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Appendix A

Evaluation of Potential for Developing Health Benchmarks for Acetoacetanilide (AAA), Acetoacet-*o*-toluidide (AAOT), and Acetoacet-*o*-anisidide (AAOA)

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A.1 Background

For the 1994 proposed listing determination for wastes from the manufacture of dyes and pigments (59 FR 66072, December 22, 1994), conditional health benchmarks were developed for acetoacetanilide (AAA), acetoacet-o-toluidide (AAOT), and acetoacet-o-anisidide (AAOA) based on structure activity relationships (SAR). The U.S. Environmental Protection Agency (EPA) used a SAR approach because, at the time, no EPA-verified health benchmark values were available for these compounds and no constituent-specific toxicity studies were identified that could be used to develop benchmarks.

The SAR analysis performed for the proposed rule relied upon metabolic pathway information to develop toxicologic values based on the carcinogenic potential of aromatic amines. The metabolic pathways for the class of compounds identified as aromatic amines were acetylation and N-hydroxylation. Using this information, EPA proposed the use of the toxicity of aniline to represent the toxicity of AAA and the toxicity of 2-aminotoluene to represent the toxicities of AAOA and AAOT.

AAA was assumed to be a structural analog of aniline and the metabolic pathways were expected to be similar. It was noted that as much as 60 percent of aniline absorbed in humans is oxidized in a dose-dependent way to give o- and p-aminophenol, the first step in amide formation. The metabolites of these products include acetylated arylamines, which are responsible for the toxicity of aniline. Because the acetyl group is already part of AAA, initial acetylation may be considered complete. And, because only 60 percent of the aniline is expected to be metabolized by the acetylation pathway and AAA is acetylated in its original form, the toxicity of AAA was expected to be proportionally greater than the toxicity of aniline. Also, because the metabolic conversions occur on a molar basis and the doses in laboratory studies are reported as parts per million, the difference in molecular weight was considered. Considering these factors, the health-based level (HBL) for AAA in drinking water was estimated to be 0.003 mg/L as compared to 0.006 mg/L for aniline.

For the proposed rule, AAOT and AAOA were considered structural analogues of 2-aminotoluene, and the metabolic pathways were expected to be similar to those previously

described for aniline. Also, because only 25 percent of the aminotoluene was expected to be metabolized by the acetylation pathway, and AAOT and AAOA are acetylated in their original forms, their toxicities were expected to be proportionally greater than the toxicity of 2-aminotoluene. Considering metabolic pathway differences and differences in molecular weight, the HBLs for AAOT and AAOA in drinking water were estimated to be 0.00004 mg/L and 0.00005 mg/L, respectively, as compared to 0.0001 mg/L for 2-aminotoluene. EPA assumed a direct quantitative relationship between the constituents of concern and these compounds that follow a similar metabolic route.

Since publication of the proposed rule, EPA has reviewed the data submitted by commenters and conducted a literature search to identify other metabolic and toxicity data recently published in the scientific literature that can be used to predict the metabolism and/or toxicity of these constituents. A review of the metabolic pathways and proposed mechanisms of toxicity for these compounds submitted by commenters and identified in the literature is presented below.

A.2 Summary of Major Comments on SAR for Proposed Rule

Commenters on the proposed rule disagree with EPA's primary assumption in the proposed rule that AAA, AAOT, and AAOA are carcinogenic based on structure activity relationships. They believe that EPA's characterization of aniline carcinogenicity is incorrect. Commenters assert that the metabolic pathways for aniline described in the proposed rule (ring-hydroxylation and acetylation) actually contribute to clearance of aniline from the body by forming conjugates with glucouonide and sulfate, which are excreted in the urine. Further, commenters note that current toxicologic data suggest that the mechanism for the carcinogenicity of aniline is attributable to the hematoxic effects of aniline, which can produce hemolytic anemia and methemoglobinemia in both humans and laboratory animals. Because this is a nongenotoxic mechanism, commenters assert that the metabolic pathways used in the SAR approach are inappropriate for characterizing the carcinogenicity of aniline and thus structural analogs of aniline. The commenters believe that the same argument holds for AAOT and AAOA.

One commenter submitted a screening information data set (SIDS) dossier on AAA as well as genotoxicity tests to support the contention that AAA, AAOT, and AAOA are not carcinogenic. The SIDS data included a 14-day preliminary oral rat study and a 28-day subchronic oral rat study.

A.3 Toxicity Data for AAA, AAOA, and AAOT

This section summarizes the available data on these compounds. Their structures are presented in Figure A-1. These compounds are classified as arylamines.

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Toxicity data provided by commenters for AAA, AAOA, and AAOT were limited to mutagenicity data and acute oral and dermal exposures to laboratory animals. LD50 values in rat and mouse following oral administration, and in guinea pig following dermal exposure, indicate a relatively low acute toxicity for these compounds, with all LD50 values >1,000 mg/kg. The primary target tissue identified in rats administered the chemicals in feed (11 days for AAOT, 14 days for AAA and AAOA, and 28 days for AAA) was the blood, with secondary effects in liver (AAA only) and spleen. Mutagenicity tests in *Salmonella* strains gave negative results for all three compounds with and without activation with hepatic S9. AAOA and AAOT were also tested in the Chinese hamster ovary and unscheduled DNA synthesis assays, and neither compound was positive with or without activation with hepatic S9. No additional constituent-specific toxicity data were located through a search of recent literature.

A.3.1 Weight of Evidence for Carcinogenic Potential for AAA, AAOA, and AAOT

To provide additional background information that may be considered when assessing the limited acute toxicity data provided by the commenter and reexamine the basis for the SAR analysis conducted for the proposed rule, the weight of evidence for potential carcinogenic metabolic pathways for the class of arylamine compounds is discussed here.

Both aniline and *o*-toluidine were evaluated for carcinogenic potential by the International Agency for Research on Cancer (IARC, 1987a and 1987b.). After reviewing the data available in1987, IARC placed aniline in group 3, inadequate evidence of carcinogenicity, because of inadequate evidence for carcinogenicity to humans and limited evidence of carcinogenicity to animals and placed o-toluidine in Group 2B, limited evidence of carcinogenicity, because of inadequate evidence of carcinogenicity to humans and sufficient evidence of carcinogenicity to animals.

Aniline hydrochloride was tested for carcinogenicity in single experiments in mice and rats by oral administration. No increase in tumor incidence was found in mice. In rats, aniline produced fibrosarcomas, sarcomas, and hemangiosarcomas of the spleen and peritoneal cavity. In other limited studies, largely negative results were noted. In bioassay testing, aniline induced mixed results. (IARC, 1987a)

In the case of *o*-toluidine, evidence for carcinogenicity to humans was judged to be inadequate, however, evidence for carcinogenicity to animals was judged sufficient. *o*-Toluidine produced neoplasms at various sites in both rats and mice by oral administration, in particular, vascular tumors including tumors of the spleen and other abdominal hemangiosarcomas. Other limited studies following subcutaneous administration showed no treatment-related neoplasms. However, several of these studies were inadequate for evaluation. No uniform results were obtained from bioassay testing. (IARC, 1987b)

Other studies indicate that aromatic amines associated with the production of dyes are often bladder carcinogens but may also attack the liver and spleen (Ward et al., 1991; Garner et al., 1984). These compounds are activated to carcinogens following N-oxidation, and this product can be further activated by N-acetyl and O-acetyl transferases (NAT/OAT) to ultimately

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form reactive acetoxy esters. The acetyl group can be directly conjugated to the hydroxyl moiety, or can be intramolecularly transferred to that atom by an *N*-acetyltransferase-catalyzed **B** to *O*-rearrangement after the formation of an acetamido metabolite. The enzymes involved in the hydroxylation include cytochrome P450 (P450), prostaglandin H synthase, and flavin-containing monooxygenases. P450 hydroxylates both the amino group of arylamines to form *N*-hydroxyarylamines and nitrosoarenes, as well as aromatic carbon atoms *ortho*- and *para*- to that substituent. The unstable product formed following N-oxidation dissociates to produce reactive carbonium and/or nitrenium ions (Parkinson, 1996).

Both 2-aminofluorene (AF) and 2-(acetylamino)fluorene (AAF) are considered the prototypical aromatic amines for which the most biological data are available and serve as biochemical models for these processes (Patel et al., 1998) (Figure A-2). The same activation scheme is involved in the activation of the aniline derivative, acetaminophen (4-hydroxyacetanilide, Tylenol, paracetamol), to the proximate hepatotoxin (Dahlin et al., 1984), although the presence of the *para*-hydroxy group provides for conjugation reactions (glucuronidation and sulfation) that predominate in its metabolism and serve as detoxifying reactions. The genotoxicity and carcinogenicity of acetaminophen has been comprehensively reviewed most recently by Bergman et al. (1996). Although the hepatotoxicity and lethality of acetaminophen is well established in humans, the genotoxicity and carcinogenicity data are ambiguous. At nonhepatotoxic levels (ca. 250 mg/kg in man), the studies do not indicate a carcinogenic potential for acetaminophen, but inconsistent positive genotoxicity and carcinogenicity have been reported at higher levels.

For *ortho*-anisidine and other aniline derivatives, a peroxidation that yields reactive diamines and quinoneimine intermediates (Figure A-3) that potentially bind protein/DNA has also been identified (Thompson and Eling, 1991). Because the urinary bladder contains substantial peroxidase activity, activation by this and other extrahepatic activating systems merit consideration when assessing the adequacy of hepatic S9 in mutagenicity tests.

The N-oxidized metabolites of arylamines can alkylate DNA and other macromolecules but also oxidize hemoglobin in a reaction that causes methemoglobinemia. In the case of aniline, the N-hydroxy, nitroso, nitro, and possibly *ortho*- and *para*- aminophenol, metabolites can oxidize hemoglobin to cause methemoglobinemia and, consequently, hyperplasia and siderosis of the spleen (Kao et al., 1978, Kiese, 1966; Radomski, 1979). However, a relatively large amount

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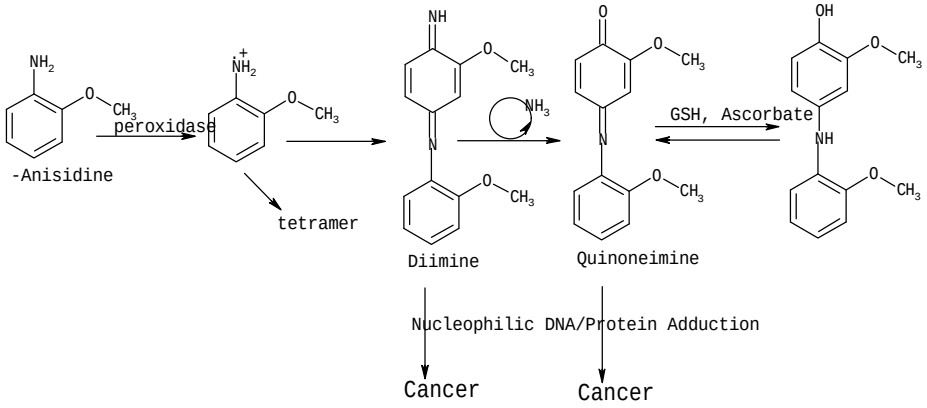

Adapted from Thompson and Eling 1991.

of the oxidized equivalents is required to convert a significant amount of the hemoglobin. Splenic damage is secondary to erythrocytic effects, and relatively high doses of arylamine are required to reach the threshold past which this toxic effect is elicited. Consequently, splenic effects found in laboratory animals may be of less concern than the causation of tumors, particularly in bladder, that have been associated with human occupational exposure to *o*-toluidine (Rubino et al., 1982) and/or aniline (Ward et al., 1991, 1996).

EPA does not believe that the data provided here are sufficient to support a quantitative estimate of the carcinogenic potency of these compounds. The best means of ascertaining if cancer risk is associated with exposure to these chemicals is through conducting 2-year carcinogenicity studies and, in the case of arylamides that may be metabolized to arylamines, paying particular attention to the carcinogenic responses of the bladder. At a minimum, a 13-week study could be performed to allow adequate assessment of the carcinogenic potential of these chemicals, but no such data are available.

In the absence of these data, it would be useful to conduct metabolism studies to determine if, for example, AAOT is deacylated to form the known carcinogen *o*-toluidine. While the carcinogenicity and metabolism of AAA, AAOT, and AAOA have not been determined, it is interesting to note that they promote methemoglobinemia in laboratory animals. This suggests that a significant portion of the dose is deacylated and N-oxidized in vivo, potentially forming known proximate carcinogens,(i.e., *o*-toluidine) . The carcinogenicity of *o*-toluidine is well established in animals. It produces significant increases in the incidence of one or more types of neoplasms in the organs of F344 rats and B6C3F1 mice of both sexes. These responses are not limited to the spleen; responses in rats include mesotheliomas of the abdominal cavity or scrotum in males and transitional-cell carcinomas of the urinary bladder in females and increased incidences of fibromas of the subcutaneous tissue in males and fibroadenomas or adenomas of the mammary gland in females (NCI, 1979). In mice, hemangiosarcomas were induced at various sites in males, and hepatocellular carcinomas or adenomas were induced in females. Similarly, *o*-anisidine has been found to be carcinogenic in F344 rats and B6C3F1 mice, inducing transitional-cell carcinomas or papillomas of the bladder in both rats and mice and in both sexes of each species, transitional-cell carcinomas of the pelvis of the kidney in male rats, and follicular-cell tumors of the thyroid in male rats (NCI, 1978). Aniline is at most a weak

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carcinogen, possibly due to the lesser reactivity of its activated derivatives with DNA (Jacobsen et al., 1988; Ward et al., 1991; Jackson et al., 1993).

Unfortunately, toxicity testing of AAA, AAOT, and AAOA has been limited to LD50 studies, gross toxicity after short-term dosing, and genotoxicity tests. Because bladder and liver carcinogenicity are the most serious effects associated with this class of molecules, the tests conducted were not well chosen to determine the hazards associated with their exposure. Although genotoxicity tests were conducted with and without S9 as an activating system, these methodologies are inadequate to allow the optimal assessment of the carcinogenic potential of aromatic amines. Concerns about the sensitivity of commonly used *Salmonella* strains in assessing the mutagenic potential of aromatic amines has led to the development of new tester strains that express enzymes that activate carcinogens (Josephy et al., 1997). Optimally, the system must be able to bioactivate the aromatic amine within the bacterial cell rather than be supplemented externally with a hepatic supernatant that may or may not contain the activating systems responsible (e.g., cytochrome P450 and NAT/OAT) for hepatic and extrahepatic toxic responses (Josephy et al., 1995). Interestingly, many of these systems were derived from some of the strains used in data submitted by commenters to test AAA, AAOT, and AAOA, and those *Salmonella* strains, TA-98 and TA-1535, are devoid or deficient in NAT and have greatly reduced sensitivity to the mutagenicity of aromatic amines. Recent research has come to fruition with the development of bacterial cell lines that simultaneously express human cytochrome P450, its reductase, and N-acetyltransferase (Josephy et al., 1998), replacing the need for S9 and increasing sensitivity.

In conclusion, the carcinogenic action of arylamines, particularly on the bladder, is the most serious health effect associated with their exposure. This can best be ascertained for AAA, AAOT and AAOA, by 2-year carcinogenicity studies, although 13-week exposures may also reveal this activity. Two of the compounds reviewed, AAOT and AAOA, are acetoacetamide derivatives of known carcinogens. It would be advisable to determine in metabolism studies whether they are hydrolyzed in vivo to form these arylamines, a reaction suggested by the methemoglobinemias observed after administration of the compound to rats. Mutagenicity tests in *Salmonella* proved negative for the three arylamides, but it is unclear if the strains used allowed for exposure of the nuclear material to proximate carcinogens. More modern strains expressing the activating enzymes may be more predictive of genotoxic actions of these compounds (Josephy et al., 1998), and should be considered for future characterization of their potential toxicity.

