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Groundwater Pathway Analysis for Aluminum Potliners (K088); Draft

GROUNDWATER PATHWAY ANALYSIS FOR ALUMINUM POTLINERS (KO88)

DRAFT

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1.0 INTRODUCTION

A Monte Carlo modeling analysis was performed to assess the potential groundwater exposure and human health risk due to dissolved chemicals associated with the disposal of aluminum potliners (KO88) in landfill waste management units. The modeling analysis was performed using the EPA Composite Model for Leachate Migration with Transformation Products model (EPACMTP; EPA, 1995a). The EPACMTP model was selected for the analyses because of its capabilities to perform a full, Monte Carlo-based, probabilistic exposure assessment.

EPACMTP has been designed for Monte Carlo groundwater exposure assessments. The model incorporates default probability distributions for the source, climatic and hydrogeologic parameters needed by the fate and transport model. These distributions have been recently revised (EPA, 1995a,b) to ensure that the most current data available are used.

This document describes the application of EPACMTP to model the groundwater impact of the disposal of aluminum potliners. Section 2 describes the modeling approach and data sources used. Section 3 presents the results of the fate and transport modeling. References are provided in Section 4.

2.0 MODELING APPROACH AND DATA SOURCES

2.1 Modeling Approach and Problem Definition

The EPACMTP modeling approach for the groundwater pathway analysis is summarized in Table 2.1 The modeling analysis was conducted in finite source, Monte Carlo mode for a Subtitle-C landfill waste management scenario. The groundwater fate and transport model was used to predict the groundwater exposure concentration at a receptor well placed, according to a specified probability distribution, within the one-mile radius down gradient of the unit. The exposure concentration is taken to be the peak receptor well concentration occurring within 10,000 years following the initial release from the waste unit for noncarcinogens and nine-year maximum average concentration for carcinogens. The Monte Carlo fate and transport simulation provides a probability distribution of receptor well concentrations which can be used to determine the likelihood that a given exposure level will be reached (or exceeded). The exposure concentrations are compared against health-based groundwater concentration numbers (HBNs) to determine the health risks.

Table 2.1 lists the methodology and data sources used to obtain values for the source-specific parameters, chemical-specific parameters, unsaturated zone parameters, saturated zone parameters, and receptor well location parameters. All parameters are, in principle, described by probability distributions. The determination of the source related parameters for the aluminum potliners modeling analysis is discussed in Section 2.2. Probability distributions for other model input parameters are presented in the EPACMTP background documents (EPA, 1995a-e). Key aspects of the modeling approach are discussed below.

In the EPACMTP Monte Carlo modeling approach, the climatic and hydrogeological model parameters were assigned values based on the geographical locations of waste sites across the U.S. This approach preserves the interdependence between site locations and climatic and hydrogeological regions. This modeling approach was implemented based upon the 1985 Agency Survey of Industrial Subtitle D waste facilities. In the aluminum potliners modeling analysis, the existing EPACMTP relations between climatic and hydrogeological regions for landfills were used. The underlying assumption in using these relationships is that the overall geographical distribution of Subtitle D industrial landfill sites, and Subtitle C landfill sites receiving aluminum potliner waste across different climatic and hydrogeological regions in the U.S., is similar.

The aluminum potliners were assumed to be disposed of at landfills across the nation with the following disposal proportion: 40 percent at the Facility in Arlington, OR; 40 percent at the Chemical Waste Management of Indiana, Inc. Adam Center Facility in Fort Wayne, IN; and the remaining 20 percent at other Subtitle C landfills. The landfill in Oregon is located within the Columbia Plateau. The local hydrogeology consists of alternating layers of basalt flows and interbed materials. Overlying the basalt bedrock are sedimentary deposits (Waste Management of Northwest, Arlington, Oregon Facility, 1991). The landfill in Indiana is located over a series of tills, sedimentary units, and dolomites (Golder and Associates, 1991). Input parameters specific to these two sites are presented in Table 2.2. In the Monte-Carlo simulation, input parameters were assigned in accordance with landfill categories governed by cumulative probability shown in Table 2.3.

