOTAL		**1.3E-3**
Proposed BAT		
Stream (No.)/Facilities (No.)	10/10	NA/NA
Carcinogens (No.)	3	NA
General Population	0	NA
Sport Fishermen	1 (1.5E-6)	1.3E-4
Subsistence Fishermen	10 (1.2E-6 to 1.2E-5)	1.7E-4
TOTAL		**3.0E-4**

NOTE: Total number of streams evaluated = 41 (39 rivers and 2 estuaries), number of landfills = 43 and number of pollutants = 32. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}. Primary contributors included in summary even if cancer risk did not exceed 10^{-6}.
NA = Not Applicable

Table 14. Summary of Pollutants Projected to Cause Human Health Impacts for Direct Nonhazardous Landfill Dischargers
(Fish Tissue Consumption)
(Sample Set)

	Cancer Risks $>10^{-4}$/ Excess Annual Cancer Cases General Population	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Sport Fishermen	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Subsistence Fishermen
Current:			
Stream No. 1			
OCDD	0/NA	9.6E-7/5.6E-7	8.1E-6/2.5E-7
1,2,3,4,6,7,8-HpCDD	0/NA	7.5E-7/4.3E-7	6.3E-6/1.9E-7
Stream No. 2			
OCDD	0/NA	0/NA	7.4E-7/1.6E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	9.7E-7/2.1E-6
Stream No. 3			
OCDD	0/NA	0/NA	6.9E-7/3.7E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	9.2E-7/4.9E-6
Stream No. 4			
OCDD	0/NA	0/NA	1.3E-6/2.2E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.3E-6/2.2E-6
Stream No. 5			
OCDD	0/NA	0/NA	4.1E-6/8.9E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	3.2E-6/7.0E-6
Stream No. 6			
OCDD	0/NA	0/NA	6.8E-7/1.5E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	9.0E-7/1.9E-6

Table 14. Summary of Pollutants Projected to Cause Human Health Impacts for Direct Nonhazardous Landfill Dischargers (continued)
(Fish Tissue Consumption)
(Sample Set)

	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases General Population	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Sport Fishermen	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Subsistence Fishermen
Current (cont'd):			
<u>Stream No. 7</u>			
OCDD	1.3E-6/1.7E-4	3.4E-6/3.0E-4	2.9E-5/1.4E-4
1,2,3,4,6,7,8-HpCDD	1.0E-6/1.3E-4	2.7E-6/2.4E-4	2.2E-5/1.1E-4
<u>Stream No. 8</u>			
OCDD	0/NA	0/NA	1.6E-6/7.4E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.2E-6/5.7E-6
<u>Stream No. 9</u>			
OCDD	0/NA	0/NA	2.3E-6/1.1E-5
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.8E-6/8.5E-6
<u>Stream No. 10</u>			
OCDD	0/NA	0/NA	3.8E-6/1.8E-5
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	2.9E-6/1.4E-5
<u>Stream No. 11</u>			
Arsenic	0/NA	0/NA	2.2E-6/6.5E-6
<u>Stream No. 12</u>			
Arsenic	0/NA	0/NA	7.0E-6/1.7E-5
<u>Stream No. 13</u>			
Arsenic	0/NA	0/NA	8.1E-6/6.2E-5

Table 14. Summary of Pollutants Projected to Cause Human Health Impacts for Direct Nonhazardous Landfill Dischargers (continued)
(Fish Tissue Consumption)
(Sample Set)

	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases General Population	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Sport Fishermen	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Subsistence Fishermen
Proposed BAT:			
Stream No. 1			
OCDD	0/NA	0/NA	8.8E-7/2.7E-8
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	2.3E-6/7.1E-8
Stream No. 2			
OCDD	0/NA	0/NA	3.7E-7/8.0E-7
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	9.7E-7/2.1E-6
Stream No. 3			
OCDD	0/NA	0/NA	3.5E-7/1.9E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	9.3E-7/5.0E-6
Stream No. 5			
OCDD	0/NA	0/NA	4.6E-7/9.9E-7
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.2E-6/2.6E-6
Stream No. 6			
OCDD	0/NA	0/NA	3.4E-7/7.4E-7
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	9.0E-7/1.9E-6
Stream No. 7			
OCDD	0/NA	4.1E-7/3.6E-5	3.4E-6/1.6E-5
1,2,3,4,6,7,8-HpCDD	0/NA	1.1E-6/9.5E-5	9.1E-6/4.2E-5
Stream No. 10			
OCDD	0/NA	0/NA	4.2E-7/2.0E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.1E-6/5.2E-6
Stream No. 11			
Arsenic	0/NA	0/NA	2.2E-6/6.5E-6

Table 14. Summary of Pollutants Projected to Cause Human Health Impacts for Direct Nonhazardous Landfill Dischargers (continued)
(Fish Tissue Consumption)
(Sample Set)

	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases General Population	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Sport Fishermen	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Subsistence Fishermen
Stream No. 12 Arsenic	0/NA	0/NA	7.0E-6/1.7E-5
Stream No. 13 Arsenic	0/NA	0/NA	8.1E-6/6.2E-5

NOTE: Total number of streams evaluated = 41 (39 rivers and 2 estuaries), number of landfills = 43 and total number of pollutants = 32. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}. Primary contributors included in summary even if cancer risk did not exceed 10^{-6}.
NA = Not Applicable

Table 15. Summary of Potential Systemic Human Health Impacts for Direct Nonhazardous Landfill Dischargers
(Fish Tissue and Drinking Water Consumption)
(Sample Set)