A.4 Developing Health Benchmarks

Insufficient data are available to make a quantitative estimation of the carcinogenic potential of AAA, AAOA, or AAOT or to establish a provisional noncancer benchmark without great uncertainty. Therefore, alternatives are presented with the associated limitations and uncertainties of each approach.

A.4.1 Precedence for Using SAR Weight-of-Evidence Approach

Insufficient constituent-specific toxicity test data currently exist to classify AAA, AAOA, or AAOT as potential carcinogens for regulatory purposes. However, a precedent

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for using SAR analysis in the absence of constituent-specific toxicity testing has been established in the final rule for the hazardous waste listing decision for organobromines. In the response to comments document for the organobromines rule, EPA addressed this policy issue for the listing program as follows:

> The Agency agrees that this listing represents a new element in the Agency's policy in that this is the first listing to use SAR as a basis for listing a wastestream as hazardous. The Agency was specifically exploring the establishment of a precedent in using other than Agency-verified toxicity data when it issued the organobromines listing proposal. EPA takes the position that, depending on the strength of the evidence, SAR-based listings are appropriate to use for the hazardous waste listings program because SAR is an available tool that can solve a problem the Agency will regularly face: making risk-based regulatory decisions (such as listing determinations) in the absence of Agency-verified or provisional health benchmark s(e.g., reference dose [RfD], reference concentration [RfC], or cancer slope factor [CSF]). SAR is one approach that was designed to specifically address this problem. The use of SAR is particularly compelling in the organobromines listing determination. The constituent has an extremely close structural analog (2,4,6-TCP) for which direct toxicity data are available. Because of this, the Agency specifically solicited comment on the policy implications of the use of QSAR in the organobromines proposal.

In addition, in the 1996 *Guidelines for Carcinogen Risk Assessment*, EPA presented guidance for the use of SAR to predict carcinogenicity in Section 2.3.2 (61 FR 17977):

> 2.3.2. Structure-Activity Relationships
>
> Structure-activity relationship (SAR) analyses and models can be used to predict molecular properties, surrogate biological endpoints, and carcinogenicity. Overall, these analyses provide valuable initial information on agents, which may strengthen or weaken the concern for an agent's carcinogenic potential. Currently, SAR analysis is useful for chemicals and metabolites that are believed to initiate carcinogenesis through covalent interaction with DNA (i.e., DNA-reactive, mutagenic, electrophilic, or proelectrophilic chemicals) (Ashby and Tennant, 1991). For organic chemicals, the predictive capability of SAR analysis combined with other toxicity information has been demonstrated (Ashby and Tennant, 1994). The following parameters are useful in comparing an agent to its structural analogues and congeners that produce tumors and affect related biological processes such as receptor binding and activation, mutagenicity, and general toxicity (Woo and Arcos, 1989):
>
> - nature and reactivity of the electrophilic moiety or moieties present,
> - potential to form electrophilic reactive intermediate(s) through chemical, photochemical, or metabolic activation,
> - contribution of the carrier molecule to which the electrophilic moiety(ies) is attached,
> - physicochemical properties (e.g., physical state, solubility, octanol-water partition coefficient, half-life in aqueous solution),
> - structural and substructural features (e.g., electronic, stearic, molecular geometric),
> - metabolic pattern (e.g., metabolic pathways and activation and detoxification ratio), and
> - possible exposure route(s) of the agent.
>
> Suitable SAR analysis of non-DNA-reactive chemicals and of DNA-reactive chemicals that do not appear to bind covalently to DNA requires knowledge or postulation of the probable mode(s) of action of closely related carcinogenic structural analogues (e.g., receptor-mediated, cytotoxicity-related). Examination of the physicochemical and biochemical properties of the agent may then provide the rest

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of the information needed in order to make an assessment of the likelihood of the agent's activity by that mode of action.

In fact, in the Guidelines, the example of using SAR to support a finding of carcinogenicity (Narrative #4) is for an aromatic amine.

Bis-benzenamine

CAS# XXX

CANCER HAZARD SUMMARY

This chemical is likely to be carcinogenic to humans by all routes of exposure. Its carcinogenic potential is indicated by (a) tumor and toxicity studies on structural analogues, which demonstrate the ability of the chemical to produce thyroid follicular cell tumors in rats and hepatocellular tumors in mice following ingestion and (b) metabolism and hormonal information on the chemical and its analogues, which contributes to a working mode of action and associates findings in animals with those in exposed humans. In comparison with other agents designated as likely carcinogens, the overall weight of evidence for this chemical places it at the lower end of the grouping. This is because there is a lack of tumor response data on this agent itself. Biological information on the compound is contradictory in terms of how to quantitate potential cancer risks. The information on disruption on thyroid-pituitary status argues for using a margin of exposure evaluation. However, the chemical is an aromatic amine, a class of agents that are DNA-reactive and induce gene mutation and chromosome aberrations, which argues for low-dose linearity. Additionally, there is a lack of mode of action information on the mouse liver tumors produced by the structural analogues, also pointing toward a low-dose linear default approach. In recognition of these uncertainties, it is recommended to quantitate tumors using both nonlinear (to place a lower bound on the risks) and linear (to place an upper bound on the risks) default approaches. Given the absence of tumor response data on the chemical per se, it is recommended that tumor data on close analogues be used to possibly develop toxicity equivalent factors or relative potencies.

Using these precedents, a conditional toxicity equivalency factor (TEF) might be calculated based on aniline for AAA and o-toluidine for AAOA and AAOT. However, EPA believes that, although a qualitative judgment can be made as to the likelihood that these compounds may be carcinogenic, the data are not sufficient to justify calculation of a CSF.

A.4.2 Available Acute Toxicity Data

The toxicity data available for AAA, AAOA, and AAOT are extremely limited. The data include a 28-day toxicity study of AAA, an 11-day toxicity study of AAOT, and a 14-day toxicity study of AAOA. These studies are all of too short duration to be considered subchronic studies. Subchronic studies are 13 weeks in duration. Hence, the uncertainties in the results from both 28-day, 14-day, and 11-day studies are significantly greater than those from 13-week (or 90-day) studies when making extrapolations to potential effects from chronic exposures.

A summary of a 28-day exposure study for AAA in rats was submitted by the commenter (Eastman Kodak). In this study, Sprague-Dawley rats that were treated orally with AAA suffered reversible dose-dependent hemolytic anemia and methemoglobinemia and irreversible siderosis of

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the spleen and splenomegaly accompanied by hepatic extramedullary hematopoiesis and renal excretion of heme. The study identified a no observed adverse effects level (NOAEL) of 12 mg/kg-d for these effects (LONZA Report, 1991). The actual detailed study report was not submitted with the comment; thus no judgment may be made concerning the conduct of the study and the validity of the NOAEL and lowest observed adverse effects level (LOAEL) determinations.

A provisional noncancer benchmark for AAA may be calculated as follows:

where

NOAEL = 12 mg/kg-d

UF = uncertainty factor of 1000 (10 x 10 x 10)
10 interspecies variation
10 human variability
10 less than chronic study

MF = modification factor of 9 (3 x 3)
3 lack of reliable reproductive/ developmental effects data
3 28-day toxicity studies are subacute and not subchronic in duration.

Thus, the overall uncertainty/modifying factors for AAA would equal 9,000.
This uncertainty value is very high for health benchmarks established for regulatory purposes.

The NOAEL from the 11-day study of AAOT and the NOAEL from the 14-day study of AAOA may be used as the starting points for developing provisional reference doses for these compounds. Given the shortness of duration of these studies, another uncertainty factor of 10, over and above the uncertainty factors used for AAA, is added. Thus, the overall uncertainty/ modifying factors for AAOA and AAOT would be 90,000. This value exceeds the usual bounds for uncertainty in establishing health benchmarks.

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A provisional noncancer benchmark for AAOA may be calculated as follows:

where

NOAEL = 75 mg/kg-d

UF = uncertainty factor of 10,000 (10 x 10 x 10 x 10)
10 interspecies variation
10 human variability
10 less than chronic study
10 extremely short duration study

MF = modification factor of 9 (3 x 3)
3 lack of reliable reproductive/ developmental effects data
3 14-day toxicity studies are subacute and not subchronic in duration.

Thus, the overall uncertainty/modifying factors for AAOA would equal 90,000.

With the same concerns a provisional noncancer benchmark for AAOT may be calculated as follows:

where

NOAEL = 96 mg/kg-d

UF = uncertainty factor of 10,000 (10 x 10 x 10 x 10)
10 interspecies variation
10 human variability
10 less than chronic study
10 extremely short duration study

MF = modification factor of 9 (3 x 3)
3 lack of reliable reproductive/ developmental effects data
3 11-day toxicity studies are subacute and not subchronic in duration.

The substantiation of the provisionally calculated reference doses described for the three compounds is contingent upon obtaining the complete study reports (including individual animal data records) of the 11-day study of AAOT, the 14-day toxicity study of AAOA, and the 14-day and 28-day studies of AAA. These reports are needed to evaluate the adequacy of the studies, both in terms of design and execution, for developing NOAELs or LOAELs.

A.5 Conclusions

This appendix has reviewed the appropriateness of developing health benchmarks for

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AAA, AAOA, and AAOT. The weight of evidence of potential carcinogenicity based on the identification of surrogates for these compounds has been evaluated. The metabolic pathways leading to carcinogenicity of the selected surrogates are documented; however, there are no data to substantiate the metabolism of AAA, AAOA, and AAOT to yield the same or similar metabolic products by the same pathways. Therefore, no benchmarks based on carcinogenic potential have been calculated. The acute toxicity data and the mutagenicity data summary submitted by the commenter does not negate the carcinogenic potential of these constituents. The acute studies are of very short duration and any use of these data to derive noncancer health benchmarks would have extremely high uncertainty (i.e., 9,000 - 90,000). In addition, before these data could be used for the development of health benchmarks, a complete study report containing all individual animal data would need to be submitted by the commenter and reviewed by EPA toxicologists for adequacy of the study design and execution. Thus, at this time, no data appear to be available that are suitable for deriving health benchmarks with an acceptable level of uncertainty based either on cancer or noncancer endpoints.

A.6 References

Bergman, K., L. Muller, and S.W. Teigen. 1996. Series: current issues in mutagenesis and carcinogenesis, No. 65. The genotoxicity and carcinogenicity of paracetamol: a regulatory (re)view. *Mutat. Res.* 349:263-288.

Dahlin, D. C., G. T. Miwa, A. Y. Lu, and S. Nelson. 1984. N-acetyl-p-benzoquinone imine: a cytochrome P-450-mediated oxidation product of acetaminophen. *Proc. Natl. Acad. Sci.* 81: 1327-1331.

Garner, R. C., C. N. Martin, and D. B. Clayson. 1984. Carcinogenic aromatic amines and related compounds. *In Chemical Carcinogenesis*, 2nd ed. (Searle, C. E., Ed.) Vol. I, pp 175-276, American Chemical Society, Washington, DC.

IARC. 1987a. *Aniline (Group3)*. Supplement 7: 99-100. Lyon, France.

IARC. 1987b. *ortho-Toluidine (Group 2B)*. Supplement 7: 362-363. Lyon, France

Jackson, M. A., H.. F. Stack, and M. D. Waters. 1993. The genetic toxicology of putative nongenotoxic carcinogens. *Mutat. Res.* 296:241-277.

Jacobson, M. D., R. Shapiro, G. R. Underwood, S. Broyde, L. Verna, and B. E. Hingerty, 1988. Synthesis and conformation of a dinucleoside monophosphate modified by aniline. *Chem. Res. Toxicol.* 1:152-159.

Josephy P. D., L. S. DeBruin, H. L. Lord, J. N. Oak, D. H. Evans, Z.. Guo, M. S. Dong, and F. P. Guengerich, F. P. 1995. Bioactivation of aromatic amines by recombinant human cytochrome P4501A2 expressed in Ames tester strain bacteria: a substitute for activation by mammalian tissue preparations. *Cancer Res.* 55:799-802.

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

Josephy, P. D., P. Gruz, and T. Nohmi. 1997. Recent advances in the construction of bacterial genotoxicity assays. *Mutat. Res.* 386:1-23.

Josephy, P. D., D. H. Evans, A. Parikh, and F. P. Guengerich. 1998. Metabolic activation of aromatic amine mutagens by simultaneous expression of human cytochrome P450 1A2, NADPH-cytochrome P450 reductase, and N-acetyltransferase in *Escherichia coli*. *Chem. Res. Toxicol.* **11**, 70-74.

Kao, J., J. Faulkner, and J. W. Bridges. 1978. Metabolism of aniline in rats, pigs, and sheep. *Drug Metab. Dispos.* 6:549-555.

Kiese, M. 1966. The biochemical production of ferrihemoglobin forming derivatives from aromatic amines, and mechanisms of ferrihemoglobin formation. *Pharmacol. Rev.* 18:1091-1160.

LONZA Report, 1991.

NCI (National Cancer Institute). 1978. Bioassay of *o*-toluidine hydrochloride for possible carcinogenicity. *Carcinogenesis Technical Report No. 153.*

NCI (National Cancer Institute). 1979. Bioassay of *o*-anisidine hydrochloride for possible carcinogenicity. *Carcinogenesis Technical Report No. 89.*

Parkinson, A. 1996. Biotransformation of xenobiotics. In *Casarett and Doull's Toxicology, 5th ed* (Klaassen, C.D., M.O. Amdur, and J. Doull, Eds) pp 113-186, MacMillan Publishing Company, New York.

Patel D. J., B. Mao, Z. Gu, B. E. Hingerty, A. Gorin, A. K. Basu, and S. Broyde. 1998. Nuclear magnetic resonance solution structures of covalent aromatic amine-DNA adducts and their mutagenic relevance. *Chem. Res. Toxicol.* 11:391-407.

Radomski, J. L. 1979. The primary aromatic amines: Their biological properties and structure-activity relationships. *Ann. Rev. Pharmacol. Toxicol.* 19:129-157.

Rubino, G. F., G. Scansetti, G. Piolatto, E. Pira. 1982. An epidemiological study on the role of *o*-toluidine and 4,4'-methylene-bis-2-methylaniline in inducing bladder cancer in man. *Environ. Res*. 27:241-254.

Thompson, D. C., and T. E. Eling. 1991. Reactive intermediates formed during the peroxidative oxidation of anisidine isomers. *Chem. Res. Toxicol.* 4:474-481.

U.S. EPA (Environmental Protection Agency). 1996. *Proposed Guidelines for Carcinogen Risk Assessment*. EPA/600/P-92/003C. Office of Research and Development, Washington, DC.

Ward, E., A. Carpenter, S. Markowitz, D. Roberts, and W. Halperin, W. 1991. Excess number of

bladder cancers in workers exposed to orthotoluidine and aniline. *J. Natl. Cancer Inst.* 83: 5-1-506.

Ward, E. M., G. Sabbioni, D. G. DeBord, A. W. Teass, K. K. Brown, G. G. Talaska, D. R. Roberts, A. M. Ruder, and R. P. Streicher. 1996. Monitoring of aromatic amine exposures in workers at a chemical plant with a known bladder cancer excess. *J. Natl. Cancer Inst.* 88: 1046-1052.

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Appendix B

Sensitivity Analysis for Nongroundwater Pathways

Appendix B

Sensitivity Analysis for Nongroundwater Pathways

B.1 Introduction

The initial phase of this risk analysis was a sensitivity analysis. The sensitivity analysis is used to identify and rank the most influential variable parameters in the analysis. The first step of a sensitivity analysis is to set all variable parameters at central tendency values and calculate central tendency risk estimates. Then, one at a time, each variable parameter is set to its high-end value, risk is calculated, and the variation in the risk from the central tendency value is noted. The parameters having the greatest effect on the resulting risks are identified as the most sensitive variables. The two most sensitive parameters identified by this method are set to high-end in the deterministic analysis.