The aluminum potliners are disposed of in Subtitle C landfills because of their classification as hazardous waste. Subtitle C landfills are typically underlain by geomembranes and geosynthetic liners to facilitate leachate collection and to mitigate leachate downward migration. In the analysis, the impact to the groundwater was assumed to be due to potential failure of the liners. In addition, the potential leakage rates through the liners were conservatively assumed based on best available information to be between 20 to 30 percent (Inyang and Tomassoni, 1992) of those estimated for Subtitle D landfills (which are unlined) using the HELP model.

In the modeling analysis, the receptor well is located anywhere within one mile downgradient side of the waste unit. The (radial) distance between the receptor well and the down-gradient side of the waste unit is given by an empirical probability distribution (Table 2.2), based upon reported distances between Subtitle D landfills and the nearest downgradient domestic drinking water well. Table 2.3 indicates a median well distance of about one-quarter mile (427 m). The horizontal transverse (y-direction) location of the well was taken to be uniform within the areal extent of the plume. The vertical position of the well intake point (z-direction) was taken to be uniform throughout the saturated thickness of the aquifer.

A list of constituents of concern, for which the modeling analysis was conducted, is presented in Table 2.4. Recently, a groundwater pathway analysis for these constituents was conducted in support of the EPA Hazardous Waste Identification Rule Proposal (HWIR; EPA, 1995-e) for Subtitle D landfills. In the current analysis, the previous HWIR results were extrapolated via the procedure presented below.

1. For a given infiltration rate, perform a Monte-Carlo run with 2,000 realizations. Each realization was based on the following conservative assumptions: no decay; no adsorption; and continuous source. Because of the absence of adsorption and decay, a single Monte-Carlo run with unit source concentration was conducted. Concentrations at the receptor for each constituent were determined by scaling the EPACMTP solution using the source concentrations described in Section 2.2.

2. Determine dilution factors for the constituents of concern using the following relationship:

$$DAF_i^{KO88} = DAF_i^{HWIR} \frac{C^{HWIR}}{C^{KO88}} \quad \textbf{(1)}$$

where

DAF_i^{KO88} = dilution factor of constituent i based on KO88 analysis

DAF_i^{HWIR} = dilution factor of constituent i based on HWIR analysis

C^{KO88} = receptor well concentration of non-sorbing, non-degrading constituent based on KO88 analysis

C^{HWIR} = receptor well concentration of non-sorbing, non-degrading constituent based on HWIR analysis

Note that the dilution factor is defined as the ratio of the leachate concentration of a constituent to the maximum concentration of that constituent at the receptor well. Note also that the ratio of HWIR-to-KO88 DAF is the inverse of the ratio of HWIR-to-KO88 receptor well concentration.

3. Estimate the receptor well concentration of each constituent in the KO88 analysis as

$$C_i^{RW} = \frac{C_i^{TCLP}}{DAF_i^{K088}} \quad (2)$$

where

C_i^{TCLP} = TCLP leaching concentration for constituent i (Table 2.5)

C_i^{RW} = Receptor well exposure concentration for constituent i

4. Determine risk for all the constituents of concern using the following relationships, for non-carcinogens and carcinogens, respectively:

non-carcinogen: $$HQ_i = \frac{C_i^{RW}}{HBN} \quad (3a)$$

carcinogen: $$RISK_i = \frac{C_i^{RW}}{HBN} * 10^{-6} \quad (3b)$$

where

HQ_i = Hazard quotient for constituent i

$RISK_i$ = cancer risk associated with constituent i

HBN = health-based number (concentration corresponding to the risk of 10^{-6} for carcinogens or hazard quotient of 1 for non-carcinogens).

The procedure described above is based on the assumption that the effect of reducing the infiltration rate and incorporating 2 landfills which receive 80% of the waste, is the same for all constituents. This impact is estimated in terms of the change in DAF for a non-degrading, non-sorbing constituent, as compared to the DAF for the HWIR modeling scenario. The constituent-specific DAFs available from the HWIR analysis are then adjusted using a constant scaling factor (Equation 1) to estimate receptor well concentrations and risks for each constituent.