	Fish Tissue Hazard Indices > 1	Drinking Water Hazard Indices > 1
Current		
Stream (No.)/Facilities (No.)	1/1	0/0
Pollutants (No.)*	1	0
General Population	0	0
Sport Fishermen	0	0
Subsistence Fishermen	1 (2.0)	0
Affected Population	328	NA
Proposed BAT		
Stream (No.)/Facilities (No.)	1/1	0/0
Pollutants (No.)*	1	0
General Population	0	0
Sport Fishermen	0	0
Subsistence Fishermen	1 (1.3)	0
Affected population	328	NA

NOTE: Total number of streams evaluated = 41 (39 rivers and 2 estuaries), number of landfills = 43, and number of pollutants = 32.
Table presents results for those streams/landfills for which the projected hazard index for any pollutant exceeds 1.0.
* Disulfoton

Table 16. Summary of Potential Human Health Impacts for Direct Nonhazardous Landfill Dischargers (Drinking Water Consumption) (Sample Set)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
Current		
Stream (No.)	2	NA
Carcinogens (No.)	1 (2.3E-6 to 2.6E-6)	NA
With Drinking Water Utility ≤ 50 miles*	1	0.03
Carcinogens (No.)**	1 (2.3E-6)	**0.03**
TOTAL		
Proposed BAT		
Stream (No.)	2	NA
Carcinogens (No.)	1 (2.3E-6 to 2.6E-6)	NA
With Drinking Water Utility ≤ 50 miles	1	NA
Carcinogens (No.)**	1 (2.3E-6)	0.03
TOTAL		**0.03**

NOTE: Total number of streams evaluated = 41 (39 rivers and 2 estuaries), number of landfills = 43, and number of pollutants = 32. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}.

NA = Not Applicable

* 3 utilities serving population of 816,750

** Arsenic; EPA has published a drinking water criterion for arsenic and it is assumed that drinking water treatment systems will reduce concentrations to below adverse effect thresholds.

Table 17. Summary of Potential Human Health Impacts for Direct Nonhazardous Landfill Dischargers (Fish Tissue Consumption) (National Level)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
<u>Current</u>		
Stream (No.)/Facilities (No.)	53/53	NA/NA
Carcinogens (No.)	3	NA
General Population	2 (2.3E-6)	5.9E-4
Sport Fishermen	4 (1.7E-6 to 6.1E-6)	1.1E-3
Subsistence Fishermen	53 (1.6E-6 to 5.1E-5)	1.7E-3
TOTAL		**3.4E-3**
<u>Proposed BAT</u>		
Stream (No.)/Facilities (No.)	41/41	NA/NA
Carcinogens (No.)	3	NA
General Population	0	NA
Sport Fishermen	2 (1.5E-6)	2.6E-4
Subsistence Fishermen	41 (1.2E-6 to 1.2E-5)	4.8E-4
TOTAL		**7.4E-4**

NOTE: Total number of streams = 154, number of landfills = 158, and number of pollutants = 32. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}. Primary contributors included in summary even if cancer risk did not exceed 10^{-6}.
NA = Not Applicable

Table 18. Summary of Potential Systemic Human Health Impacts for Direct Nonhazardous Landfill Dischargers
(Fish Tissue and Drinking Water Consumption)
(National Level)

	Fish Tissue Hazard Indices > 1	Drinking Water Hazard Indices > 1
Current		
Stream (No.)/Facilities (No.)	2/2	0/0
Pollutants (No.)*	1	0
General Population	0	0
Sport Fishermen	0	0
Subsistence Fishermen	2 (2.0)	0
Affected Population	643	NA
Proposed BAT		
Stream (No.)/Facilities (No.)	2/2	0/0
Pollutants (No.)*	1	0
General Population	0	0
Sport Fishermen	0	0
Subsistence Fishermen	2 (2.0)	0
Affected population	643	NA

NOTE: Total number of streams = 154, number of landfills = 158, and number of pollutants = 32.
Table presents results for those streams/landfills for which the projected hazard index for any pollutant exceeds 1.0.

* Disulfoton

Table 19. Summary of Potential Human Health Impacts for Direct Nonhazardous Landfill Dischargers (Drinking Water Consumption) (National Level)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
Current		
Stream (No.)	4	NA
Carcinogens (No.)*	1 (2.3E-6 to 2.6E-6)	NA
With Drinking Water Utility ≤ 50 miles	2	NA
Carcinogens (No.)*	1 (2.3E-6)	0.06
TOTAL		**0.06**
Proposed BAT		
Stream (No.)	4	NA
Carcinogens (No.)*	1 (2.3E-6 to 2.6E-6)	NA
With Drinking Water Utility ≤ 50 miles	2	NA
Carcinogens (No.)*	1 (2.3E-6)	0.06
TOTAL		**0.06**

NOTE: Total number of streams = 154, number of landfills = 158, and number of pollutants = 32. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}.
NA = Not Applicable
* Arsenic; EPA has published a drinking water criterion for arsenic and it is assumed that drinking water treatment systems will reduce concentrations to below adverse effect thresholds.