For this analysis, the initial landfill waste concentration for each constituent is set at a constant value (1,000 mg/kg). Then, setting all variable parameters at their central tendency values a central tendency risk value was calculated for each constituent. Then each independent parameter was varied to high end one at a time and the risk values were calculated. Note that the parameters associated with location (both meteorological and soil parameters) are varied as a single variable to their high end values to determine the risk for the high end location. The resulting risks for each constituent and each variation are compared to the central tendency risk value to determine the sensitivity of each variable or the degree to which changing an individual variable impacts the risk results.

The nongroundwater sensitivity analysis considers the emissions of volatile constituents from the landfill and their dispersion and deposition at receptor locations. The exposure pathways evaluated for the nongroundwater analysis include direct inhalation of vapors, inadvertent ingestion of soil that has been contaminated by vapor deposition, ingestion of plant products that are contaminated by vapor deposition and air-to-plant transfer of vapors, and the ingestion of beef and dairy products that have been contaminated by cattle ingestion of contaminated soil and vegetation. Receptors for the nongroundwater pathways are assumed to be farmers and their children as these are considered to be the most highly exposed individuals.

TAM and filter aid waste streams are evaluated separately for the nongroundwater

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sensitivity analysis. Therefore, the waste-stream-specific parameters for volume, bulk density, and fraction organic carbon are specific to each waste stream. However, due to CBI constraints, a single set of constituents is evaluated for both TAM sludge and spent filter aids. Parameters varied in the nongroundwater sensitivity analysis are listed below.

- Waste quantity (metric tons)
- Waste stream foc
- Geographic location
  - Precipitation (cm/yr)
  - Evapotranspiration (cm/yr)
  - Runoff (cm/yr)
- Landfill dimensions
  - Area (m^2)
  - Depth (m).
- Distance to receptor (m)
- Exposure factors.

B.2 Parameters Varied for the Sensitivity Analysis

Parameters considered in the nongroundwater sensitivity analysis can be grouped into four categories; 1) waste stream specific parameters; 2) waste management unit parameters; 3) location related parameters; and 4) exposure factors. Parameters varied within each of these categories for the sensitivity analysis are described below.

B. 2.1 Waste Stream Specific Parameters

Waste stream specific parameters include:

- Constituent composition
- Bulk density of waste
- Waste stream foc
- Waste quantity

These parameters are described below and the specific values used in the sensitivity analysis for waste-stream specific parameters are identified.

Constituent Composition - For this analysis, the constituent-specific waste concentration is not an independent variable. Rather, due to CBI constraints, risk-based constituent concentrations are back-calculated in this assessment. Therefore constituent concentration is not varied as part of the sensitivity analysis. Instead, concentrations of the 53 constituents of concern evaluated for both the TAM sludge and spent filter aid waste streams are set at a fixed value of 1000 mg/kg for the sensitivity analysis. The constituents, their health benchmarks, and the constituent specific physical and chemical property data used in the fate and transport modeling are presented in Appendix D. The method used to identify constituents of concern in these waste streams is described in the listing technical background document (EPA, 1999).

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Waste Bulk Density and Fraction Organic Carbon (foc) - The physical properties data needed for the risk analysis are waste fraction organic carbon (foc) and waste bulk density. These data are obtained from separate sources. The foc data were obtained from the sampling and analysis data collected for the 1994 proposed rule for the dye and pigment industry (EPA, 1999). The foc data for filter aid wastes are the results from sampling conducted on filter aids from all industry segments and various processes within the industry. EPA does not have sampling and analysis data for noncommingled TAM sludge waste streams. Therefore, the foc for TAM sludges is assumed to be the same as for other dye and pigment industry wastewater treatment sludges that were sampled and analyzed for the 1994 proposed rule. The value for the dry bulk densities of spent filter aids and TAM sludges is obtained from the EPA survey of all hazardous waste generators (U.S. EPA, 1991). The generator survey requested information about the bulk density of various types of wastes, including spent filter aids and biological wastewater treatment sludge. The central tendency bulk density values from this survey are used because little variability is expected in this parameter and no waste-specific data are available from the sampling and analysis phase of this listing determination. Physical property data used in the deterministic and Monte Carlo analyses are presented in Tables 2-1 and 2-2.

Waste Quantity - Spent filter aids may be generated by any dye or pigment process. The generation rates for the filter aid waste stream have been declared Confidential Business Information (CBI) by the facilities that report generating these wastes. Therefore, specific generation rates are not used in the analysis. Instead, the reported waste volumes are entered into a data set from which a distribution of volumes is developed. The 50^{th} and 90^{th} percentile values for waste volumes are pulled from this distribution for use as waste generation rates in the sensitivity analysis.

The TAM volume used in the sensitivity analysis is 57.2 metric tons per year. Waste quantity data are presented in Tables 2-1 and 2-2.

Table 2-1. Filter Aid Waste Stream Specific Parameters

Parameter	Units	Central Tendency (50^{th} Percentile)	High End (90^{th} Percentile)	Reference
Waste Quantity	Mg/yr	%	%	EPA, 1999
Bulk Density of Waste	g/cm^3	1.07		U.S. EPA, 1991 (Generator Survey)
Fraction of Organic Carbon	unitless	%	%	SAIC, 1999

* Relevant data are not included at present because of business confidentiality concerns

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Table 2-2. TAM Sludge Waste Stream Specific Parameters

Parameter	Units	Central Tendency (50th Percentile)	High End (90th Percentile)	Reference
Waste Quantity	tonne	57.2		SAIC, 1999
Bulk Density of Waste	g/cm^3	1.07		U.S. EPA, 1991 (Generator Survey)
Fraction of Organic Carbon	unitless	%	%	SAIC, 1999

* Relevant data are not included at present because of business confidentiality concerns

B. 2.2 Waste Management Unit Parameters

The waste management practice modeled for TAM sludge and spent filter aids is disposal in a municipal landfill. For this analysis, any municipal landfill described in the distribution of municipal landfills is assumed possible.

The landfill parameters used in the nongroundwater sensitivity analysis are:

- total surface area of landfill
- surface area of active cell
- depth of waste in landfill
- active life of the landfill
- operating days per year
- length of time daily waste addition is uncovered
- depth of daily cover
- depth of landfill cap

The landfills analyzed for the sensitivity analysis are assumed to comply with current municipal landfill management practices regarding landfill cover regulations in 40 CFR 258. These regulations require application of 6 inches of daily cover (soil) and application of a 2-foot soil cap for each annual cell. The landfills are not, however, assumed to have liner systems, because those requirements are not in effect for all existing landfills. The landfill is evaluated as an unlined landfill and does not include a landfill liner or leachate collections system.

The municipal landfill parameters used in this risk assessment are not specific to any location. A national distribution of landfill areas is used for the surface area parameter. The lifetime of the landfill is assumed to be 30 years (U.S. EPA, 1988). There is no national distribution available for the third important parameter, landfill depth. Therefore, the values for municipal landfill depth used in this analysis are a distribution of permitted waste column depths for municipal landfills in the State of Texas. The Texas data are presented in Appendix G. The depth values were assessed for correlation with the associated landfill areas in the Texas permit data and found to correlate with a coefficient of 0.5.

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The landfill partitioning model was used to estimate contaminant loss from a landfill due to volatilization, and leaching. The distribution of total landfill surface areas used in this analysis is from the survey of municipal landfills conducted in support of the Toxicity Characteristic (U.S. EPA, 1988). The distribution is presented in Table 2-3. The municipal landfill parameters used in the landfill partitioning model for the sensitivity analysis are presented in Table 2-4.

Table 2-3. Distribution for Area of Municipal Subtitle D Landfills

Area (m^2)	Cumulative Probability
4,000	0.00
8,094	0.10
20,200	0.25
60,705	0.50
194,000	0.75
420,888	0.90
9,348,570	1.00

Source: U.S. EPA, 1988

Table 2-4. Landfill Parameters Used in Sensitivity Analysis

Parameter	Units	Landfill			Reference
		10th Percentile	50th Percentile	90th Percentile	
Area	m^2	8,094	60,705	420,888+	U.S. EPA, 1988.
Area of Active Face (Cell Area)	m^2	269.8	2,024	14,030+	Calculated
Active Life of Landfill	yr	30			U.S. EPA, 1988.
Total Porosity of Municipal Waste	unitless	0.671			Help Model
Liquid Filled Porosity of Municipal Waste	unitless	0.12			Help Model
Depth of Daily Waste Addition	m	0.76			Assumption
Uncovered Time	hrs	12			Estimated
Thickness of Daily Cover	m	0.15			CFR 258
Thickness of Cap	m	0.6			CFR 258

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Parameter	Units	Landfill			Reference
		10th Percentile	50th Percentile	90th Percentile	
Operating Days per Year	d/yr	350			Assumption
Layers	unitless	5.4			Calculated
Daily additions/layer	unitless	65			Calculated
Average Exposed Time	d	67.93			Calculated
Area of Daily Waste Addition	m^2	31.06			Calculated

✢ Used only in groundwater sensitivity analysis.

B.2.3 Location Related Parameters

The municipal landfills assumed to receive filter aid and TAM sludge waste streams are assumed located near the facility where the waste is generated. Hydrogeologic and climate parameters used in the fate and transport modeling of the two waste streams are taken from the hydrogeologic and climate stations located nearest each of the facilities being evaluated. Facility locations for the filter aid waste streams are claimed as CBI. Therefore, only the designation of the hydrogeologic codes and climate stations nearest the facilities are identified for the spent filter aid analysis. The location at which dedicated TAM sludges are reported to be generated is used in modeling conducted for TAM sludges. The geographic location is used to identify the soil, climate, and hydrogeologic parameters used in the fate and transport modeling. The climate data, soil parameters, and hydrogeologic descriptor data are linked to specific locations. Thus, for the sensitivity analysis, high end and central tendency locations are treated as a single variable and all climate and soil parameters associated with each location were varied together. The climate and soil parameter values used in the analysis are consistent between the groundwater and nongroundwater pathway sensitivity analyses.

It is important to note, however, that it is difficult to identify meaningful central tendency and high-end facility locations because of the numerous interrelated variables associated with each location. For instance, infiltration rate, unsaturated zone thickness, and aquifer thickness are among the most important groundwater pathway parameters tied to location. Other location-related parameters, such as wind speed and temperature, are important for nongroundwater pathways. Most locations are likely to have a mix of high-end, central-tendency, and low-end parameter values. In many cases, conditions that favor high-end exposure for one pathway may have the opposite effect on another pathway. For instance, locations with high precipitation may be high-end for the groundwater pathway but will tend to reduce exposure from the air transport pathways.

Because these waste streams are modeled in municipal landfills, it was anticipated that the groundwater pathway would present the highest risk. Therefore, for the sensitivity analysis for filter aids, the central tendency and high-end locations were selected based on the groundwater pathway. On this basis, _____* was chosen to represent the central tendency case

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and_____* was chosen to represent the high-end case in the sensitivity analysis. Climate data from the LaGuardia meteorologic station and hydrogeologic data from Edison, NJ, hydrogeology station are used for the TAM sludge analysis. These locations were judged to be close enough and similar enough to the location of the TAM landfill to be representative.

Soil Parameters - In general, soil parameter variability does not impact nongroundwater risk results as much as groundwater risk results. This is partly because only the surficial properties are used in nongroundwater analyses whereas for groundwater analyses both the unsaturated zone and saturated zone parameters are used. Also, the degree of variability in the parameters that are used in the nongroundwater analyses generally tend to be fairly small. Typical parameter values associated with surface soils in these geographic locations have been identified for use in the nongroundwater sensitivity analysis. It is assumed that wastes disposed in municipal landfills are sent to facilities near the point of generation. Therefore, the soil parameters are estimated by considering soil parameters near the dye or pigment manufacturing facility area using the States Soil Geographic (STATSGO) database and selected subsets of this database (USSOILS and CONUS).

The (STATSGO) database is a Geographic Information System (GIS) database designed primarily for regional, multistate, river basin, State, and multicounty resource planing management and monitoring. Soil maps for STATSGO are compiled from more detailed county soil survey maps. Where county soil survey maps are not available, data on geology, topography, vegetation, and climate are assembled together with Land Remote Sensing Satellite (LANDSAT) images. Soils of like areas are studied, and the probable classification and extent of the soils are determined. Soil parameters used for this analysis are presented in Table 2-5.

* Relevant data are not included at present because of business confidentiality concerns

Table 2-5. Soil Parameters for Central Tendency and High End Locations of Dye and Pigment Facilities Producing Deferred Wastes

Parameter	Units	Central Tendency[1]	High End[2]	Reference
Predominant Soil Texture	unitless		Loamy sand	CONUS (STATSGO)
Fraction Organic Carbon	unitless		0.009	USOILS (STATSGO)
USLE Erodibility Factor	tons/acre		0.16	USOILS (STATSGO)
Hydraulic Conductivity	cm/hr		14.59	Carsel and Parrish (1988)
Saturated Water Content	unitless		0.41	Carsel and Parrish (1988)
Moisture Retention Exponent	unitless		4.38	Clapp and Hornberger (1978)
Dry bulk density	g/cm3		1.56	Calculated

[1] Relevant data are not included at present because of business confidentiality concerns

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[2] Only site for TAM Sludges

Climate Parameters - Detailed climate and meteorologic data are required to conduct fate and transport modeling. These data are needed to conduct air dispersion and deposition modeling to estimate concentrations constituents in surrounding areas due to vapor air emissions from the municipal landfill.

The climate data used in this analysis were downloaded from the CD-ROM *International Station Meteorological Climate Summary* (ISMCS) (NOC, 1992). Annual precipitation, average annual temperature, and annual average wind speed were used.

This analysis also used 5 years of representative ISCMS surface and upper air data for each of the meteorologic region locations modeled to determine long-term average air concentrations and deposition rates. Surface data are obtained from the Solar and Meteorological Surface Observation Network (SAMSON) CD-ROM (NOAA, 1993) for each meteorologic station. These data include 5 years of hourly observations of the following surface meteorologic parameters:

- opaque sky,
- temperature,
- wind direction,
- windspeed,
- ceiling height,
- current weather,
- station pressure, and
- precipitation type and amount.

The corresponding upper air data are obtained from EPA's SCRAM Bulletin Board (U.S. EPA). These data are paired with the surface data for air dispersion modeling through the use of the meteorologic preprocessor PCRAMMET. PCRAMMET pairs the surface data with the upper air data to create a meteorologic file that contains hourly windspeed, wind direction, atmospheric stability class, temperature, and mixing height for deposition calculations. PCRAMMET requires additional site-specific land-use data to calculate additional meteorologic parameters for with EPA's Industrial Source Complex Short Term, version 3 (ISC3). The landuse data used in this analysis were based on telephone surveys and assessed topographic maps. PCRAMMET inputs were developed for each meteorological location corresponding to the high-end and central tendency sites evaluated. The climate parameters for the central tendency and high end site considered in the nongroundwater risk analysis are presented in Table 2-6.

Table 2-6. Climate Parameters for Central Tendency and High End Location for Spent Filter Aid and TAM Sludge Wastes

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Parameter	Units	Central Tendency[1]	High End[2]	Reference
Location	NA		LaGuardia, NY	
Annual Rainfall	cm/yr		109	ISMCS, June, 1992
Average Windspeed	m/s		6	ISMCS, June, 1992
Average Temperature	deg F		55	ISMCS, June, 1992

[1] Relevant data are not included at present because of business confidentiality concerns
[2] Only site for TAM Sludges

B.2.4 Exposure Parameters

Receptor Location The receptors for the nongroundwater pathways are assumed to be farmers and their children. For the nongroundwater pathway the values for distance to receptor are presented in Table 2-7.

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Table 2-7 Distance from Source to Receptor

Pathway	units	Central Tendendy	High End	Reference
Nongroundwater	m	500	75	U.S. EPA, 1998

Exposure Factors The exposure factors considered in the sensitivity analysis for the nongroundwater pathways are ingestion rates, inhalation rate, and exposure durations. The primary source for these factors is the 1997 Exposure Factors Handbook (U.S. EPA, 1997). These factors are used in estimating risk through inhalation of vapors emitted from the landfill, ingestion of crops and/or animal products (beef, dairy) exposed to these emissions, and inadvertent ingestion of soil. The central tendency and high end values for exposure parameters for all pathways and receptors included in the sensitivity analysis are presented in Table 2-8.