Table 2.1 EPACMTP Modeling Options for LBP Analysis

Management Scenarios:	Subtitle C landfill
Modeling Scenario:	Finite Source Monte Carlo; 2,000 realizations
Exposure evaluation:	Down gradient groundwater receptor well; peak well concentration 10,000 year exposure time limit
Source Parameters:	
Waste Unit Area: Infiltration Rate:	Site-specific data from two landfills, and OPPI Survey of D landfills (EPA, 19995-b) Site-based, 20%-30% of values derived using the HELP model for Subtitle D landfills
Leaching Duration	Infinite
Chemical Specific Parameters:	
Decay Rate:	Constituent-specific
Sorption:	Constituent-specific
Unsaturated Zone Parameters:	
Depth to groundwater: Soil Hydraulic Parameters: Fraction Organic Carbon: Bulk Density:	Site-based, from API/USGS hydrogeologic database ORD data based on national distribution of three soil types (sandy loam, silt loam, silty clay loam) ORD data based on national distribution of three soil types (sandy loam, silt loam, silty clay loam) ORD data based on national distribution of three soil types (sandy loam, silt loam, silty clay loam)
Saturated Zone Parameters:	
Recharge Rate: Saturated Thickness: Hydraulic Conductivity: Porosity: Bulk Density: Dispersivity: Groundwater Temperature: Fraction Organic Carbon: pH	Site-based, derived from regional precipitation/evaporation and soil type Site-based, from API/USGS hydrogeologic database Site-based, from API/USGS hydrogeologic database Effective porosity derived from national distribution of aquifer particle diameter Derived from porosity Derived from distance to receptor well Site-based, from USGS regional temperature map National distribution, from EPA STORET database National distribution, from EPA STORET database
Receptor Well Location:	
X-distance Y-distance Depth of Intake Point	Empirical distribution within 0-1 mile from waste unit Uniform within 1 mile downgradient radius Uniform throughout saturated thickness of aquifer

Table 2.2 Site-Specific Input Parameters

Parameter	Oregon Site	Indiana Site
Landfill Area (m^2)	182,115*	543,810**
Climatic Region	2 (Boise, ID)	73 (Indianapolis, IN)
Hydrogeologic Region	1 (Metamorphic and Igneous)	15 (outwash)
Weight of the Site (%)	40***	40***
Groundwater Temperature (°C)	12.5	12.5
Depth to the Ground Water (m)	45.73*	13.2**
Saturated Zone Thickness (m)	15.2*	21.34**
Hydraulic Conductivity (m/yr)		
Reported	Range(3.15E-3 - 31.5)*	Range(9.46E+3 - 1.89E+4)**
Default HWIR Data Base	Range(3.15 - 1.1E+4)	Range(4.57- 1.1E+5)
Hydraulic Gradient		
Reported	Range(0.01 - 0.04)*	Range(0.001 - 0.004)**
Default HWIR Data Base	Range(7.0E-6 - 0.1)	Range(8.0E-7 - 0.075)

Notes

* Chem Waste of Northwest, Arlington, Oregon, Facility (1991)

** Golder and Associates (1991)

*** Assumed disposed of at 40% at each of these two landfills and the remaining 20% at other Subtitle C landfills distributed nationally.

Table 2.3 Frequency Distribution of Receptor Well Distance

Distance (m)	Cumulative Frequency
0.0	0.00
0.6	0.00
13.7	0.03
19.8	0.04
45.7	0.05
104	0.10
152	0.15
183	0.20
244	0.25
305	0.30
305	0.35
366	0.40
427	0.50
610	0.60
805	0.70
914	0.80
1160	0.85
1220	0.90
1370	0.95
1520	0.98
1610	1.00

2.2 Source Related Parameters

EPACMTP requires specification of the waste source area, and the leachate concentration emanating from the base of the waste source. These two parameters are entered directly as input parameters to the model. The discussion as to how the two parameters were determined for the aluminum potliners analysis is presented below.

Landfill Area

As discussed in Section 2.1, the cumulative probability distribution of the landfill is according to Table 2.3. As shown in the table, the landfill area is equal to that of the Oregon site 40 percent of the realizations, is equal to that of the Indiana site 40 percent of the realizations, and assumes the OPPI Survey distribution (EPA, 1986) 20 percent of the realizations.