Table 20. Summary of Potential Human Health Impacts for Indirect Hazardous Landfill Dischargers (Fish Tissue Consumption) (Sample Set)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
Current		
Stream (No.)/Facilities (No.)	1/1	NA/NA
Carcinogens (No.)	1	NA
General Population	0	NA
Sport Fishermen	0	NA
Subsistence Fishermen	1 (6.0E-6)	4.6E-5
TOTAL		**4.6E-5**
Proposed Pretreatment		
Stream (No.)/Facilities (No.)	1/1	NA/NA
Carcinogens (No.)	1	NA
General Population	0	NA
Sport Fishermen	0	NA
Subsistence Fishermen	1 (4.5E-6)	3.5E-5
TOTAL		**3.5E-5**

NOTE: Total number of streams evaluated = 3 (2 rivers and 1 estuary), number of landfills = 3, number of POTWs = 3, and number of pollutants = 60. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}. Primary contributors included in summary even if cancer risk did not exceed 10^{-6}.
NA = Not Applicable

Table 21. Summary of Pollutants Projected to Cause Human Health Impacts for Indirect Hazardous Landfill Dischargers
(Fish Tissue Consumption)
(Sample Set)

	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases General Population	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Sport Fishermen	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Subsistence Fishermen
Current:			
<u>Stream No. 1</u> Arsenic	0/NA	0/NA	6.0E-6/4.6E-5
Proposed Pretreatment:			
<u>Stream No. 1</u> Arsenic	0/NA	0/NA	4.5E-6/3.5E-5

NOTE: Total number of streams evaluated = 3 (2 rivers and 1 estuary), number of landfills = 3, number of POTWs = 3, and total number of pollutants = 60.
Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}. Primary contributors included in summary even if cancer risk did not exceed 10^{-6}.
NA = Not Applicable

Table 22. Summary of Potential Systemic Human Health Impacts for Indirect Hazardous Landfill Dischargers
(Fish Tissue and Drinking Water Consumption)
(Sample Set)

	Fish Tissue Hazard Indices > 1	Drinking Water Hazard Indices > 1
Current		
Stream (No.)/Facilities (No.)	0/0	0/0
Pollutants (No.)	0	0
General Population	0	0
Sport Fishermen	0	0
Subsistence Fishermen	0	0
Proposed Pretreatment		
Stream (No.)/Facilities (No.)	0/0	0/0
Pollutants (No.)	0	0
General Population	0	0
Sport Fishermen	0	0
Subsistence Fishermen	0	0

NOTE: Total number of streams evaluated = 3 (2 rivers and 1 estuary), number of landfills = 3, number of POTWs = 3, and number of pollutants = 60.
Table presents results for those streams/landfills for which the projected hazard index for any pollutant exceeds 1.0.

Table 23. Summary of Potential Human Health Impacts for Indirect Hazardous Landfill Dischargers (Drinking Water Consumption) (Sample Set)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
<u>Current</u>		
Stream (No.)	1	NA
Carcinogens (No.)*	1 (2.0E-6)	NA
With Drinking Water Utility ≤ 50 miles	0	NA
Carcinogens (No.)	0	NA
TOTAL		
<u>Proposed Pretreatment</u>		
Stream (No.)	1	NA
Carcinogens (No.)*	1 (1.5E-6)	NA
With Drinking Water Utility ≤ 50 miles	0	NA
Carcinogens (No.)	0	NA
TOTAL		

NOTE: Total number of streams evaluated = 3 (2 rivers and 1 estuary), number of landfills = 3, number of POTWs = 3, and number of pollutants = 60. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6}.
NA = Not Applicable
* Arsenic; EPA has published a drinking water criterion for arsenic and it is assumed that drinking water treatment systems will reduce concentrations to below adverse effect thresholds.

Table 24. Summary of Potential Human Health Impacts for Indirect Nonhazardous Landfill Dischargers (Fish Tissue Consumption) (Sample Set)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
Current		
Stream (No.)/Facilities (No.)	8/8	NA/NA
Carcinogens (No.)	2	NA
General Population	1 (3.2E-6)	1.0E-4
Sport Fishermen	2 (1.2E-6 to 8.3E-3)	4.3E-4
Subsistence Fishermen	8 (1.1E-6 to 1.4E-4)	2.2E-4
TOTAL		**7.5E-4**

NOTE: Total number of streams evaluated = 80 (70 rivers and 10 estuaries), number of landfills = 85, number of POTWs = 80, and number of pollutants = 32. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6} (1E-6). Primary contributors included in summary even if cancer risk did not exceed 10^{-6} (1E-6).
NA = Not Applicable

Table 25. Summary of Pollutants Projected to Cause Human Health Impacts for Indirect Nonhazardous Landfill Dischargers
(Fish Tissue Consumption)
(Sample Set)

	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases General Population	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Sport Fishermen	Cancer Risks $>10^{-6}$/ Excess Annual Cancer Cases Subsistence Fishermen
Current:			
Stream No. 1			
OCDD	0/NA	1.1E-6/1.5E-4	9.1E-6/6.8E-5
1,2,3,4,6,7,8-HpCDD	0/NA	1.1E-6/1.6E-4	9.4E-6/7.1E-5
Stream No. 2			
OCDD	0/NA	0/NA	5.3E-7/1.1E-6
1,2,3,4,6,7,8-H-CDD	0/NA	0/NA	7.1E-7/1.5E-6
Stream No. 3			
OCDD	0/NA	0/NA	5.4E-7/1.2E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	5.6E-7/1.2E-6
Stream No. 4			
OCDD	0/NA	0/NA	5.4E-7/9.2E-7
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	5.6E-7/9.5E-7
Stream No. 5			
OCDD	0/NA	0/NA	5.2E-7/1.5E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	5.3E-7/1.6E-6
Stream No. 6			
OCDD	0/NA	0/NA	1.5E-6/2.1E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	1.6E-6/2.2E-6
Stream No. 7			
OCDD	1.6E-6/4.9E-5	4.1E-6/5.8E-5	3.4E-5/2.6E-5
1,2,3,4,6,7,8-HpCDD	1.6E-6/5.1E-5	4.2E-6/5.9E-5	3.5E-5/2.6E-5
Stream No. 8			
OCDD	0/NA	0/NA	8.9E-7/6.7E-6
1,2,3,4,6,7,8-HpCDD	0/NA	0/NA	9.2E-7/6.9E-6