Table 2-8 Central Tendency and High End Exposure Factors

Farmer				
Media	**Units**	**Central Tendency**	**High End**	**Reference**
Soil[a]	kg/day	5.0E-05	NA	EFH Table 4-23
Exposed Vegetables[b]	kg(DW)/d	7.3E-03	3.6E-02	EFH Table 13-63
Fruits[c]	kg(DW)/d	1.2E-02	5.5E-02	EFH Table 13-61
Root Vegetables[d]	kg(DW)/d (Metals)	7.5E-03	3.9E-02	EFH Table 13-65
	kg(WW)/d (Organics)	5.3E-02	2.8E-01	

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Farmer				
Media	**Units**	**Central Tendency**	**High End**	**Reference**
Beef[e]	kg(WW)/d	1.1E-01	4.5E-01	EFH Table 13-36
Dairy[f]	kg(WW)/d	6.5E-01	2.6	EFH Table 13-28
Inhalation[g]	m^3/hr	0.63	NA	EFH Table 5-23
Exposure Duration	yr	10	58.4	
Child of Farmer				
Soil[a]	kg/d	1.0E-04	4.0E-04	EFH Table 4-23
Exposed Vegetables[b]	kg(DW)/d	3.5E-03	2.0E-02	EFH Table 13-63
Fruits[c]	kg(DW)/d	5.4E-03	4.3E-02	EFH Table 13-61
Root Vegetables[d]	kg(DW)/d (Metals)	4.8E-03	2.8E-02	EFH Table 13-65
	kg(WW)/d (Organics)	3.4E-02	2.0E-01	
Beef[e]	kg(WW)/d	9.1E-02	2.1E-01	EFH Table 13-36
Dairy[f]	kg(WW)/day	7.1E-01	1.7	EFH Table 11-2
Inhalation[g]	m^3/hr	0.27	NA	EFH Table 5-23
Exposure Duration	yrs	7.3 6 (soil)	18	EFH Table
Fraction of Intake from Contaminated Source				
Soil	NA	1		Assumption
Exposed Vegetables	NA	0.42		EFH Table 13-71
Fruits	NA	0.328		EFH Table 13-71
Root Vegetables	NA	0.173		EFH Table 13-71
Beef	NA	0.478		EFH Table 13-71
Dairy	NA	0.207		EFH Table 13-71

B.3 Risk Assessment Methodology

The sensitivity analysis is used to identify the most influential variable parameters that are then set to high-end values to estimate high-end risks. As discussed above, the first step of a

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sensitivity analysis is to set all variable parameters at central tendency values and calculate central tendency risk estimates. Then, one at a time, each variable parameter is set to its high-end value, risk is calculated, and the variation in the risk from the central tendency value is noted. The parameters having the greatest effect on the resulting risks are identified as the most sensitive variables. The two most sensitive parameters identified by this method are set to high-end in the deterministic analysis.

Models used to conduct the nongroundwater sensitivity analyses include the landfill partitioning model, the EPA Industrial Source Complex Short Term, Version 3 air dispersion model and the Indirect Exposure Model (IEM). These models are described in greater detail in Section 4 below. The landfill partitioning model estimates volatile emissions and leachate concentrations from a landfill simultaneously to maintain a mass balance between the pathways. Each landfill partitioning model run produces a volatile emission rate that is then used with the ISCST3 air dispersion model.

The ISCST3 model uses some of the same parameters included in the landfill partitioning model. It also uses a variable for distance to receptor that is not included in the landfill partitioning model. ISCST3 dispersion and deposition modeling is conducted using inputs from the landfill partitioning model. First, all parameters are set at central tendency. Then the model is run once with each of the variable parameters set to high end while the others are fixed at central tendency. The location parameter is considered a single parameter and all meteorologic variables associated with location are varied together.

Parameters shared between the landfill partitioning model and the air modeling are coordinated in the risk modeling. For example, the location parameter is used in the landfill partitioning model to produce an emission rate. ISC3 modeling for that emission rate is conducted using data for the same location. Landfill area is similarly coordinated between the two models.

The remaining variables considered in the nongroundwater sensitivity analysis are exposure factors which are varied using the the IEM. Other exposures that are considered but not varied in the sensitivity analysis include inhalation of vapors and adult ingestion of soil. The sensitivity of the varied exposure parameters is determined by setting each parameter at high end while all other variable parameters are set at central tendency as described above.

The sensitivity analysis modeling produces a risk estimate associated with the use of a single high-end parameter for each modeling run. The most sensitive parameters are those that produce the highest estimate of risk when set at their high-end values.

B.4 Fate and Transport Models

As mentioned in Section 3 above, the models and equations used in estimating risk through the nongroundwater pathways for the sensitivity analysis are:

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- landfill partitioning model - based on the Jury equations (Jury et al. 1983, 1984, and 1990)
- ISCST3 - for air dispersion and deposition modeling (U.S. EPA, 1995)
- indirect exposure model (IEM)- for assessing risk due to direct and indirect exposures (IEM is a model based on equations presented in U.S. EPA, 1990 and U.S. EPA, 1993.)

Each model or set of equations is discussed in greater detail in the sections below. Parameters shared between the landfill partitioning model and the air modeling are coordinated in the risk modeling. For example, the location parameter is used in the landfill partitioning model to produce an emission rate. ISC3 modeling for that emission rate is conducted using data for the same location. Landfill area is similarly coordinated between the two models.

B.4.1 Landfill Partitioning Model

A summary description of the landfill partitioning model is provided here. The partitioning equations and a more detailed description of the model is provided in Section 3 of this report. A spreadsheet calculation model is used to determine the contaminant loss from a landfill due to volatilization, runoff, degradation, and leaching. The model uses partitioning equations developed for estimating volatilization of contaminants from soil (Jury et al. 1983, 1984, 1990). For this risk assessment, the equations have been adapted to represent the management practices and design criteria required by regulation for municipal landfills. Runoff losses are assumed to be zero because landfills are assumed to have berms or other control devices sufficient to prevent runoff. Aerobic degradation is assumed not to occur in landfills.

Key assumptions for the landfill partitioning model are that waste will be collected 350 d/yr and each daily addition volume will be placed in a daily pile in the landfill. The model evaluates contaminant losses from the landfill over three separate conditions: (1) losses from the daily pile which is uncovered for a portion of the day; (2) losses from the daily pile after cover is applied; and (3) losses after closure of the landfill cell when the waste is covered by a 2-ft thick landfill cap.

Daily piles are assumed to be uncovered for a period of 12 h prior to the application of daily cover. After the 12-h period, the waste is assumed to be covered by a 6-in daily cap as required by the municipal landfill regulations (40 Code of Federal Regulations [CFR] 258). The amount of contaminant lost during the uncovered duration is calculated, and the total contaminant concentration remaining in the waste is calculated and used as the starting concentration for the covered daily waste addition.

On each successive day, the daily waste addition is placed in piles assumed to be adjacent to the previous day's waste addition. For each daily addition of waste, 12-h emissions are estimated from the newly added uncovered pile, and vapor emissions are estimated through the daily soil cover for waste added on previous days. The model estimates partitioning of the waste through the daily cover until new waste is added onto that daily pile.

Additions of new daily piles continue until the area of the cell is filled with a layer of daily waste. When a layer is completed, a second layer is begun by placing the next daily waste addition

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on top of the initial daily waste pile. Once waste is added on top of a daily addition, losses from that pile are assumed to be minimal. This process continues until the annual cell is filled. The number of daily piles in a cell is estimated based on the area of the landfill cell divided by the area of each daily pile.

At the end of each year, the annual cell is assumed to be capped and a new cell started. The closed landfill cell is assumed to be covered by a 2-ft thick landfill cap as required under the municipal landfill regulations. The emission rate is greatly reduced by the cap; however, it is not zero.

In the first year, a mass of the constituent is added to the landfill, and the model estimates the mass partitioned to each media (air, leachate, and soil) for each of the emission scenarios. As noted previously, no biodegradation is included within the landfill. The losses to the air and leachate are summed over these three conditions for the year and subtracted from the initial mass of the constituent added to the landfill. The mass of the constituent remaining after accounting for these losses is carried forward and summed with the new annual waste mass added to the landfill. (Note: A check mechanism is included in the model to ensure that the solubility limit of the constituent is not exceeded in the leachate.)

This process continues for the life of the landfill, which is assumed to be 30 years. At the end of the active life of the landfill, all cells are capped, but leaching and limited air emissions are assumed to continue and are modeled for an additional 40 years after landfill closure. Potential release mechanisms for the municipal landfill are graphically presented in Figure 4-1.

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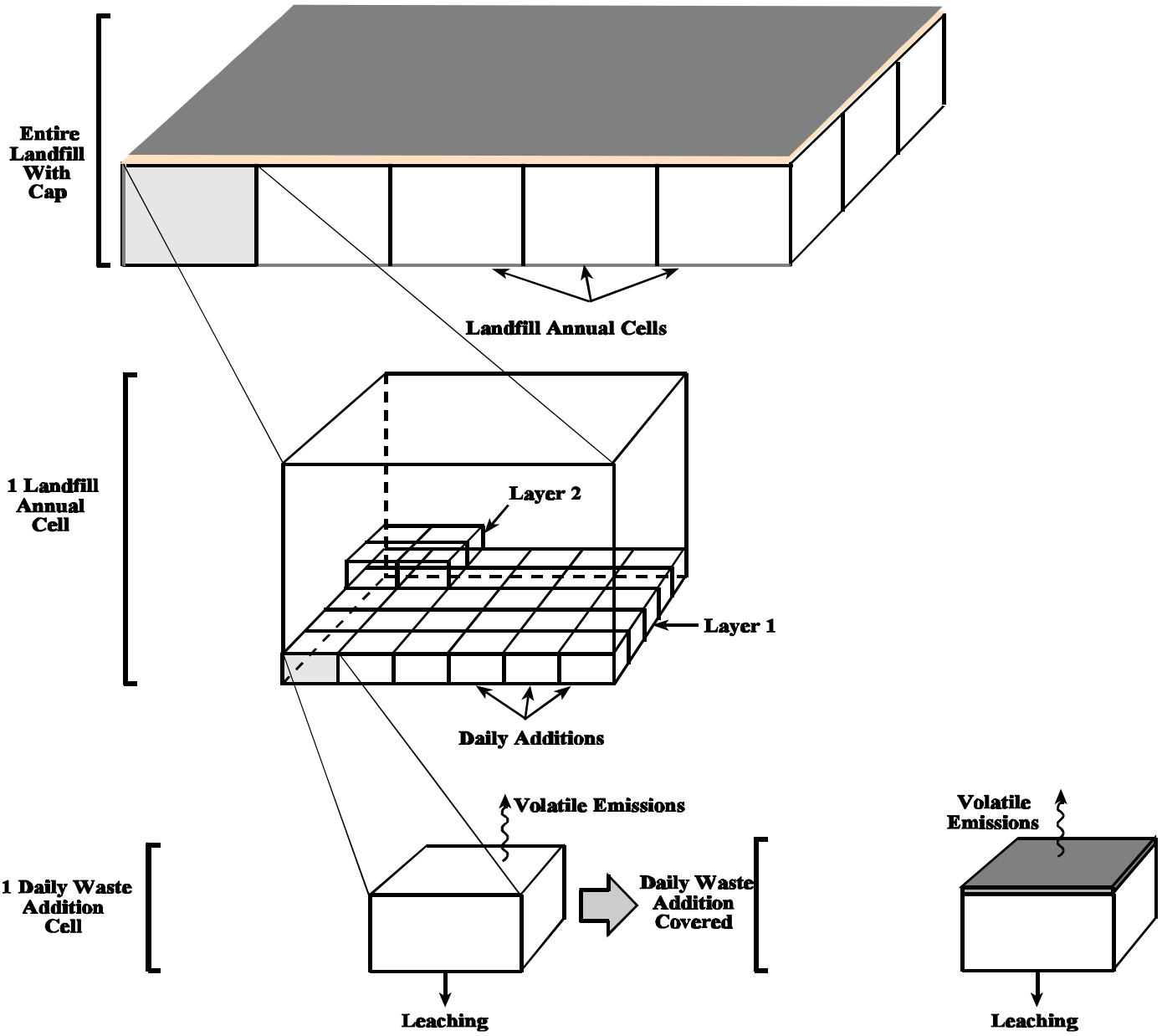

Figure 4-1. Schematic View of Landfill

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B.4.2 ISCST3 Model for Air Dispersion and Deposition

Air dispersion modeling for the sensitivity analysis is conducted with EPA's Industrial Source Complex Short Term, version 3 (ISCST3). ISCST3 is a Gaussian plume model that can simulate both wet and dry deposition and plume depletion. The ISCST3 outputs are used to estimate the vapor air concentrations and deposition rates needed to develop relative risk estimates associated with vapor air emissions from the municipal landfill. The EPA's ISCST3 model is applicable in simple, intermediate, and complex terrains. However, as discussed in Volume II of the ISCST3 User's Guide (U.S. EPA, 1995) the complex terrain screening algorithms do not apply to area sources such as the emission source (i.e., municipal landfill) being investigated as part of the this analysis. Consequently, regardless of the location being modeled, receptor elevations and the terrain grid pathway are not specified in the ISCST3 input files for this analysis. The ISCST3 model was run using "default" model options.

As part of the sensitivity analysis, modeling is conducted using two different landfill sizes (50^{th} percentile landfill - 246 m x 246 m; 10^{th} percentile landfill 90 m x 90 m) assumed located in two geographic locations _____ and Newark, NJ. Receptors are evenly spaced at distances 75 m and 500 m from the edge of the landfill unit. The maximum vapor air concentrations and deposition rates obtained as outputs from the ISCST3 model are used in combination with food chain transfer factors and exposure assumptions to develop relative risk estimates for the individual receptor. Table 4-1 presents the air modeling results from this effort. The results presented in this table reflect a unit emission rate of 1 g/s/ m^2. These air modeling results are converted to chemical-specific air concentrations and deposition rates by multiplying the values in the table by the chemical-specific emission rates that are estimated using the landfill partitioning model.

Table 4-1. Results of the ISCST3 Air Modeling

	Location	Landfill Size (m^2)	Air Concentration of Vapors ($\mu g/m^3$)/ ($g/s/m^2$)
Central tendency	*	60,705	
Landfill area	*	2,024	
Distance to Receptor	*	60,705	
Meteorologic Location	Newark, NJ	60,705	13,050

* Relevant data are not included at present because of business confidentiality concerns.

B.5 Exposure Modeling Equations

This analysis includes estimates of risks to the farmer and farm child due to direct inhalation of vapors emitted from the landfill and from indirect food-chain pathways (i.e., risks from ingestion of contaminated crops, livestock, or fish). The ISCST3 air dispersion and deposition model (with landfill air emission rates for volatile constituents estimated with the landfill partitioning model) is used to estimate the air concentration and deposition of vapor for

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each constituent at receptor locations. All subsequent risk estimates are dependent upon the concentration and deposition of vapors at the receptor site. The air concentration of vapors is used directly to estimate the risk due to inhalation by the farmer and child. It is also used in IEM to estimate vapor transfer and subsequent contaminant concentrations in fruits, vegetables, grain, and forage (due to air-to-plant transfer). Vapor deposition is used in IEM to estimate soil concentrations.

IEM equations are used to combine the outputs from the ISCST3 air dispersion and deposition model with food chain transfer factors and exposure assumptions to estimate exposure point concentrations for the various intake media (air, plants, animal products). IEM then estimates risks to receptors who consume these media. The IEM equations that are used to estimate the fate and transport, media concentration, and human health risk presented in Appendix B-1. All transfer factors used in this risk assessment are assumed to be constant values and for most organic compounds are calculated based on K_{OW} values. Transfer factors used for each constituent are presented in Appendix D. The exposure factors used in the sensitivity analysis are presented in Table 2-8.