Leachate Concentration

Leachate concentrations of constituents of concern were assumed to be equal to their respective average Toxicity Characteristics Leaching Procedure (TCLP) concentrations. In the event that the TCLP concentrations were unavailable, the TCLP concentrations were assumed to be equal to 1/20 of the respective total waste concentrations (Conrad and Deever, 1992). The leachate concentrations of constituents of concern are presented in Table 2.5. It may be noted that for those constituent for which both leachate and total waste concentration values are available, the ratio of waste-to-leachate concentration is generally much greater than 20. In other words, the assumed ratio of 20 used in this analysis likely results in a conservative (high-end) estimate of the leachate concentration.

Table 2.4 TCLP Concentrations of Constituents of Concern

Constituent	CAS No.	TCLP (mg/L)	Data Source
Cyanide (Total)	57-12-5	1.09e+02	c
Cyanide (Amenable)	57-12-5	4.60e+01	c
Fluoride	16964-48-8	2.33e+03	c
Lead	7439-92-1	5.10e-02	a
Benzo(a)pyrene	50-32-8	1.19e+00	c
Beryllium	7440-41-7	2.67e-02	b
Arsenic	7440-38-2	3.23e-01	a
Antimony	7440-36-0	1.79e-01	a
Chromium (total)	7440-47-3	3.50e-02	a
Barium	7440-39-3	1.14e-01	a
Nickel	7440-02-0	2.18e-01	a
Cadmium	7440-43-9	8.00e-03	a
Pyrene	129-00-0	1.41e+00	c
Fluoranthene	206-44-0	1.74e+00	c
Selenium	7782-49-2	2.80e-02	a
Mercury	7439-97-6	1.00e-03	a
Silver	7440-22-4	2.80e-02	a

Data Sources

a) Aluminum Association sampling results.
b) Characterization of spent potliners reduction of aluminum, EPA (1991)
c) No TCLP value available, concentration was estimated as 1/20 of average waste concentration (mg/kg) obtained from KO88 sampling

3.0 RESULTS

Shown in Table 3.1 are health-based numbers (see Section 2.1 for definition) and dilution factors from the HWIR analysis (EPA, 1995-e). Following the analysis procedure outlined in Section 2.1, two sets of Monte-Carlo simulations were performed: one with 20 percent of the infiltration rate for the Subtitle D landfills; and the other with 30 percent of the infiltration rate for the Subtitle D landfills. For each Monte-Carlo simulation, utilizing the constituent concentrations at the receptor well from the KO88 and HWIR analyses, as well as the dilution factors from the HWIR analysis (Table 3.1), dilution factors were calculated for respective constituents. The dilution factors were then employed to determine groundwater exposure concentrations at receptor wells. The constituent concentrations thus determined at the 50th and 90th percentiles were then used to determine risks (for carcinogens) or hazard quotients (for non-carcinogens). The 50th and 90th percentile groundwater exposure concentrations and associated risks or hazard quotients for the cases of 20 percent and 30 percent infiltration rates are presented in Tables 3.2 and 3.3, respectively.

In Table 3.2, it can be seen that, the 90th-percentile risks associated with all three carcinogens exceed 10^{-6}. Among the three carcinogens, benzo(a)pyrene has the highest risk. The 50th-percentile risk of this chemical is the only one exceeding 10^{-6}. For the non-carcinogens shown in the table, all the 50th-percentile hazard quotients are below unity, with fluoride being the constituent with the highest hazard quotient. At the 90th percentile, the hazard quotients of fluoride and lead well exceed unity.

Results shown in Table 3.3 are similar to those in Table 3.2. Groundwater exposure concentrations, risks, and hazard quotients in this table are somewhat greater(approximately 1.5 to three times) than those in Table 3.2, as expected. Also shown in the table, the 50th percentile, risks due to two carcinogens, arsenic and benzo(a)pyrene, exceed 10^{-6}.