NOTE: Total number of streams evaluated = 80 (70 rivers and 10 estuaries), number of landfills = 85, number of POTWs = 80, and total number of pollutants = 32. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6} (1E-6). Primary contributors included in summary even if cancer risk did not exceed 10^{-6} (1E-6).
NA = Not Applicable

Table 26. Summary of Potential Systemic Human Health Impacts for Indirect Nonhazardous Landfill Dischargers
(Fish Tissue and Drinking Water Consumption)
(Sample Set)

	Fish Tissue Hazard Indices > 1	Drinking Water Hazard Indices > 1
<u>Current</u>		
Stream (No.)/Facilities (No.)	1/1	0/0
Pollutants (No.)*	1	0
General Population	0	0
Sport Fishermen	0	0
Subsistence Fishermen	1 (1.6)	0
Affected Population	52	NA

NOTE: Total number of streams evaluated = 80 (70 rivers and 10 estuaries), number of landfills = 85, number of POTWs = 80, and number of pollutants = 32.
Table presents results for those streams/landfills for which the projected hazard index for any pollutant exceeds 1.0.

* Disulfoton

Table 27. Summary of Potential Human Health Impacts for Indirect Nonhazardous Landfill Dischargers (Drinking Water Consumption) (Sample Set)

	Total Individual Cancer Risks > 10^{-6}	Total Excess Annual Cancer Cases
Current		
Stream (No.)	0	NA
Carcinogens (No.)	0	NA
With Drinking Water Utility ≤ 50 miles	0	NA
Carcinogens (No.)	0	NA
TOTAL		

NOTE: Total number of streams evaluated = 80 (70 rivers and 10 estuaries), number of landfills = 85, number of POTWs = 80, and number of pollutants = 32. Table presents results for those streams/landfills for which the projected excess cancer risk for any pollutant exceeds 10^{-6} (1E-6).

NA = Not Applicable

Table 28. Summary of Ecological (Recreational) Benefits for Direct Nonhazardous Landfill Dischargers
(Sample Set and National Level)

Data	Number of Stream Segments with Concentrations Exceeding AWQC Eliminated	Total Fishing Days	Baseline Value of Fisheries ($ 1992)	Increased Value of Fisheries ($ 1992)
Sample Set	1	20,873	$579,000 - $733,000	$64,300 - $230,000
National Level	2	40,911	$1,135,000 - 1,438,000	$126,000 - $450,000

NOTE: Value per person day of recreational fishing = $27.75 (warm water) and $35.14 (cold water).

Increase value of contaminant-free fishing = 11.1 to 31.3 percent.

Table 29. Potential Fate and Toxicity of Pollutants of Concern (Hazardous Landfills)

	Chemical Name	CAS Number	Aquatic Toxicity Category	Volatility Category	Sediment Adsorption Category	Bioaccumulation Category	Biodegradation	Carcinogenic Effect	Systemic Health Effect	Drinking Water Value	Priority Pollutant
1	1,1-Dichloroethane	75343	Slight	High	Slight	Slight	Slow	X	X		X
2	1,2-Dichloroethane	107062	Slight	Moderate	Slight	Nonbioaccumulative	Slow	X		M	X
3	1,4-Dioxane	123911	Slight	Slight	Slight	Nonbioaccumulative	Slow	X			
4	2-Butanone	78933	Slight	Moderate	Nonadsorptive	Nonbioaccumulative	Fast		X		
5	2-Propanone	67641	Slight	Moderate	Slight	Nonbioaccumulative	Fast		X		
6	2,4-D	94757	Slight	Nonvolatile	Slight	Moderate	Slow		X	M	
7	2,4-DB	94826	Slight	Unknown	Slight	Moderate	Fast		X		
8	2,4-Dimethylphenol	105679	Slight	Slight	Slight	Moderate	Fast		X		X
9	2,4,5-T	93765	Moderate	Nonvolatile	Slight	Moderate	Moderate		X		
10	2,4,5-TP	93721	Moderate	Nonvolatile	Slight	Moderate	Slow		X	M	
11	4-Methyl-2-Pentanone	108101	Slight	Moderate	Slight	Nonbioaccumulative	Fast		X		
12	Alpha-BHC	319846	Moderate	Slight	Moderate	Moderate	Slow	X			X
13	Alpha-Terpineol	98555	Slight	Unknown	Unknown	Unknown	Unknown				
14	Amenable Cyanide	C-025	Unknown	Unknown	Unknown	Unknown	Unknown				
15	Ammonia (As N)	7664417	Slight	Moderate	Nonadsorptive	Unknown	Moderate				
16	Aniline	62533	Moderate	Slight	Slight	Slight	Moderate	X			
17	Arsenic	7440382	Moderate	Unknown	Unknown	Slight	Unknown	X	X	M	X
18	Atrazine	1912249	Moderate	Nonvolatile	Slight	Moderate	Resistant	X	X	M	
19	Benzene	71432	Slight	High	Slight	Slight	Moderate	X		M	X
20	Benzoic Acid	65850	Slight	Slight	Slight	Slight	Moderate		X		
21	Benzyl Alcohol	100516	Slight	Slight	Nonadsorptive	Nonbioaccumulative	Moderate		X		
22	BOD	C-002	Unknown	Unknown	Unknown	Unknown	Unknown				
23	Boron	7440428	Unknown	Unknown	Unknown	Unknown	Unknown		X		
24	Chromium	7440473	Slight	Unknown	Unknown	Slight	Unknown		X	M	X
25	COD	C-004	Unknown	Unknown	Unknown	Unknown	Unknown				
26	Copper	7440508	High	Unknown	Unknown	Moderate	Unknown			TT	X
27	Cyanide	57125	High	Unknown	Slight	Nonbioaccumulative	Moderate		X	M	X
28	Dicamba	1918009	Slight	Nonvolatile	Slight	Slight	Slow		X		
29	Dichlorprop	120365	Moderate	Nonvolatile	Slight	Slight	Slow				
30	Diethyl Ether	60297	Slight	Moderate	Slight	Nonbioaccumulative	Moderate		X		
31	Ethylbenzene	100414	Slight	High	Slight	Slight	Moderate		X	M	X
32	Hexane Extractable Material	C-036	Unknown	Unknown	Unknown	Unknown	Unknown				
33	Hexanoic Acid	142621	Slight	Unknown	Slight	Slight	Unknown				
34	Isobutyl Alcohol	78831	Slight	Moderate	Slight	Nonbioaccumulative	Moderate		X		
35	Lithium	7439932	Unknown	Unknown	Unknown	Unknown	Unknown				
36	MCPA	94746	Slight	Nonvolatile	Slight	Slight	Fast		X		
37	MCPP	7085190	Slight	Nonvolatile	Nonadsorptive	Nonbioaccumulative	Unknown		X		
38	Methylene Chloride	75092	Slight	High	Slight	Nonbioaccumulative	Moderate	X	X	M	X
39	Molybdenum	7439987	Unknown	Unknown	Unknown	Unknown	Unknown		X		
40	M-Xylene	108383	Slight	High	Slight	Moderate	Moderate		X	M	
41	Naphthalene	91203	Slight	Moderate	Slight	Slight	Moderate		X		X
42	Nickel	7440020	Slight	Unknown	Slight	Slight	Unknown		X	M	X
43	Nitrate/Nitrite	C-005	Unknown	Unknown	Unknown	Unknown	Unknown		X	M	
44	OCDD	3268879	Unknown	Slight	High	High	Unknown	X	X		
45	OCDF	39001020	Unknown	Slight	Unknown	Unknown	Unknown	X	X		
46	O-Cresol	95487	Slight	Slight	Slight	Slight	Fast	X	X		
47	O+P Xylene*	136777612	Slight	High	Slight	Moderate	Moderate		X	M	
48	P-Cresol	106445	Slight	Slight	Slight	Slight	Fast	X	X		
49	Phenol	108952	Slight	Slight	Slight	Nonbioaccumulative	Fast		X		X
50	Picloram	1918021	High	Nonvolatile	Slight	Nonbioaccumulative	Unknown		X	M	
51	Pyridine	110861	Slight	Slight	Nonadsorptive	Nonbioaccumulative	Fast		X		