B.6 Results

The results of the sensitivity analysis for the nongroundwater pathways are presented in Tables 6-1 through 6-8. The risk results for the ingestion pathways for the farmer and child of farmer are presented in Tables 6-9 through 6-12 and the risk results for the inhalation pathway are presented in Tables 6-13 through 6-16.

The limiting receptors for this analysis are the farmer and child of farmer. Thus, because the risk based concentrations derived in support of this listing are calculated based on the pathway estimated to pose the highest risk, only the limiting receptors need to be evaluated. The home gardener and resident will by definition be less exposed than the farmer or child of farmer. The farmer and child both are assumed exposed by direct inhalation and ingestion of home produced exposed vegetables, exposed fruits, root vegetables, beef and dairy products.

A comparison of the results of the nongroundwater sensitivity analysis to the results of the groundwater pathway sensitivity analysis, which is done using the same inputs indicates that in all cases, the groundwater risk analysis produces higher risk estimates for all constituents.

Because the purpose of this analysis is to set risk-based concentration limits, only the pathways of most concern, or those that present the highest risk, are required to determine protective concentrations. Based on the results of the sensitivity analysis, groundwater pathways were found to be most limiting (i.e., to present the highest risk) in all cases for all constituents of concern; therefore, only the groundwater pathway needs to be further evaluated using deterministic and Monte Carlo analyses. In other words, risk-based concentrations set based on groundwater pathway risks will also be protective of nongroundwater pathway risks. Based on this finding, no further modeling of nongroundwater risks has been conducted.

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Table. 6-1 Filter Aid Ingestion Results for Sensitivity Analysis - Farmer *

* Not included at present due to business confidentiality concerns

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Table. 6-2 Filter Aid Ingestion Results for Sensitivity Analysis - Child *

* Not included at present due to business confidentiality concerns

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Table 6-3. TAM Ingestion Results for Sensitivity Analysis - Farmer

Name	Cas Number	Central Tendency	Exposure Duration	Beef Ingestion	Dairy Ingestion	Vegetable Ingestion	Root Ingestion	Fruit Ingestion	Distance to receptor	Landfill area	foc
Formaldehyde	50-00-0	1.0E-09	1.0	1.0	1.0	3.0	1.0	3.0	20.0	0.4	4.0
Aniline	62-53-3	6.0E-13	5.8	1.0	1.0	2.6	1.0	3.2	21.2	0.5	0.1
Acetone	67-64-1	7.0E-10	1.0	1.0	1.0	2.9	1.0	2.9	28.6	0.4	1.0
Chloroform	67-66-3	1.1E-14	5.8	1.0	1.0	2.2	1.0	3.6	21.2	0.4	1.0
Benzene	71-43-2	5.3E-14	5.8	1.0	1.0	2.1	1.0	3.6	21.2	0.4	1.0
Methylene chloride	75-09-2	8.1E-15	5.8	1.0	1.0	2.5	1.0	3.3	21.2	0.4	1.1
Bromodichloromethane	75-27-4	4.6E-13	5.8	1.0	1.0	2.3	1.0	3.4	21.2	0.4	0.4
N-Nitrosodiphenylamine	86-30-6	1.1E-13	5.8	1.1	1.2	1.8	1.0	3.6	21.2	0.4	0.4
Naphthalene	91-20-3	2.0E-09	1.0	1.0	1.0	1.5	1.0	4.0	25.0	0.5	0.2
Benzidine	92-87-5	1.8E-05	4.6	1.0	1.0	1.5	1.0	4.2	21.2	0.4	0.2
Dichlorobenzene, 1,2-	95-50-1	2.0E-09	1.0	1.0	1.0	1.0	1.0	3.0	15.0	0.3	0.1
Toluidine, o-	95-53-4	1.5E-11	5.8	1.0	1.0	2.5	1.0	3.3	21.2	0.5	0.1
o-Phenylenediamine	95-54-5	1.7E-12	5.8	1.0	1.0	2.7	1.0	3.0	21.2	0.5	0.8
Ethylbenzene	100-41-4	7.0E-10	1.0	1.0	1.1	1.4	1.0	2.9	14.3	0.4	0.4
Benzaldehyde	100-52-7	2.0E-09	1.0	1.0	1.0	2.5	1.0	3.0	20.0	0.4	0.2
Cresol, p-	106-44-5	5.0E-08	0.8	1.0	1.0	2.0	1.0	4.0	20.0	0.4	0.4
Dichlorobenzene, 1,4-	106-46-7	4.8E-13	5.8	1.3	1.3	1.6	1.0	3.4	21.2	0.4	0.1
Chloroaniline, p-	106-47-8	1.0E-07	0.9	1.0	1.0	3.0	1.0	3.0	20.0	0.5	0.4
Toluidine, p-	106-49-0	7.8E-12	5.8	1.0	1.0	2.5	1.0	3.3	21.2	0.4	0.2
p-Phenylenediamine	106-50-3	2.0E-09	1.0	1.0	1.0	3.5	1.0	4.0	25.0	0.5	1.0
Methyl isobutyl ketone	108-10-1	2.0E-09	1.0	1.0	1.0	2.0	1.0	3.0	15.0	0.4	0.4
Toluene	108-88-3	2.0E-10	1.0	1.0	1.0	1.5	1.0	4.0	20.0	0.4	0.5
Chlorobenzene	108-90-7	4.0E-09	1.0	1.0	1.0	1.8	1.0	2.5	20.0	0.3	0.3
Phenol	108-95-2	5.0E-10	1.0	1.0	1.0	2.0	1.0	4.0	20.0	0.4	0.4
Pyridine	110-86-1	5.0E-07	1.0	1.0	1.0	2.0	1.0	2.0	20.0	0.4	0.4
Dimethyoxybenzidine, 3,3'-	119-90-4	7.3E-08	5.8	1.0	1.0	1.5	1.0	4.2	21.2	0.4	0.6
Trichlorobenzene, 1,2,4-	120-82-1	4.0E-09	1.0	2.0	2.0	1.5	1.0	2.5	25.0	0.5	0.5
N-N-Dimethylaniline	121-69-7	1.0E-07	1.0	1.0	1.0	3.0	1.0	5.0	30.0	0.5	0.3
Diphenylamine	122-39-4	5.0E-08	1.0	1.2	1.2	1.4	1.0	2.0	18.0	0.4	0.4
1,2-Diphenylhydrazine	122-66-7	2.8E-11	5.4	1.0	1.0	2.0	1.0	3.8	21.2	0.4	0.4

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Table 6-4. TAM Ingestion Results for Sensitivity Analysis - Child

Name	Cas Number	Central Tendency	Exposure Duration	Beef Ingestion	Dairy Ingestion	Vegetable Ingestion	Root Ingestion	Fruit Ingestion	Child soil Ingestion	Distance to receptor	Landfill area	foc
Formaldehyde	50-00-0	6.3E-10	1.0	1.0	1.0	2.1	1.3	5.2	1.0	20.6	0.3	3.2
Aniline	62-53-3	2.5E-13	2.4	1.0	1.0	2.9	1.1	4.8	1.0	21.2	0.5	0.1
Acetone	67-64-1	4.3E-10	1.0	1.0	1.0	2.8	1.4	5.1	1.0	22.3	0.4	1.0
Chloroform	67-66-3	4.6E-15	2.4	1.0	1.0	2.4	1.0	5.7	1.0	21.1	0.4	1.0
Benzene	71-43-2	2.2E-14	2.5	1.0	1.0	2.4	1.0	5.9	1.0	21.4	0.4	1.0
Methylene chloride	75-09-2	3.4E-15	2.4	1.0	1.0	2.7	1.1	5.0	1.0	20.9	0.4	1.1
Bromodichloromethane	75-27-4	1.9E-13	2.5	1.0	1.0	2.6	1.1	5.3	1.0	21.6	0.4	0.4
N-Nitrosodiphenylamine	86-30-6	5.5E-14	2.5	1.1	1.3	1.8	1.0	4.9	1.0	21.8	0.4	0.4
Naphthalene	91-20-3	1.7E-09	1.0	1.1	1.3	1.5	1.0	4.1	1.0	22.4	0.4	0.1
Benzidine	92-87-5	7.6E-06	2.0	1.0	1.0	1.6	1.0	6.8	1.0	21.1	0.4	0.2
Dichlorobenzene, 1,2-	95-50-1	1.4E-09	0.9	1.1	1.4	1.5	1.0	4.1	1.0	18.6	0.4	0.1
Toluidine, o-	95-53-4	6.3E-12	2.4	1.0	1.0	2.9	1.1	5.2	1.0	20.6	0.5	0.1
o-Phenylenediamine	95-54-5	7.1E-13	2.5	1.0	1.0	3.0	1.2	4.8	1.0	21.1	0.5	0.8
Ethylbenzene	100-41-4	5.0E-10	1.0	1.1	1.2	1.7	1.0	4.4	1.0	19.4	0.4	0.4
Benzaldehyde	100-52-7	1.1E-09	1.0	1.0	1.0	3.3	1.1	4.1	1.0	18.2	0.4	0.2
Cresol, p-	106-44-5	3.0E-08	1.0	1.0	1.0	2.4	1.0	3.7	1.0	20.3	0.4	0.4
Dichlorobenzene, 1,4-	106-46-7	2.9E-13	2.4	1.1	1.4	1.4	1.0	4.1	1.0	20.7	0.4	0.1
Chloroaniline, p-	106-47-8	6.1E-08	1.0	1.0	1.0	2.3	1.1	5.2	1.0	19.7	0.5	0.3
Toluidine, p-	106-49-0	3.2E-12	2.5	1.0	1.0	2.8	1.1	5.3	1.0	21.3	0.4	0.2
p-Phenylenediamine	106-50-3	1.5E-09	1.0	1.0	1.0	3.3	1.3	4.5	1.0	21.3	0.4	0.9
Methyl isobutyl ketone	108-10-1	9.2E-10	1.0	1.0	1.0	2.7	1.1	4.8	1.0	18.5	0.6	0.6
Toluene	108-88-3	1.1E-10	1.0	1.1	1.2	1.7	1.1	5.7	1.0	25.5	0.4	0.6
Chlorobenzene	108-90-7	1.8E-09	1.0	1.1	1.2	1.9	1.1	6.1	1.0	26.1	0.5	0.5
Phenol	108-95-2	3.0E-10	1.0	1.0	1.0	2.7	1.1	3.7	1.0	20.3	0.4	0.4
Pyridine	110-86-1	3.1E-07	1.0	1.0	1.0	2.6	1.1	3.5	1.0	16.5	0.4	0.3
Bis(2-ethylhexyl)phthalate	117-81-7	2.4E-08	2.5	1.3	2.1	1.0	1.0	1.0	1.0	21.3	0.4	0.5
Dimethyoxybenzidine, 3,3'-	119-90-4	3.0E-08	2.5	1.0	1.0	1.6	1.0	7.0	1.0	21.3	0.4	0.6
Trichlorobenzene, 1,2,4-	120-82-1	5.2E-09	1.0	1.4	1.9	1.2	1.0	2.5	1.0	23.1	0.4	0.4
N-N-Dimethylaniline	121-69-7	8.1E-08	1.0	1.0	1.0	2.0	1.0	6.4	1.0	17.3	0.3	0.1
Diphenylamine	122-39-4	3.7E-08	1.0	1.2	1.5	1.5	1.0	3.2	1.0	20.5	0.4	0.4
1,2-Diphenylhydrazine	122-66-7	1.2E-11	2.3	1.0	1.0	2.1	1.0	6.0	1.0	20.8	0.4	0.4
Xylenes (total)	1330-20-7	3.3E-11	1.0	1.1	1.4	1.5	1.0	3.3	1.0	16.1	0.4	0.3

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Table. 6-5 Filter Aid Inhalation Results for Sensitivity Analysis - Farmer

* Not included at present due to business confidentiality concerns

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Table 6-6. Filter Aid Inhalation Results for Sensitivity Analysis - Child

* Not included at present due to business confidentiality concerns

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Table 6-7. TAM Inhalation Results for Sensitivity Analysis - Child

Name	Cas Number	Central Tendency	Exposure Duration	Distance to receptor	Landfill area	foc
Aniline	62-53-3	0.1	1.0	20	0.6	0.08
Acetone	67-64-1	0.00004	1.0	22.5	0.5	1
Naphthalene	91-20-3	0.005	1.0	20	0.4	0.14
Dichlorobenzene, 1,2-	95-50-1	0.001	1.0	30	0.6	0.2
Ethylbenzene	100-41-4	0.001	1.0	20	0.5	0.5
Dichlorobenzene, 1,4-	106-46-7	0.0004	1.0	22.5	0.5	0.15
Methyl isobutyl ketone	108-10-1	0.01	1.0	30	0.6	0.7
Toluene	108-88-3	0.003	1.0	23.3	0.3	0.7
Chlorobenzene	108-90-7	0.05	1.0	20	0.4	0.4
Phenol	108-95-2	0.0003	1.0	20	0.3	0.3
Pyridine	110-86-1	0.08	1.0	25	0.4	0.4
Bis(2-ethylhexyl)phthalate	117-81-7	0.000002	1.0	20	0.4	0.45
Trichlorobenzene, 1,2,4-	120-82-1	0.00005	1.0	20	0.4	0.4
Xylenes (total)	1330-20-7	0.002	1.0	25	0.5	0.4
Benzidine	92-87-5	2.633E-05	1.9	21.2	0.4	0.2
1,2-Diphenylhydrazine	122-66-7	4.3E-08	2.3	21.2	0.4	0.4
Bromodichloromethane	75-27-4	2.966E-06	2.5	21.2	0.4	0.4
Benzene	71-43-2	1.738E-06	2.5	21.2	0.4	1.0
Chloroform	67-66-3	4.679E-06	2.5	21.2	0.4	1.0
Methylene chloride	75-09-2	9.066E-08	2.5	21.2	0.4	1.1
Toluidine, o-	95-53-4	7.205E-07	2.5	21.2	0.5	0.1
Formaldehyde	50-00-0	6.527E-08	2.5	21.2	0.4	3.4
N-Nitrosodiphenylamine	86-30-6	5.878E-10	2.5	21.2	0.4	0.4
Azobenzene	103-33-3	3.383E-10	2.5	21.2	0.4	0.4

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Table 6-8. TAM Inhalation Results for Sensitivity Analysis - Farmer

Name	Cas Number	Central Tendency	Exposure Duration	Distance to receptor	Landfill area	foc
Aniline	62-53-3	0.1	1.0	20.0	0.6	0.1
Acetone	67-64-1	0.00004	1.0	22.5	0.5	1.0
Naphthalene	91-20-3	0.005	1.0	20.0	0.4	0.1
Dichlorobenzene, 1,2-	95-50-1	0.001	1.0	30.0	0.6	0.2
Ethylbenzene	100-41-4	0.001	1.0	20.0	0.5	0.5
Dichlorobenzene, 1,4-	106-46-7	0.0004	1.0	22.5	0.5	0.2
Methyl isobutyl ketone	108-10-1	0.01	1.0	30.0	0.6	0.7
Toluene	108-88-3	0.003	1.0	23.3	0.3	0.7
Chlorobenzene	108-90-7	0.05	1.0	20.0	0.4	0.4
Phenol	108-95-2	0.0003	1.0	20.0	0.3	0.3
Pyridine	110-86-1	0.08	1.0	25.0	0.4	0.4
Bis(2-ethylhexyl)phthalate	117-81-7	0.000002	1.0	20.0	0.4	0.5
Trichlorobenzene, 1,2,4-	120-82-1	0.00005	1.0	20.0	0.4	0.4
Xylenes (total)	1330-20-7	0.002	1.0	25.0	0.5	0.4
Benzidine	92-87-5	1.692E-05	4.6	21.2	0.4	0.2
1,2-Diphenylhydrazine	122-66-7	2.763E-08	5.4	21.2	0.4	0.4
Bromodichloromethane	75-27-4	1.905E-06	5.8	21.2	0.4	0.4
Benzene	71-43-2	1.117E-06	5.8	21.2	0.4	1.0
Chloroform	67-66-3	3.006E-06	5.8	21.2	0.4	1.0
Methylene chloride	75-09-2	5.825E-08	5.8	21.2	0.4	1.1
Toluidine, o-	95-53-4	4.629E-07	5.8	21.2	0.5	0.1
Formaldehyde	50-00-0	4.194E-08	5.8	21.2	0.4	3.4
Azobenzene	103-33-3	2.174E-10	5.8	21.2	0.4	0.4