Table 3.1 HWIR-based Leachate Concentrations and Dilution Factors

Constituent	CAS No.	HBN (mg/L)	HWIR Min. Leachate Conc. (mg/L)	HWIR DAF
Cyanide (Total) #	57-12-5	7.30e-01	1.00e+06	1.37e+06
Cyanide (Amenable) #	57-12-5	7.30e-01	1.00e+06	1.37e+06
Fluoride #	16964-48-8	2.20e+00	1.80e+01	8.18e+00
Lead	7439-92-1	3.70e-06	7.50e+01	2.03e+07
Benzo(a)pyrene	50-32-8	1.00e-05	1.80e-04	1.80e+01
Beryllium	7440-41-7	2.00e-05	2.10e-03	1.05e+02
Arsenic	7440-38-2	5.00e-05	9.60e-04	1.92e+01
Antimony	7440-36-0	1.00e-02	3.40e-01	3.40e+01
Chromium (total) *	7440-47-3	2.00e-01	3.10e+00	1.55e+01
Barium	7440-39-3	3.00e+00	8.40e+01	2.80e+01
Nickel	7440-02-0	7.00e-01	2.60e+01	3.71e+01
Cadmium	7440-43-9	2.00e-02	6.00e-01	3.00e+01
Pyrene	129-00-0	1.00e+00	1.90e+01	1.90e+01
Fluoranthene	206-44-0	1.00e+00	1.90e+01	1.90e+01
Selenium	7782-49-2	2.00e-01	2.30e+00	1.15e+01
Mercury	7439-97-6	1.00e-02	7.50e-01	7.50e+01
Silver	7440-22-4	2.00e-01	4.10e+00	2.05e+01

Notes

1. TCLP = mean value of reported TCLP concentrations for each constituent; for cyanide, fluoride, benzo(a)pyrene, fluoranthene, and pyrene TCLP estimated as 1/20-th of total concentration.
2. HBN = reference exposure concentration corresponding to risk=10 -6 / HQ= 1; values as used for HWIR, except cyanide, fluoride and lead from EPA Region III RBC tables
3. * The HWIR DAF presented above is that of Chromium (+6).
4. # Constituent is not in the HWIR list, however, DAF has been calculated based on HWIR modeling procedure, using hydrolysis half-life of 8.41 yrs for cyanides.

Table 3.2 KO88 Groundwater Pathways Analysis with 20% Infiltration Rate

Constituent	CAS No.	HBN (mg/L)	TCLP (mg/L)	GW Exposure Conc. (mg/L)		Risk or HQ	
				50th Percentile	90th Percentile	50th Percentile	90-th Percentile
Cyanide (Total)	57-12-5	0.73	1.09e+02	2.35e-07	8.38e-05	3.22e-07	1.15e-04
Cyanide (Amenable)	57-12-5	0.73	4.60e+01	9.94e-08	3.55e-05	1.36e-07	4.86e-05
Fluoride	16964-48-8	2.20	2.33e+03	2.80e-01	9.98e+01	1.27e-01	4.54e+01
Lead	7439-92-1	3.70e-06	5.10e-02	2.20e-08	7.86e-06	5.95e-03	2.12e+00
Benzo(a)pyrene	50-32-8	1.00e-05	1.19e+00	1.43e-04	5.09e-02	1.43e-05	5.09e-03
Beryllium	7440-41-7	2.00e-05	2.67e-02	5.55e-07	1.98e-04	2.77e-08	9.89e-06
Arsenic	7440-38-2	5.00e-05	3.23e-01	3.63e-05	1.29e-02	7.26e-07	2.59e-04
Antimony	7440-36-0	0.01	1.79e-01	1.13e-05	4.02e-03	1.13e-03	4.02e-01
Chromium (total)	7440-47-3	0.20	3.50e-02	4.89e-06	1.75e-03	2.45e-05	8.73e-03
Barium	7440-39-3	3.00	1.14e-01	8.85e-06	3.16e-03	2.95e-06	1.05e-03
Nickel	7440-02-0	0.70	2.18e-01	1.25e-05	4.47e-03	1.79e-05	6.39e-03
Cadmium	7440-43-9	0.02	8.00e-03	5.76e-07	2.05e-04	2.88e-05	1.03e-02
Pyrene	129-00-0	1.00	1.41e+00	1.60e-04	5.72e-02	1.60e-04	5.72e-02
Fluoranthene	206-44-0	1.00	1.74e+00	1.98e-04	7.06e-02	1.98e-04	7.06e-02
Selenium	7782-49-2	0.20	2.80e-02	5.21e-06	1.86e-03	2.61e-05	9.30e-03
Mercury	7439-97-6	0.01	1.00e-03	2.90e-08	1.03e-05	2.90e-06	1.03e-03
Silver	7440-22-4	0.20	2.80e-02	2.52e-06	8.99e-04	1.26e-05	4.49e-03