Table 29. Potential Fate and Toxicity of Pollutants of Concern (Hazardous Landfills)

	Chemical Name	CAS Number	Aquatic Toxicity Category	Volatility Category	Sediment Adsorption Category	Bioaccumulation Category	Biodegradation	Carcinogenic Effect	Systemic Health Effect	Drinking Water Value	Priority Pollutant
52	Selenium	7782492	High	Unknown	Unknown	Nonbioaccumulative	Unknown		X	M	X
53	Silicon	7440213	Unknown	Unknown	Unknown	Unknown	Unknown				
54	Simazine	122349	High	Nonvolatile	Slight	Nonbioaccumulative	Slow	X	X	M	
55	Strontium	7440246	Unknown	Unknown	Unknown	Unknown	Unknown		X		
56	TDS	C-010	Unknown	Unknown	Unknown	Unknown	Unknown				
57	Terbuthylazine	5915413	Slight	Nonvolatile	Moderate	Moderate	Unknown				
58	Tin	7440315	Unknown	Unknown	Unknown	Unknown	Unknown		X		
59	Titanium	7440326	Unknown	Unknown	Unknown	Unknown	Unknown				
60	TOC	C-012	Unknown	Unknown	Unknown	Unknown	Unknown				
61	Toluene	108883	Slight	High	Slight	Slight	Moderate		X	M	X
62	Total Phenols	C-020	Unknown	Unknown	Unknown	Unknown	Unknown				
63	Trans-1,2-Dichlorethene	156605	Slight	High	Slight	Nonbioaccumulative	Moderate		X	M	X
64	Trichloroethene	79016	Slight	High	Slight	Slight	Resistant	X		M	X
65	Tripropyleneglycol Methyl Ether	20324338	Slight	Nonvolatile	Slight	Nonbioaccumulative	Unknown				
66	TSS	C-009	Unknown	Unknown	Unknown	Unknown	Unknown				
67	Vinyl Chloride	75014	Slight	High	Slight	Nonbioaccumulative	Slow	X		M	X
68	Zinc	7440666	Moderate	Unknown	Unknown	Slight	Unknown		X	SM	X

* Values for p-Xylene assumed.

Note: M = Maximum Contaminant Level established for health-based effect.
SM = Secondary Maximum Contaminant Level (SMCL) established for taste or aesthetic effect.
TT = Treatment technology action level established.