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Table 6.9 - Filter Aid Ingestion Risk Results for Sensitivity Analysis - Farmer

* Not included at present due to business confidentiality concerns

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Table 6-10 - Filter Aid Ingestion Risk Results for Sensitivity Analysis - Child

* Not included at present due to business confidentiality concerns

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Table 6-11 TAM Ingestion Risk Results for Sensitivity Analysis - Child

Name	CAS Number	Central Tendency	Exposure	Beef	Dairy	Vegetables	Root	Fruit	Child soil	Distance to receptor	Landfill area	foc
Formaldehyde	50-00-0	0.0000000006	0.0000000006	0.0000000006	0.0000000006	0.000000001	0.0000000008	0.000000003	0.0000000006	0.00000001	0.00000000002	0.000000002
Aniline	62-53-3	3.E-13	7.E-13	3.E-13	3.E-13	7.E-13	3.E-13	2.E-12	3.E-13	7.E-12	1.E-13	2.E-12
Acetone	67-64-1	0.00000004	0.00000004	0.00000004	0.00000004	0.0000001	0.00000006	0.0000002	0.00000004	0.000001	0.00000002	0.00000004
Chloroform	67-66-3	5.E-15	1.E-14	5.E-15	5.E-15	1.E-14	5.E-15	3.E-14	5.E-15	1.E-13	2.E-15	5.E-15
Benzene	71-43-2	2.E-14	6.E-14	2.E-14	2.E-14	5.E-14	2.E-14	1.E-13	2.E-14	5.E-13	9.E-15	2.E-15
Methylene chloride	75-09-2	3.E-15	8.E-15	3.E-15	3.E-15	9.E-15	4.E-15	2.E-14	3.E-15	7.E-14	2.E-15	4.E-15
Bromodichloromethane	75-27-4	2.E-13	5.E-13	2.E-13	2.E-13	5.E-13	2.E-13	1.E-12	2.E-13	4.E-12	8.E-14	8.E-14
Naphthalene	91-20-3	0.000000002	0.000000002	0.000000002	0.000000002	0.000000003	0.000000002	0.000000007	0.000000002	0.00000004	0.0000000007	0.0000000002
Benzidine	92-87-5	0.000008	0.00002	0.000008	0.000008	0.00001	0.000008	0.00005	0.000008	0.0002	0.000003	0.000002
Dichlorobenzene, 1,2-	95-50-1	0.00000001	0.00000001	0.00000002	0.00000002	0.00000002	0.00000001	0.00000006	0.00000001	0.0000003	0.0000000006	0.0000000002
Toluidine, o-	95-53-4	6.E-12	2.E-11	6.E-12	6.E-12	2.E-11	7.E-12	3.E-11	6.E-12	1.E-10	3.E-12	7.E-13
o-Phenylenediamine	95-54-5	7.E-13	2.E-12	7.E-13	7.E-13	2.E-12	9.E-13	3.E-12	7.E-13	2.E-11	4.E-13	6.E-13
Ethylbenzene	100-41-4	0.0000000005	0.0000000005	0.0000000006	0.0000000006	0.0000000008	0.0000000005	0.000000002	0.0000000005	0.00000001	0.0000000002	0.0000000002
Benzaldehyde	100-52-7	0.0000001	0.0000001	0.0000001	0.0000001	0.0000004	0.0000001	0.0000005	0.0000001	0.000002	0.00000004	0.00000002
Cresol, p-	106-44-5	0.00000003	0.00000003	0.00000003	0.00000003	0.00000007	0.00000003	0.0000001	0.00000003	0.0000006	0.00000001	0.00000001
Dichlorobenzene, 1,4-	106-46-7	3.E-13	7.E-13	3.E-13	4.E-13	4.E-13	3.E-13	1.E-12	3.E-13	6.E-12	1.E-13	4.E-14
Chloroaniline, p-	106-47-8	0.00000006	0.00000006	0.00000006	0.00000006	0.0000001	0.00000007	0.0000003	0.00000006	0.000001	0.00000003	0.00000002
Toluidine, p-	106-49-0	3.E-12	8.E-12	3.E-12	3.E-12	9.E-12	3.E-12	2.E-11	3.E-12	7.E-11	1.E-12	6.E-13
p-Phenylenediamine	106-50-3	0.000000002	0.000000002	0.000000002	0.000000002	0.000000005	0.000000002	0.000000007	0.000000002	0.00000003	0.0000000006	0.000000001
Methyl isobutyl ketone	108-10-1	0.0000000009	0.0000000009	0.0000000009	0.0000000009	0.000000003	0.0000000010	0.000000004	0.0000000009	0.00000002	0.0000000005	0.0000000005
Toluene	108-88-3	0.0000000001	0.0000000001	0.0000000001	0.0000000001	0.0000000002	0.0000000001	0.0000000006	0.0000000001	0.000000003	0.00000000005	0.00000000007
Chlorobenzene	108-90-7	0.000000002	0.000000002	0.000000002	0.000000002	0.000000003	0.000000002	0.00000001	0.000000002	0.00000005	0.0000000001	0.0000000009
Phenol	108-95-2	0.0000000003	0.0000000003	0.0000000003	0.0000000003	0.0000000008	0.0000000003	0.000000001	0.0000000003	0.000000006	0.0000000001	0.0000000001
Pyridine	110-86-1	0.0000003	0.0000003	00.000003	0.0000003	0.0000008	0.0000003	0.000001	0.0000003	0.000005	0.0000001	0.00000009
Bis(2-ethylhexyl)phthalate	117-81-7	2.E-08	6.E-08	3.E-08	5.E-08	2.E-08	2.E-08	2.E-08	2.E-08	5.E-07	1.E-08	1.E-08
Dimethyoxybenzidine3,3'-	119-90-4	3.E-08	8.E-08	3.E-08	3.E-08	5.E-08	3.E-08	2.E-07	3.E-08	6.E-07	1.E-08	2.E-08
Trichlorobenzene, 1,2,4-	120-82-1	0.000000005	0.000000005	0.000000007	0.00000001	0.000000006	0.000000005	0.00000001	0.000000005	0.0000001	0.000000002	0.000000002
N-N-Dimethylaniline	121-69-7	0.00000008	0.00000008	0.00000008	0.00000008	0.0000002	0.00000008	0.0000005	0.00000008	0.000001	0.00000003	0.00000001
Diphenylamine	122-39-4	0.00000004	0.00000004	0.00000004	0.00000006	0.00000005	0.00000004	0.0000001	0.00000004	0.0000008	0.00000001	0.00000002
1,2-Diphenylhydrazine	122-66-7	1.E-11	3.E-11	1.E-11	1.E-11	3.E-11	1.E-11	7.E-11	1.E-11	3.E-10	5.E-12	5.E-12
Xylenes (total)	1330-20-7	3.E-11	3.E-11	4.E-11	5.E-11	5.E-11	3.E-11	1.E-10	3.E-11	5.E-10	1.E-11	1.E-11

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Table 6-12 TAM Ingestion Risk Results for Sensitivity Analysis - Farmer

Name	CAS Number	Central Tendency	Exposure	Beef	Dairy	Vegetables	Root	Fruit	Distance to receptor	Landfill area	foc
Formaldehyde	50-00-0	0.000000001	0.000000001	0.000000001	0.000000001	0.000000003	0.000000001	0.000000003	0.0000000002	0.0000000004	0.000000004
Aniline	62-53-3	6.E-13	3.E-12	6.E-13	6.E-13	2.E-12	6.E-13	2.E-12	1.E-11	3.E-13	4.E-14
Acetone	67-64-1	0.0000000007	0.0000000007	0.0000000007	0.0000000007	0.000000002	0.0000000007	0.000000002	0.00000002	0.0000000003	0.0000000007
Chloroform	67-66-3	1.E-14	6.E-14	1.E-14	1.E-14	2.E-14	1.E-14	4.E-14	2.E-13	5.E-15	1.E-14
Benzene	71-43-2	5.E-14	3.E-13	5.E-14	5.E-14	1.E-13	5.E-14	2.E-13	1.E-12	2.E-14	5.E-14
Methylene chloride	75-09-2	8.E-15	5.E-14	8.E-15	8.E-15	2.E-14	8.E-15	3.E-14	2.E-13	4.E-15	9.E-15
Bromodichloromethane	75-27-4	5.E-13	3.E-12	5.E-13	5.E-13	1.E-12	5.E-13	2.E-12	1.E-11	2.E-13	2.E-13
N-Nitrosodiphenylamine	86-30-6	1.E-13	6.E-13	1.E-13	1.E-13	2.E-13	1.E-13	4.E-13	2.E-12	5.E-14	5.E-14
Naphthalene	91-20-3	0.000000002	0.000000002	0.000000002	0.000000002	0.000000003	0.000000002	0.000000008	0.00000005	0.0000000009	0.0000000003
Benzidine	92-87-5	0.00002	0.00008	0.00002	0.00002	0.00003	0.00002	0.00008	0.0004	0.000008	0.000004
Dichlorobenzene, 1,2-	95-50-1	0.000000002	0.000000002	0.000000002	0.000000002	0.000000002	0.000000002	0.000000006	0.00000003	0.0000000006	0.0000000002
Toluidine, o-	95-53-4	2.E-11	9.E-11	2.E-11	2.E-11	4.E-11	2.E-11	5.E-11	3.E-10	7.E-12	2.E-12
o-Phenylenediamine	95-54-5	2.E-12	1.E-11	2.E-12	2.E-12	5.E-12	2.E-12	5.E-12	4.E-11	9.E-13	1.E-12
Ethylbenzene	100-41-4	0.0000000007	0.0000000007	0.0000000007	0.0000000008	0.000000001	0.0000000007	0.000000002	0.00000001	0.0000000003	0.0000000003
Benzaldehyde	100-52-7	0.000000002	0.000000002	0.000000002	0.000000002	0.000000005	0.000000002	0.000000006	0.00000004	0.0000000007	0.0000000004
Cresol, p-	106-44-5	0.00000005	0.00000004	0.00000005	0.00000005	0.0000001	0.00000005	0.0000002	0.000001	0.00000002	0.00000002
Dichlorobenzene, 1,4-	106-46-7	5.E-13	3.E-12	6.E-13	6.E-13	8.E-13	5.E-13	2.E-12	1.E-11	2.E-13	7.E-14
Chloroaniline, p-	106-47-8	0.0000001	0.00000009	0.0000001	0.0000001	0.0000003	0.0000001	0.0000003	0.000002	0.00000005	0.00000004
Toluidine, p-	106-49-0	8.E-12	5.E-11	8.E-12	8.E-12	2.E-11	8.E-12	3.E-11	2.E-10	3.E-12	1.E-12
p-Phenylenediamine	106-50-3	0.000000002	0.000000002	0.000000002	0.000000002	0.000000007	0.000000002	0.000000008	0.00000005	0.000000001	0.000000002
Methyl isobutyl ketone	108-10-1	0.000000002	0.000000002	0.000000002	0.000000002	0.000000004	0.000000002	0.000000006	0.00000003	0.0000000007	0.0000000008
Toluene	108-88-3	0.0000000002	0.0000000002	0.0000000002	0.0000000002	0.00000003	0.0000000002	0.0000000008	0.000000004	0.000000000008	0.0000000001
Chlorobenzene	108-90-7	0.000000004	0.000000004	0.000000004	0.000000004	0.000000007	0.000000004	0.00000001	0.00000008	0.000000001	0.000000001
Phenol	108-95-2	0.0000000005	0.0000000005	0.0000000005	0.0000000005	0.000000001	0.0000000005	0.000000002	0.00000001	0.0000000002	0.0000000002
Pyridine	110-86-1	0.0000005	0.0000005	0.0000005	0.0000005	0.000001	0.0000005	0.000001	0.00001	0.0000002	0.0000002
Bis(2-ethylhexyl)phthalate	117-81-7	2.E-08	1.E-07	4.E-08	5.E-08	2.E-08	2.E-08	2.E-08	4.E-07	8.E-09	8.E-09
Dimethyoxybenzidine, 3,3'-	119-90-4	7.E-08	4.E-07	7.E-08	7.E-08	1.E-07	7.E-08	3.E-07	2.E-06	3.E-08	4.E-08
Trichlorobenzene, 1,2,4-	120-82-1	0.000000004	0.000000004	0.000000008	0.000000008	0.000000006	0.000000004	0.00000001	0.0000001	0.000000002	0.000000002
N-N-Dimethylaniline	121-69-7	0.0000001	0.0000001	0.0000001	0.0000001	0.0000003	0.0000001	0.0000005	0.000003	0.00000005	0.00000003
Diphenylamine	122-39-4	0.00000005	0.00000005	0.00000006	0.00000006	0.00000007	0.00000005	0.0000001	0.0000009	0.00000002	0.00000002
1,2-Diphenylhydrazine	122-66-7	3.E-11	2.E-10	3.E-11	3.E-11	6.E-11	3.E-11	1.E-10	6.E-10	1.E-11	1.E-11

Table 6-13 Filter Aid Inhalation Risk Results for Sensitivity Analysis - Farmer

* Not included at present due to business confidentiality concerns

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Table 6-14 Filter Aid Inhalation Risk Results for Sensitivity Analysis - Child

* Not included at present due to business confidentiality concerns

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Table 6-15 TAM Inhalation Risk Results for Sensitivity Analysis - Farmer

Name	CAS Number	Central Tendency	Exposure	Distance to Receptor	Landfill Area	foc
Formaldehyde	50-00-0	4.E-08	2.E-07	9.E-07	2.E-08	1.E-07
Aniline	62-53-3	0.1	0.1	2	0.06	0.008
Acetone	67-64-1	0.00004	0.00004	0.0009	0.00002	0.00004
Chloroform	67-66-3	3.E-06	2.E-05	6.E-05	1.E-06	3.E-06
Benzene	71-43-2	1.E-06	6.E-06	2.E-05	5.E-07	1.E-06
Methylene chloride	75-09-2	6.E-08	3.E-07	1.E-06	3.E-08	6.E-08
Bromodichloromethane	75-27-4	2.E-06	1.E-05	4.E-05	8.E-07	8.E-07
Naphthalene	91-20-3	0.005	0.005	0.1	0.002	0.0007
Benzidine	92-87-5	2.E-05	8.E-05	4.E-04	7.E-06	4.E-06
Dichlorobenzene, 1,2-	95-50-1	0.001	0.001	0.03	0.0006	0.0002
Toluidine, o-	95-53-4	5.E-07	3.E-06	1.E-05	2.E-07	5.E-08
Ethylbenzene	100-41-4	0.001	0.001	0.02	0.0005	0.0005
Azobenzene	103-33-3	2.E-10	1.E-09	5.E-09	9.E-11	9.E-11
Dichlorobenzene, 1,4-	106-46-7	0.0004	0.0004	0.009	0.0002	0.00006
Methyl isobutyl ketone	108-10-1	0.01	0.01	0.3	0.006	0.007
Toluene	108-88-3	0.003	0.003	0.07	0.001	0.002
Chlorobenzene	108-90-7	0.05	0.05	1	0.02	0.02
Phenol	108-95-2	0.0003	0.0003	0.006	0.0001	0.0001
Pyridine	110-86-1	0.08	0.08	2	0.03	0.03
Bis(2-ethylhexyl)phthalate	117-81-7	0.000002	0.000002	0.00004	0.0000008	0.0000009
Trichlorobenzene, 1,2,4-	120-82-1	0.00005	0.00005	0.001	0.00002	0.00002
1,2-Diphenylhydrazine	122-66-7	3.E-08	2.E-07	6.E-07	1.E-08	1.E-08
Xylenes (total)	1330-20-7	0.002	0.002	0.05	0.0009	0.0008