TCLP = mean value of reported TCLP concentrations for each constituent; for cyanide, fluoride, benzo(a)pyrene, fluoranthene, and pyrene TCLP estimated as 1/20-th of total concentration.

HBN = reference exposure concentration corresponding to a risk of 10 -6 for carcinogens and HQ of 1 for non-carcinogens;values as used for HWIR, except cyanide, fluoride and lead from EPA Region III RBC tables

* infiltration is assumed to be 30% of the infiltration from a subtitle D landfill

Shaded region indicates carcinogens

Table 3.3 KO88 Groundwater Pathways Analysis with 30% Infiltration Rate

Constituent	CAS No.	HBN (mg/L)	TCLP (mg/L)	GW Exposure Conc. (mg/L)		Risk or HQ	
				50th Percentile	90th Percentile	50th Percentile	90-th Percentile
Cyanide (Total)	57-12-5	0.73	1.09e+02	6.50e-07	1.28e-04	8.90e-07	1.75e-04
Cyanide (Amenable)	57-12-5	0.73	4.60e+01	2.75e-07	5.41e-05	3.77e-07	7.42e-05
Fluoride	16964-48-8	2.20	2.33e+03	7.74e-01	1.52e+02	3.52e-01	6.93e+01
Lead	7439-92-1	3.70e-06	5.10e-02	6.10e-08	1.20e-05	1.65e-02	3.24e+00
Benzo(a)pyrene	50-32-8	1.00e-05	1.19e+00	3.95e-04	7.78e-02	3.95e-05	7.78e-03
Beryllium	7440-41-7	2.00e-05	2.67e-02	1.53e-06	3.02e-04	7.67e-08	1.51e-05
Arsenic	7440-38-2	5.00e-05	3.23e-01	1.00e-04	1.98e-02	2.01e-06	3.95e-04
Antimony	7440-36-0	0.01	1.79e-01	3.12e-05	6.14e-03	3.12e-03	6.14e-01
Chromium (total)	7440-47-3	0.20	3.50e-02	1.35e-05	2.67e-03	6.77e-05	1.33e-02
Barium	7440-39-3	3.00	1.14e-01	2.45e-05	4.82e-03	8.16e-06	1.61e-03
Nickel	7440-02-0	0.70	2.18e-01	3.47e-05	6.83e-03	4.95e-05	9.75e-03
Cadmium	7440-43-9	0.02	8.00e-03	1.59e-06	3.14e-04	7.97e-05	1.57e-02
Pyrene	129-00-0	1.00	1.41e+00	4.43e-04	8.73e-02	4.43e-04	8.73e-02
Fluoranthene	206-44-0	1.00	1.74e+00	5.47e-04	1.08e-01	5.47e-04	1.08e-01
Selenium	7782-49-2	0.20	2.80e-02	1.44e-05	2.84e-03	7.21e-05	1.42e-02
Mercury	7439-97-6	0.01	1.00e-03	8.02e-08	1.58e-05	8.02e-06	1.58e-03
Silver	7440-22-4	0.20	2.80e-02	6.97e-06	1.37e-03	3.49e-05	6.86e-03

TCLP = mean value of reported TCLP concentrations for each constituent; for cyanide, fluoride, benzo(a)pyrene, fluoranthene, and pyrene TCLP estimated as 1/20-th of total concentration.

HBN = reference exposure concentration corresponding to a risk of 10 -6 for carcinogens and HQ of 1 for non-carcinogens;values as used for HWIR, except cyanide, fluoride and lead from EPA Region III RBC tables

* infiltration is assumed to be 30% of the infiltration from a subtitle D landfill

Shaded region indicates carcinogens

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