Table 30. Toxicants Exhibiting Systemic and Other Adverse Effects (Hazardous Landfills)*

	Toxicant	Reference Dose Target Organ and Effects
1	1,1-Dichloroethane	No adverse effects observed**
2	2,4,5-TP	Histopathological changes in liver
3	2,4,5-TP	Increased urinary caproporphyrins, reduced neonatal survival
4	2,4-D	Hematologic, hapatic and renal toxicity
5	2,4-DB	Internal hemorrhage, mortality
6	2,4-Dimethylphenol	Clinical signs (lethargy, prostration, and ataxia) and hematological changes
7	2-Butanone	Decreased fetal birth weight
8	2-Propanone	Increased liver and kidney weights and nephrotoxicity
9	4-Methyl-2-Pentanone	Lethargy, increased relative and absolute weight in liver and kidney
10	Arsenic	Hyperpigmentation, keratosis, and possible vascular complications
11	Atrazine	Decreased weight gain, cardiac toxicity and moderate-to-severe dilation of right atrium
12	Benzoic Acid	No adverse effects observed**
13	Benzyl Alcohol	Epithelial hyperplasia, forestomach
14	Boron	Testicular atrophy, spermatogenic arrest
15	Chromium	No adverse effects observed**
16	Cyanide	Weight loss, thyroid effects, and myeline degeneration
17	Dicamba	Maternal and fetal toxicity
18	Diethyl Ether	Depressed body weights
19	Ethylbenzene	Liver and kidney toxicity
20	Isobutyl Alcohol	Hypoactivity and ataxia
21	M-Xylene	Hyperactivity, decreased weight
22	MCPA	Kidney and liver toxicity
23	MCPP	Increased absolute and relative kidney weights
24	Methylene Chloride	Liver toxicity
25	Molybdenum	Increased uric acid
26	Naphthalene	Eye damage, decreased body weight
27	Nickel	Decreased body and organ weghts
28	Nitrate/Nitrite	Methemoglobinemia
29	O+P Xylene	Hyperactivity, decreased body weight and increased mortality
30	O-Cresol	Decreased body weights and neurotoxicity
31	OCDD	Reproductive and developmental effects, immunotoxicity, chloracne
32	OCDF	Reproductive and developmental effects, immunotoxicity, chloracne
33	P-Cresol	Hypoactivity, distress, and maternal death
34	Phenol	Reduced fetal body weight in rats
35	Picloram	Increased liver weights
36	Pyridine	Increased liver weight
37	Selenium	Clinical selenosis (hair or nail loss), liver dysfunction
38	Simazine	Reduction in weight gains, hematological changes in females
39	Strontium	Rachitic bone
40	Tin	Kidney and liver lesions
41	Toluene	Changes in liver and kidney weights
42	Trans-1,2-Dichloroethene	Increased serum alkaline phosphatase in male rice
43	Zinc	Anemia

* Chemicals with EPA verified or provisional human health-based reference doses, referred to as "systemic toxicants."
** Reference dose based on no observed adverse effect level (NOEL).

Table 31. Human Carcinogens Evaluated, Weight-of-Evidence Classifications, and Target Organs (Hazardous Landfills)

	Carcinogen	Weight-of-Evidence Classification	Target Organs
1	1,1-Dichloroethane	C	Mammary
2	1,2-Dichloroethane	B2	Circulatory System
3	1,4-Dioxane	B2	Liver and Gall Bladder
4	Alpha-BHC	B2	Liver
5	Aniline	B2	Spleen
6	Arsenic	A	Skin and Lung
7	Atrazine	C	Mammary
8	Benzene	A	Blood
9	Methylene Chloride	B2	Liver and Lung
10	O-Cresol	C	Skin
11	OCDD	B2*	Liver
12	OCDF	B2*	Liver
13	P-Cresol	C	Bladder
14	Simazine	C	Mammary
15	Trichloroethene	**	
16	Vinyl Chloride	A	Liver and Lung

A = Human Carcinogen
B2 = Probably Human Carcinogen (animal data only)
C = Possible Human Carcinogen

* - Classified as carcinogen based on TEF of dioxin.
** - Under review. Classified as carcinogen based on human health toxicity values set for carcinogenicity protection.

Table 32. Potential Fate and Toxicity of Pollutants of Concern (Nonhazardous Landfills)