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Table 6-16 TAM Inhalation Risk Results for Sensitivity Analysis - Child

Name	CAS Number	Central Tendency	Exposure	Distance to Receptor	Landfill Area	foc
Formaldehyde	50-00-0	7.E-08	2.E-07	1.E-06	3.E-08	2.E-07
Aniline	62-53-3	0.1	0.1	2	0.06	0.008
Acetone	67-64-1	0.00004	0.00004	0.0009	0.00002	0.00004
Chloroform	67-66-3	5.E-06	1.E-05	1.E-04	2.E-06	5.E-06
Benzene	71-43-2	2.E-06	4.E-06	4.E-05	7.E-07	2.E-06
Methylene chloride	75-09-2	9.E-08	2.E-07	2.E-06	4.E-08	1.E-07
Bromodichloromethane	75-27-4	3.E-06	7.E-06	6.E-05	1.E-06	1.E-06
Naphthalene	91-20-3	0.005	0.005	0.1	0.002	0.0007
Benzidine	92-87-5	3.E-05	5.E-05	6.E-04	1.E-05	6.E-06
Dichlorobenzene, 1,2-	95-50-1	0.001	0.001	0.03	0.0006	0.0002
Toluidine, o-	95-53-4	7.E-07	2.E-06	2.E-05	4.E-07	8.E-08
Ethylbenzene	100-41-4	0.001	0.001	0.02	0.0005	0.0005
Azobenzene	103-33-3	3.E-10	8.E-10	7.E-09	1.E-10	1.E-10
Dichlorobenzene, 1,4-	106-46-7	0.0004	0.0004	0.009	0.0002	0.00006
Methyl isobutyl ketone	108-10-1	0.01	0.01	0.3	0.006	0.007
Toluene	108-88-3	0.003	0.003	0.07	0.001	0.002
Chlorobenzene	108-90-7	0.05	0.05	1	0.02	0.02
Phenol	108-95-2	0.0003	0.0003	0.006	0.0001	0.0001
Pyridine	110-86-1	0.08	0.08	2	0.03	0.03
Bis(2-ethylhexyl)phthalate	117-81-7	0.000002	0.000002	0.00004	0.0000008	0.0000009
Trichlorobenzene, 1,2,4-	120-82-1	0.00005	0.00005	0.001	0.00002	0.00002
1,2-Diphenylhydrazine	122-66-7	4.E-08	1.E-07	9.E-07	2.E-08	2.E-08
Xylenes (total)	1330-20-7	0.002	0.002	0.05	0.0009	0.0008

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B.7 References

Carsel, Robert and Rudolph Parrish. 1988. Developing joint probability distributions of soil water retention characteristics. *Water Resources Research*, 25, (5):755-769.

Clapp, R.B., and G.M.Hornberger. 1978. Empirical equations for some hydraulic properties. Water Resources Research. 14:601-604.

Jury, W.A., W.J. Farmer, and W.F. Spencer. 1984. Behavior assessment model for trace organics in soil: II. chemical classification and parameter sensitivity. *J. Environ. Qual.* 13(4):567-572.

Jury, W.A., W.F. Spencer, and W.J. Farmer. 1983. Behavior assessment model for trace organics in soil: I. Model description. *J. Environ. Qual.* 12(4):558-564.

Jury, W.A., D. Russo, G. Streile, and H.E. Abd. 1990. Evaluation of volatilization by organic chemicals residing below the soil surface. *Water Resources Research* 26(1):13-20.

NOC (Naval Oceanography Command). 1992. International Station Meteorological Climate Summary (CD-ROM), Version 2.0. Jointly produced by: Naval Oceanography Command Detachment Asheville, USAFETAC OL-A, and National Climatic Data Center.

U.S. EPA. SCRAM Bulletin Board. http://www.epa.gov/scram001/. U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina.

U.S. EPA (Environmental Protection Agency), 1999, *Background Document for Identification and Listing of the Deferred Dye and Pigment Wastes*. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1997. *Exposure Factors Handbook. Volume II, Food Ingestion Factors*. EPA/600/P-95/002Fb. Office of Research and Development, Washington, DC.

U.S. EPA (Environmental Protection Agency. 1998. Air Characteristic Study: Technical Background Document. EPA530-R-98-009B. May

U.S. EPA. 1995. PCRAMMET User's Guide (Draft). U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Technical Support Division (MD-14). Research Triangle Park, North Carolina.

U.S. EPA (Environmental Protection Agency). 1988. *Draft National Survey of Solid Waste (Municipal) Landfill Facilities*, EPA/530-SW-88-034. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1991. *National Survey of Hazardous Waste Generators and Treatment Storage, Disposal and Recycling Facilities in 1986: Hazardous Waste Management in RCRA TSDR Units*. EPA 530-SW-91-060. Office of Solid Waste and Emergency Response, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1995a. *User's Guide for the Industrial Source*

Complex (ISC3) Dispersion Models - Volume II. EPA-454/B-95-003b. Office of Air Quality Planning and Standards. Emissions, Monitoring, and Analysis Division. Research Triangle Park, NC.

U.S. EPA, 1990. *Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions; Interim Final.* EPA/600/6-90/003. Office of Research and Development. Cincinnati, OH.

U.S. EPA, 1993. *Addendum to; Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. EPA/600/AP-93/003. Office of Health and Environmental Assessment. November, 1993.

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Appendix B-1

Indirect and Direct Exposure Equations

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Table B-1-1.1. Deposition Rate Factor to Agricultural Field from Source

Farmer Exposure Scenario		
$$Ds_{(1),SF} = \frac{100\ x\ Q}{Z_{SF}\ x\ BD}\ x\ [F_v\ (0.31536\ x\ Vdv_{SF}\ x\ Cyv_{SF} + Dywv_{SF}) + (Dydp_{SF} + Dywp_{SF})\ x\ (1 - F_v)]$$		
Parameter	**Definition**	**Input Value**
$Ds_{(1),SF}$	Deposition term for agricultural field (mg/kg-yr)	
100	Units conversion factor ([mg-m^2]/[kg-cm^2])	
Q	Source emissions (g/sec)	Waste management scenario-specific
Z_{SF}	Soil mixing depth of agricultural field (cm)	20
BD	Soil bulk density (g/cm^3)	Site-specific
F_v	Fraction of air concentration in vapor phase (dimensionless)	Chemical-specific
0.31536	Units conversion factor (m-g-s/cm-µg-yr)	
Vdv_{SF}	Dry deposition velocity for agricultural field (cm/s)	3
Cyv_{SF}	Normalized vapor phase air concentration for agricultural field (µg-s/g-m^3)	Modeled ISC3
$Dywv_{SF}$	Normalized yearly wet deposition from vapor phase for agricultural field (s/m^2-yr)	Modeled ISC3
$Dydp_{SF}$	Normalized yearly dry deposition from particle phase for agricultural field (s/m^2-yr)	0
$Dywp_{SF}$	Normalized yearly wet deposition from particle phase for agricultural field (s/m^2-yr)	0
Description		
These equations calculate average air deposition occurring over the exposure duration as a result of wet and dry deposition of particles onto soil, deposition of wet vapors to soil, and diffusion of dry vapors to soil. Constituents are assumed to be incorporated only to a finite depth (the mixing depth, Z).		

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Table B-1-1.2. Soil Loss Constant

Farmer Exposure Scenario			
$ks_{SF} = ksl_{SF} + kse_{SF} + ksr_{SF} + ksg_{SF} + ksv_{SF}$			
Parameter	**Definition**	**Central Tendency**	**High End**
ks_{SF}	Constituent soil loss constant due to all processes from agricultural field (1/yr)		
ksl_{SF}	Constituent loss constant due to leaching (1/yr)	Calculated (see Table B-1-1.4)	
kse_{SF}	Constituent loss constant due to soil erosion (1/yr)	Calculated (see Table B-1-1.7)	
ksr_{SF}	Constituent loss constant due to surface runoff (1/yr)	Calculated (see Table B-1-1.10)	
ksg_{SF}	Constituent loss constant due to degradation (1/yr)	Chemical-specific	
ksv_{SF}	Constituent loss constant due to volatilization (1/yr)	Calculated (see Table B-1-1.11)	
Description			
This equation calculates the constituent loss constant, which accounts for the loss of constituent from soil by several mechanisms.			

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Table B-1-1.3. Loss Constant Due to Leaching

Farmer Exposure Scenario			
$$ksl_{SF} = \frac{P + I - R - E_v}{\theta \; x \; Z_{SF} \; x \; [1.0 + (BD \; x \; Kd_s / \theta)]}$$			
Parameter	**Definition**	**Central Tendency**	**High End**
ksl_{SF}	Constituent loss constant due to leaching for agricultural field (1/yr)		
P	Average annual precipitation (cm/yr)	Site-specific	
I	Average annual irrigation (cm/yr)	0	
R	Average annual runoff (cm/yr)	Site-specific	
E_v	Average annual evapotranspiration (cm/yr)	Site-specific	
θ	Soil volumetric water content (mL/cm^3)	Calculated (see Table B-1-1.5)	
Z_{SF}	Soil depth of agricultural field from which leaching removal occurs – tilled (cm)	20	
BD	Soil bulk density (g/cm^3)	Site-specific	
Kd_s	Soil-water partition coefficient (cm^3/g)	Chemical-specific	
Description			
This equation calculates the constituent loss constant due to leaching from soil.			

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Table B-1-1.4. Soil Volumetric Water Content

All Exposure Scenarios			
$\theta = \theta_s \left[\frac{q}{K_s}\right]^{\left(\frac{1}{2b+3}\right)}$			
Parameter	Definition	Central Tendency	High End
θ	Soil volumetric water content (mL/cm^3)		
θ_s	Soil saturated volumetric water content (mL/cm^3)	Site-specific	
q	Average annual recharge rate (cm/yr)	Calculated (see Table B-1-1.6)	
K_s	Saturated hydraulic conductivity (cm/yr)	Site-specific	
b	Soil-specific exponent representing water retention (unitless)	Site-specific	

Source: SEAM.

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Table B-1-1.5. Constituent Loss Constant Due to Volatilization

Farmer Exposure Scenario

$$ksv_{SF} = \left[\frac{3.1536x10^{7} \, x \, H}{Z_{SF} \, x \, Kd_s \, x \, R \, x \, T \, x \, BD}\right] x \left[0.482 \, x \, u^{0.78} \, x \left(\frac{\mu_a}{\rho_a \, x \, D_a}\right)^{-0.67} x \left(\sqrt{\frac{4 \, x \, A_F}{\pi}}\right)^{-0.11}\right]$$

Parameter	Definition	Central Tendency	High End
ksv_{SF}	Constituent loss constant due to volatilization for **landfill** (1/yr)		
$3.1536x10^{7}$	Conversion constant (s/yr)		
H	Henry's law constant (atm-m^3/mol)	Chemical-specific	
Z_{SF}	Soil mixing depth of **agricultural** field (cm)	20	
Kd_s	Soil-water partition coefficient (cm^3/g)	Chemical-specific	
R	Universal gas constant (atm-m^3/mol-K)	$8.205x10^{-5}$	
T	Ambient air temperature (K)	Site-specific	
BD	Soil bulk density (g/cm^3)	Site-specific	
u	Average annual windspeed (m/s)	Site-specific	
μ_a	Viscosity of air (g/cm-s)	$1.81x10^{-4}$	
ρ_a	Density of air (g/cm^3)	$1.2x10^{-3}$	
D_a	Diffusivity of constituent in air (cm^2/s)	Chemical-specific	

Description

This equation calculates the constituent loss constant due to volatilization from soil.

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Table B-1-1.6. Mass of Soil in Mixing Depth of Agricultural Field

Farmer Exposure Scenario			
$M_{SF} = Z_{SF} \times A_F \times BD \times 10$			
Parameter	**Definition**	**Central Tendency**	**High End**
M_{SF}	Mass of soil in mixing depth of agricultural field (kg)		
Z_{SF}	Soil mixing depth for agricultural field – tilled (cm)	20	
A_F	Area of agricultural field (m^2)	2,000,000	
BD	Soil bulk density (g/cm^3)	Site-specific	
10	Units conversion factor		
Description			
This equation is used to calculate the total mass of soil in the agricultural field that will be mixing with the mass of eroded material.			

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Table B-1-1.7. Aboveground Produce Concentration Due to Air-to-Plant Transfer

Farmer Exposure Scenario		
$$Pv_{SF} = Q \times F_v \times \frac{Cyv_{SF} \times Bv \times VG_{ag}}{\rho_a}$$		
Parameter	**Definition**	**Default Value**
Pv_{SF}	Concentration of constituent in the plant due to air-to-plant transfer (mg/kg) - Farmer	
Q	Emissions (g)	Waste management scenario-specific
F_v	Fraction of air concentration in vapor phase (dimensionless)	Chemical-specific
Cyv_{SF}	Normalized vapor phase air concentration (µg-s/g-m^3)	Modeled ISC3
Bv	Air-to-plant biotransfer factor ([mg constituent/kg plant tissue DW]/[µg constituent/g air])	Chemical-specific
VG_{ag}	Empirical correction factor for above-ground produce (dimensionless)	0.01
ρ_a	Density of air (g/cm^3)	1.2×10^{-3}
Description		
This equation calculates the constituent concentration in aboveground vegetation due to direct uptake of vapor phase chemical into the plant leaves.		

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Table B-1-1.8. Aboveground Produce Concentration Due to Root Uptake

Farmer Exposure Scenario			
$Pr_{SF} = C_{SF} \times Br$			
Parameter	**Definition**	**Central Tendency**	**High End**
Pr_{SF}	Concentration of constituent in the plant due to direct uptake from soil (mg/kg) - Farmer		
C_{SF}	Average soil concentration of constituent over exposure duration (mg/kg)	Calculated (see Table B-1-1.2)	
Br	Plant-soil bioconcentration factor for aboveground produce [µg/g DW]/[µg/g soil]	Chemical-specific	
Description			
This equation calculates the constituent concentration in aboveground vegetation due to direct uptake of chemicals from soil.			

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Table B-1-1.9. Root Vegetable Concentration Due to Root Uptake

Farmer Exposure Scenario			
$$Pr_{bg,SF} = \frac{C_{SF} \; x \; RCF}{Kd_s}$$			
Parameter	**Definition**	**Central Tendency**	**High End**
$Pr_{bg, SF}$	Concentration of constituent in belowground plant parts due to root uptake (mg/kg) - Farmer		
C_{SF}	Soil concentration of constituent (mg/kg)	Calculated (see Table B-1-1.2)	
RCF	Ratio of concentration in roots to concentration in soil pore water ([mg constituent/kg plant tissue WW] / [μg constituent/mL pore water])	Chemical-specific	
Kd_s	Soil-water partition coefficient (mL/g)	Chemical-specific	
Description			
This equation calculates the constituent concentration in root vegetables due to uptake from the soil water.			

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Table B-1-1.10. Beef Concentration Due to Plant and Soil Ingestion

Farmer Scenario			
$A_{beef} = (F \times Qp \times P + Qs \times C_{SF}) \times Ba_{beef}$			
Parameter	**Definition**	**Central Tendency**	**High End**
A_{beef}	Concentration of constituent in beef (mg/kg)		
F	Fraction of plant grown on contaminated soil and eaten by the animal grain or forage (dimensionless)	1	
Qp	Quantity of plant eaten by the animal each day (kg plant tissue DW/day) - beef cattle–grain - beef cattle–forage	 0.47 8.8	
P	Total concentration of constituent in the plant eaten by the animal (mg/kg) = Pd + Pv + Pr	Calculated (see Tables B-1-1.19, B-1-1.20, B-1-1.21)	
Qs	Quantity of soil eaten by the foraging animal (kg soil/day)	0.5	
C_{SF}	Soil concentration (mg/kg)	Calculated (see Table B-1-1.2)	
Ba_{beef}	Biotransfer factor for beef (d/kg)	Chemical-specific	
Description			
This equation calculates the concentration of constituent in beef from ingestion of forage and soil.			