	Chemical Name	CAS Number	Aquatic Toxicity Category	Volatility Category	Sediment Adsorption Category	Bioaccumulation Category	Biodegradation	Carcinogenic Effect	Systemic Health Effect	Drinking Water Value	Priority Pollutant
1	1234678-HPCDD	35822469	Unknown	Moderate	Unknown	Unknown	Unknown	X	X		
2	1,4-Dioxane	123911	Slight	Slight	Slight	Nonbioaccumulative	Slow	X			
3	2-Butonone	78933	Slight	Moderate	Nonadsorptive	Nonbioaccumulative	Fast		X		
4	2-Propanone	67641	Slight	Moderate	Slight	Nonbioaccumulative	Fast		X		
5	4-Methyl-2-Pentanone	108101	Slight	Moderate	Slight	Nonbioaccumulative	Fast		X		
6	Alpha-Terpineol	98555	Slight	Unknown	Unknown	Unknown	Unknown				
7	Ammonia (As N)	7664417	Slight	Moderate	Nonadsorptive	Unknown	Moderate				
8	Arsenic	7440382	Moderate	Unknown	Unknown	Slight	Unknown	X	X	M	X
9	Barium	7440393	Slight	Unknown	Unknown	Unknown	Unknown		X	M	
10	Benzoic Acid	65850	Slight	Slight	Slight	Slight	Moderate		X		
11	BOD	C-002	Unknown	Unknown	Unknown	Unknown	Unknown				
12	Boron	7440428	Unknown	Unknown	Unknown	Unknown	Unknown		X		
13	Chromium	7440473	Slight	Unknown	Unknown	Slight	Unknown		X	M	X
14	COD	C-004	Unknown	Unknown	Unknown	Unknown	Unknown				
15	Dichlorprop	120365	Moderate	Nonvolatile	Slight	Slight	Slow				
16	Disulfoton	298044	High	Slight	Moderate	Moderate	Moderate		X		
17	Hexanoic Acid	142621	Slight	Unknown	Slight	Slight	Unknown				
18	Hexavalent Chromium	18540299	High	Unknown	Unknown	Slight	Unknown	X	X	M	X
19	MCPA	94746	Slight	Nonvolatile	Slight	Slight	Fast		X		
20	MCPP	7085190	Slight	Nonvolatile	Nonadsorptive	Nonbioaccumulative	Unknown		X		
21	Methylene Chloride	75092	Slight	High	Slight	Nonbioaccumulative	Moderate	X	X	M	X
22	Molybdenum	7439987	Unknown	Unknown	Unknown	Unknown	Unknown		X		
23	Nitrate/Nitrite	C-005	Unknown	Unknown	Unknown	Unknown	Unknown		X	M	
24	N,N-Dimethylformamide	68122	Slight	Nonvolatile	Nonadsorptive	Nonbioaccumulative	Moderate		X		
25	OCDD	3268879	Unknown	Slight	High	High	Unknown	X	X		
26	O-Cresol	95487	Slight	Slight	Slight	Slight	Fast	X	X		
27	P-Cresol	106445	Slight	Slight	Slight	Slight	Fast	X	X		
28	Phenol	108952	Slight	Slight	Slight	Nonbioaccumulative	Fast		X		X
29	Silicon	7440213	Unknown	Unknown	Unknown	Unknown	Unknown				
30	Strontium	7440246	Unknown	Unknown	Unknown	Unknown	Unknown		X		
31	TDS	C-010	Unknown	Unknown	Unknown	Unknown	Unknown				
32	Titanium	7440326	Unknown	Unknown	Unknown	Unknown	Unknown				
33	TOC	C-012	Unknown	Unknown	Unknown	Unknown	Unknown				
34	Toluene	108883	Slight	High	Slight	Slight	Moderate		X	M	X
35	Total Phenols	C-020	Unknown	Unknown	Unknown	Unknown	Unknown				
36	Tripropyleneglycol Methyl Ether	20324338	Slight	Nonvolatile	Slight	Nonbioaccumulative	Unknown				
37	TSS	C-009	Unknown	Unknown	Unknown	Unknown	Unknown				
38	Zinc	7440666	Moderate	Unknown	Unknown	Slight	Unknown		X	SM	X

Note: M = Maximum Contaminant Level established for health-based effect.
SM = Secondary Maximum Contaminant Level (SMCL) established for taste or aesthetic effect.

Table 33. Toxicants Exhibiting Systemic and Other Adverse Effects (Nonhazardous Landfills)*

	Toxicant	Reference Dose Target Organ and Effects
1	1234678-HpCDD	Reproductive and developmental effects, immunotoxicity, chloracne
2	2-Butanone	Decreased fetal birth weight
3	2-Propanone	Increased liver and kidney weights and nephrotoxicity
4	4-Methyl-2-Pentanone	Lethargy, increased relative and absolute weight in liver and kidney
5	Arsenic	Hyperpigmentation, keratosis, and possible vascular complications
6	Barium	Increased blood pressure
7	Benzoic Acid	No adverse effects observed**
8	Boron	Testicular atrophy, spermatogenic arrest
9	Chromium	No adverse effects observed**
10	Disulfoton	ChE inhibition, optic nerve degeneration
11	Hexavalent Chromium	No adverse effects observed**
12	MCPA	Kidney and liver toxicity
13	MCPP	Increased absolute and relative kidney weights
14	Methylene Chloride	Liver toxicity
15	Molybdenum	Increased uric acid
16	N,N-Dimethylformamide	Hepatotoxic
17	Nitrate/Nitrite	Methemoglobinemia
18	O-Cresol	Decreased body weights and neurotoxicity
19	OCDD	Reproductive and developmental effects, immunotoxicity, chloracne
20	P-Cresol	Hypoactivity, distress, and maternal death
21	Phenol	Reduced fetal body weight in rats
22	Strontium	Rachitic bone
23	Toluene	Changes in liver and kidney weights
24	Zinc	Anemia

* Chemicals with EPA verified or provisional human health-based reference doses, referred to as "systemic toxicants."
** Reference dose based on no observed adverse effect level (NOEL).

Table 34. Human Carcinogens Evaluated, Weight-of-Evidence Classifications, and Target Organs (Nonhazardous Landfills)

	Carcinogen	Weight-of-Evidence Classification	Target Organs
1	1,4-Dioxane	B2	Liver and Gall Bladder
2	1234678-HpCDD	B2*	Liver
3	Arsenic	A	Skin and Lung
4	Hexavalent Chromium	A	Lung
5	Methylene Chloride	B2	Liver and Lung
6	O-Cresol	C	Skin
7	OCDD	B2*	Liver
8	P-Cresol	C	Bladder

A = Human Carcinogen
B2 = Probably Human Carcinogen (animal data only)
C = Possible Human Carcinogen

* - Classified as carcinogen based on TEF of dioxin.

Table 35. Landfills Included on State 304(L) Short Lists

Subcategory	SIC Code	Landfill NPDES	Landfill Name	City	Waterbody	REACH Number	Listed Pollutants
Municipal*	4953	MD0061093	Reich's Ford Road Landfill	Frederick	Bush Creek	02070009005	Cyanide, silver
Unknown	4953	MD0061646	Round Glade Landfill	Oakland	Round Glade Run	05020006-	Selenium, silver

Source: Compiled from OW files dated April/May 1991.
* Included in water quality modeling analysis.

Table 36. POTWs Which Receive Discharge From Landfills and are Included On State 304(L) Short Lists

Landfill Name	Subcategory	City	Receiving POTW	POTW NPDES	Waterbody	REACH Number	Listed Pollutants
Chambers Atlanta Landfill, Inc.	Municipal	Atlanta	Atlanta-R.M. Clayton WPCP	GA0021482	Chattahoochee River	03130002044	Lead, Cadmium
Eastern Sanitary Landfill	Municipal	Towson	Back River WWTP	MD0021555	Back River	0206000325	Mercury, Lead, Selenium
BFI of SE MI, Arbor Hills Landfill Collier Road Landfill	Municipal Municipal	Northville Pontiac	Detroit WWTP	MI0022802	Rouge River	04090004014	Copper, Lead, Cadmium, Mercury, PCBs
Y&S Maintn. Inc. (WMX)	Municipal	Scottdale	Frankin Twp MSA-Meadowbrook	PA0025674	Turtle Creek	05020005---	
Cedar Hills Regional LF/King Co. Solid Waste Div. Kent Highlands Landfill	Municipal Municipal	Seattle Seattle	Metro (Renton STP)	WA0029581	Green River	17110013005	
Olympic View Sanitary Landfill	Municipal	Bremerton	City of Port Orchard (STP)	WA0020346	Sinclair Inlet	17110019024	
Chrin Brothers Sanitary Landfill	Municipal	Easton	Easton Area Jt. Sewer Auth.	PA0027235	Delaware River	02040105012	Cadmium, Nickel, Chloroform
Lynchburg Waste Management	Municipal	Lynchburg	Lynchburg POTW	VA0024970	James River	02080203049	Silver
Town of Hartland	Subtitle D	Hartland	Town of Hartland WWTP	ME0101443	Sebasticook River	01030003072	Chromium
CMW Landfill	Subtitle D	Marion	Fall River WWTP	MA0100382	Mount Hope Bay	01090004001	Zinc, Copper, Toxicity Limits

Source: Compiled from OW files dated April/May 1991.

All facilities included in water quality modeling analysis.

Table 37. Modeled Landfill Facilities/POTWs Located on Waterbodies With State-Issued Fish Consumption Advisories

Subcategory	Discharge Type	Advisory Date	REACH Number	State	Waterbody	Pollutant	Species	Population
Municipal	Direct	February 1992	02040105004	PA	Delaware River	Chlordane, PCBs	American Eel, Channel Catfish, White Perch	NCGP
Municipal	Direct	February 1992	01040002001	ME	Androscoggin River	Dioxins	Fish	NCSP, RGP
Municipal	Indirect	January 1991	01090002040	MA	New Bedford Harbour	PCBs	Shellfish	NCGP
Municipal	Indirect	April 1988	01080201004	MA	Connecticut River	PCBs	Channel Catfish, White Catfish, American Eel, Yellow Perch	NCGP
Municipal	Indirect	May 1991	07040001004	WI	Mississippi River	PCBs, Pesticides	Carp >21", Flathead Catfish >30", White Bass >13"	NCGP
						PCBs	Channel Catfish >21"	NCGP
						Pesticides	Channel Catfish 16-23"	NCGP
							Channel Catfish 21-23"	RGP
Municipal	Indirect	June 1986	05020005001	PA	Monongahela River	Chlordane, PCBs	Carp, Channel Catfish	NCGP
Municipal	Indirect	January 1982	08010209001	TN	Loosahatchie River	Chlordane	Fish	NCGP
Municipal	Indirect	March 1986	05050008010	WV	Kanawha River	Dioxins	Bottom Fish	NCGP
Municipal	Indirect	May 1993	10240011001	KS	Missouri River	Multiple	Fish	RGP
Municipal	Indirect	April 1988	01080201009	MA	Connecticut River	PCBs	Channel Catfish, White Catfish, American Eel, Yellow Perch	NCGP
Municipal	Indirect	May 1993	04090004009	MI	Detroit River	PCBs	Carp	NCGP
						Mercury	Drum >14"	RGP, RSP
Municipal	Indirect	July 1988	05030103001	OH	Mahoning River	PAHs, Phthalate Esters, PCBs, Mirex	All	NCGP
Municipal	Indirect	September 1989	05030202039	WV	Ohio River	Chlordane, PCBs	Carp, Channel Catfish	NCGP

Table 37. Modeled Landfill Facilities/POTWs Located on Waterbodies With State-Issued Fish Consumption Advisories (continued)

Subcategory	Discharge Type	Advisory Date	REACH Number	State	Waterbody	Pollutant	Species	Population
Subtitle D	Direct	January 1977	07130007003	IL	Sugar Creek (Lake Springfield)	Chlordane, Dieldrin	Buffalo Bigmouth, Catfish >15"	NCSP, RGP
							Carp >26"	NCGP
Subtitle D	Direct/Indirect	April 1986	01090004001	RI	Mount Hope Bay	PCBs	Striped Bass	NCSP, RGP
							Striped Bass 26-37"	CFB
		July 1988	01090004001	RI	Mount Hope Bay	PCBs	Bluefish >25"	NCSP, RGP
Subtitle D	Indirect	July 1988	02080206045	VA	James River	Kepone	Fish	RGP

Source: The National Listing of Fish Consumption Advisories (NLFCA) - December 1995

NCSP - Advises against consumption of fish and shellfish by subpopulations potentially at greater risk (e.g., pregnant or nursing women or small children).
RGP - Advises the general population to restrict size and frequency of meals of fish and shellfish.
NCGP - Advises against consumption of fish and shellfish by general population.
CFB - Bans commercial harvest and/or sale of fish and shellfish.
RSP - Advises subpopulations potentially at greater risk (e.g., pregnant or nursing women or small children) to restrict the size and/or frequency of meals of fish and shellfish.

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