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Table B-1-1.11. Milk Concentration Due to Plant and Soil Ingestion

Farmer Scenario			
$A_{milk} = (F \times Qp \times P + Qs \times C_{SF}) \times Ba_{milk}$			
Parameter	**Definition**	**Central Tendency**	**High End**
A_{milk}	Concentration of constituent in milk (mg/kg)		
F	Fraction of plant grown on contaminated soil and eaten by the animal grain or forage (dimensionless)	1	
Qp	Quantity of plant eaten by the animal each day (kg plant tissue DW/day) - dairy cattle–grain - dairy cattle–forage	 3 13.2	
P	Total concentration of constituent in the plant eaten by the animal (mg/kg) = Pd + Pv + Pr	Calculated (see Tables B-1-1.19, B-1-1.20, B-1-1.21)	
Qs	Quantity of soil eaten by the foraging animal (kg soil/day)	0.4	
C_{SF}	Soil concentration (mg/kg)	Calculated (see Table B-1-1.2)	
Ba_{milk}	Biotransfer factor for milk (day/kg)	Chemical-specific	
Description			
This equation calculates the concentration of constituent in milk from ingestion of forage and soil.			

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Table B-1-1.12. Forage (Pasture Grass/Hay) Concentration Due to Air-to-Plant Transfer

Farmer Scenario			
$$Pv = \frac{Cyv_{SF} \times Bv \times VG_{ag}}{\rho_a}$$			
Parameter	**Definition**	**Central Tendency**	**High End**
Pv	Concentration of constituent in the plant due to air-to-plant transfer (mg/kg)		
Cyv_{SF}	Vapor phase air concentration of constituent in air due to direct emissions (µg constituent/m^3)	Modeled ISC3	
Bv	Air-to-plant biotransfer factor ([mg constituent/kg plant tissue DW]/[µg [constituent/g air])	Chemical-specific	
VG_{ag}	Empirical correction factor that reduces produce concentration because Bv was developed for azalea leaves.	1.0	
ρ_a	Density of air (g/cm^3)	$1.2x10^{-3}$	
Description			
This equation calculates the constituent concentration in aboveground vegetation due to direct uptake of vapor phase chemicals into the plant leaves.			

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Table B-1-1.13. Forage/Silage/Grain Concentration Due to Root Uptake

Farmer Scenario		
$$Pr = \sum_i C_{SF} \; x \; Br_i$$		
Parameter	**Definition**	**Default Value**
Pr	Concentration of constituent in the plant due to direct uptake from soil (mg/kg)	
C_{SF}	Average soil concentration of constituent over exposure duration (mg/kg)	Calculated (see Table B-1-1.2)
Br_i	Plant-soil bioconcentration factor plant species i (forage/silage/grain) [µg/g DW]/[µg/g soil]	Chemical-specific
Description		
This equation calculates the constituent concentration in aboveground vegetation due to direct uptake of constituents from soil.		

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Table B-1-2.1. Contaminant Intake from Soil

$$I_{soil} = Sc \cdot CR_{soil} \cdot F_{soil}$$

Parameter	Description	Values
I_{soil}	Daily intake of contaminant from soil (mg/d)	
Sc	Average soil concentration of pollutant over exposure duration (mg/kg)	Calculated (see Table B-1-1.2)
CR_{soil}	Consumption rate of soil (kg/d)	Varies
F_{soil}	Fraction of consumed soil contaminated (unitless)	1

Description

This equation calculates the daily intake of contaminant from soil consumption. The soil concentration will vary with each scenario, and the soil consumption rate varies for children.

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Table B-1-2.2. Contaminant Intake from Exposed Vegetable Intake

$$I_{ev} = (Pd + Pv + Pr) \cdot CR_{ev} \cdot F_{ev}$$

Parameter	Description	Values
I_{ev}	Daily intake of contaminant from exposed vegetables (mg/d)	
Pd	Concentration in exposed vegetables due to deposition (mg/kg DW)	Calculated (see Table B-1-1.13 for the Farmer)
Pv	Concentration in exposed vegetables due to air-to-plant transfer (mg/kg DW)	Calculated (see Table B-1-1.14 for the Farmer)
Pr	Concentration in exposed vegetables due to root uptake (mg/kg DW)	Calculated (see Table B-1-1.15 for the Farmer)
CR_{ev}	Consumption rate of exposed vegetables (kg DW/d)	Varies
F_{ev}	Fraction of exposed vegetables contaminated (unitless)	Varies

Description

This equation calculates the daily intake of contaminant from ingestion of exposed vegetables. The consumption rate varies for children and adults. The contaminated fraction and the concentration in exposed vegetables will vary with each scenario.

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Table B-1-2.3. Contaminant Intake from Exposed Fruit Intake

$$I_{ef} = (Pd + Pv + Pr) \cdot CR_{ef} \cdot F_{ef}$$

Parameter	Description	Values
I_{ef}	Daily intake of contaminant from exposed fruit (mg/d)	
Pd	Concentration in exposed fruit due to deposition (mg/kg DW)	Calculated
Pv	Concentration in exposed fruit due to air-to-plant transfer (mg/kg DW)	Calculated (see Table B-1-1.14 for the Farmer)
Pr	Concentration in exposed fruit due to root uptake (mg/kg DW)	Calculated (see Table B-1-1.15 for the Farmer)
CR_{ag}	Consumption rate of exposed fruit (kg DW/d)	Varies
F_{ag}	Fraction of exposed fruit contaminated (unitless)	Varies

Description

This equation calculates the daily intake of contaminant from ingestion of exposed fruit. The consumption rate varies for children and adults. The contaminated fraction and the concentration in exposed fruit will vary with each scenario.

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Table B-1-2.4. Contaminant Intake from Root Vegetable Intake

$$I_{rv} = Pr_{rv} \cdot CR_{rv} \cdot F_{rv}$$

Parameter	Description	Values
I_{rv}	Daily intake of contaminant from root vegetables (mg/d)	
Pr_{rv}	Concentration in root vegetables due to deposition, for organics (mg/kg WW), metals	Calculated (see Table B-1-1.16 for the Farmer)
CR_{rv}	Consumption rate of root vegetables for organics (kg WW/d)	Varies
F_{rv}	Fraction of root vegetables contaminated (unitless)	Varies

Description

This equation calculates the daily intake of contaminant from ingestion of root vegetables. The consumption rate varies for children and adults. The contaminated fraction and the concentration in exposed vegetables will vary with each scenario.

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Table B-1-2.5. Contaminant Intake from Beef and Dairy Intake

$$I_i = A_i \bullet CR_i \bullet F_i$$

Parameter	Description	Values
I_i	Daily intake of contaminant from animal tissue *i* (mg/d)	
A_i	Concentration in animal tissue *i* (mg/kg WW)	Calculated (see Table B-1-1.17 for beef, Table B-1-1.18 for dairy)
CR_i	Consumption rate of animal tissue *i* (kg WW/d)	Varies
F_i	Fraction of animal tissue *i* contaminated (unitless)	Varies

Description

This equation calculates the daily intake of contaminant from ingestion of animal tissue (where the "*i*" in the above equation refers to beef and dairy). The consumption rate varies for children and adults and for the type of animal tissue.

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Table B-1-2.6. Total Daily Intake for Nongroundwater Indirect Pathways

Farmer and Child of Farmer

$$I = I_{soil} + I_{ev} + I_{beef} + I_{dairy} + I_{ef} + I_{rv}$$

Parameter	Description	Values
I	Total daily intake of contaminant (mg/d)	
I_{soil}	Daily intake of contaminant from soil (mg/d)	Calculated (see Table B-1-2.1)
I_{ev}	Daily intake of contaminant from exposed vegetables	Calculated (see Table B-1-2.2)
I_{ef}	Daily intake of contaminant from exposed fruit (mg/d)	Calculated (see Table B-1-2.3)
I_{rv}	Daily intake of contaminant from root vegetables	Calculated (see Table B-1-2.4)
I_{beef}, I_{dairy}	Daily intake of contaminant from animal tissue (mg/d)	Calculated (see Table B-1-2.5)

Description

This equation calculates the daily intake of contaminant on a pathway-by-pathway basis.

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Table B-1-2.7. Individual Cancer Risk: Carcinogens

$$Cancer\ Risk = \frac{I \cdot ED \cdot EF \cdot CSF}{BW \cdot AT \cdot 365}$$

Parameter	Description	Values
Cancer Risk	Individual lifetime cancer risk (unitless)	
I	Total daily intake of contaminant (mg/d)	Calculated (see Tables B-1-2.1 - B-1-2.5)
ED	Exposure duration (yr)	Varies
EF	Exposure frequency (d/yr)	350
BW	Body weight (kg)	Adult: 70 Child: 15
AT	Averaging time (yr)	70
365	Units conversion factor (d/yr)	
CSF	Oral cancer slope factor (per mg/kg/d)	Chemical-specific

Description

This equation calculates the individual cancer risk from indirect exposure to carcinogenic chemicals. The body weight varies for the child. The exposure duration varies for different scenarios.

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Table B-1-2.8. Hazard Quotient: Noncarcinogens

$$HQ = \frac{I}{BW \cdot RfD}$$

Parameter	Description	Values
HQ	Hazard quotient (unitless)	
I	Total daily intake of contaminant (mg/d)	Calculated (see Tables B-1-2.1 - B-1-2.6)
BW	Body weight (kg)	Adult: 70 Child: 15
RfD	Reference Dose (mg/kg/d)	Chemical-specific

Description

This equation calculates the hazard quotient for indirect exposure to noncarcinogenic chemicals. The body weight varies for the child.

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Table B-1-3.1. Concentration in Air

$$C_a = (C_{vapor} \bullet J_{air,t}) + (PM_{10} \bullet C_0 \bullet C_{particulate} \bullet \frac{1}{1000} \bullet \frac{1}{1000})$$

Parameter	Description	Values
C_a	Concentration in air ($\mu g/m^3$)	
C_{vaport}	Annual average vapor air concentration (($\mu g/m^3$)/(g/m^2-s))	Modeled ISC3
$J_{air,t}$	Total contaminant flux to atmosphere (g/m^2-s)	Modeled (Chemical-specific)
PM_{10}	Particulate matter (<10 micrometers) (g/m^2-s)	Modeled
C_0	Source constituent concentration (mg/kg)	Chemical-specific
$C_{particulate}$	Annual average particulate air concentration (($\mu g/m^3$)/(g/m^2-s))	Modeled ISC3

Description

This equation calculates the inhalation cancer risk for individual constituents using the Unit Risk Factor.

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Table B-1-3.2. Inhalation Cancer Risk for Individual Chemicals from Unit Risk Factor: Carcinogens

$$Cancer\ Risk = C_a \bullet URF$$

Parameter	Description	Values
Cancer Risk	Individual Lifetime cancer risk (unitless)	
C_a	Concentration in air ($\mu g/m^3$)	Calculated (see Table B-1-3.1)
URF	Inhalation Unit Risk Factor (per $\mu g/m^3$)	Chemical-specific

Description

This equation calculates the inhalation cancer risk for individual constituents using the Unit Risk Factor.

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Table B-1-3.3. Inhalation Cancer Risk for Individual Chemicals from Carcinogenic Slope Factor: Carcinogens

$$Cancer\ Risk = ADI \bullet CSF_{inh}$$

$$ADI = \frac{C_a \bullet IR \bullet ET \bullet EF \bullet ED \bullet 0.001\ mg/\mu g}{BW \bullet AT \bullet 365\ day/yr}$$

Parameter	Description	Values
Cancer Risk	Individual lifetime cancer risk (unitless)	
ADI	Average daily intake via inhalation (mg/kg/d)	
C_a	Concentration of contaminant in the air ($\mu g/m^3$)	Calculated (see Table B-1-3.1)
IR	Inhalation rate (m^3/h)	Varies
ET	Exposure time (h/d)	24
EF	Exposure frequency (d/yr)	350
ED	Exposure duration (yr)	Varies
BW	Body weight (kg)	Adult = 70 Child = 15
AT	Averaging time (yr)	70
CSF_{inh}	Inhalation Carcinogenic Slope Factor (per mg/kg/d)	Chemical-specific

Description

This equation calculates the inhalation cancer risk for individual constituents using the Carcinogenic Slope Factor.

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Table B-1-3.4. Inhalation Hazard Quotient for Individual Chemicals: Noncarcinogens

$$HQ = \frac{C_a \bullet 0.001\ mg/\mu g}{RfC}$$

Parameter	Description	Values
HQ	Hazard quotient (unitless)	
C_a	Concentration in air ($\mu g/m^3$)	Calculated (see Table B-1-3.1)
RfC	Reference concentration (mg/m^3)	Chemical-specific

Description

This equation calculates the inhalation hazard quotient for individual constituents.

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Table B-1-4.1. Calculation of Waste Concentration after Volatilization for Organic Constituents of Concern in Landfills

Landfill Scenarios			
$C_{W(AV)} = \frac{M_{C(AV)}}{M_{T(AV)}}$ $M_{C(AV)} = (C_{W(BV)} \quad BD \quad V_W) - M_V$ $M_{T(AV)} = (BD \quad V_W) - M_V$			
Parameter	Definition	Central Tendency	High End
$C_{W(AV)}$	Waste concentration after volatilization (mg/Kg)		
$M_{C(AV)}$	Contaminant mass after volatilization (mg)		
$M_{T(AV)}$	Total mass of waste after volatilization (Kg)		
$C_{W(BV)}$	Average waste concentration before volatilization (mg/Kg), wet-weight basis	Waste stream-specific	
BD	Bulk density of waste (g/cm^3)	Waste stream-specific	
V_W	Waste volume (m^3)	Waste stream-specific	Waste stream-specific
M_V	Contaminant mass volatilized during first 30 years of landfill operation (mg)	Chemical-specific	
Description			
Above equations are used to calculate the waste concentration at the time the landfill is closed, that is, after 30 years. Volatilization is assumed to occur only during the active life of the landfill, prior to installation of clay cap. This waste concentration which is adjusted for volatilization losses is then used as input for the groundwater fate and transport modeling.			

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Table B-1-4.2. Calculation of Soil-Water Partition Coefficients for Organic Constituents of Concern, Landfills and Land Treatment Units

Landfill			
$k_d = k_{oc} \times f_{oc}$			
Parameter	Definition	Central Tendency	High End
k_d	Soil-water partition coefficient (cm^3/g)		
k_{oc}	Normalized distribution coefficient for organic carbon (cm^3/g)	Chemical-specific (see Appendix)	
f_{oc}	Fractional organic carbon content	Waste specific	
Description			
This equation is used to calculate the soil-water partition coefficient for organic constituents.			

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Table B-1-5.1. Individual Cancer Risk from Ingestion: Carcinogens

$$Cancer\ Risk = \frac{I \cdot ED \cdot EF \cdot CSF}{BW \cdot AT \cdot 365}$$

Parameter	Description	Values
Cancer Risk	Individual lifetime cancer risk (unitless)	
I	Total daily intake of contaminant (mg/d)	Calculated (see Tables B-1-2.1 - B-1-2.6)
ED	Exposure duration (yr)	Varies
EF	Exposure frequency (d/yr)	350
BW	Body weight (kg)	Adult: 70 Child: 15
AT	Averaging time (yr)	70
365	Units conversion factor (d/yr)	
CSF	Oral cancer slope factor (per mg/kg/d)	Chemical-specific

Description

This equation calculates the individual cancer risk from tap water ingestion of carcinogenic chemicals. The body weight varies for the child. The exposure duration varies for different scenarios.

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Table B-1-5.2. Hazard Quotient: Noncarcinogens

$$HQ = \frac{I}{BW \cdot RfD}$$

Parameter	Description	Values
HQ	Hazard quotient (unitless)	
I	Total daily intake of contaminant (mg/d)	Calculated (see Tables B-1-2.1 - B-1-2.6)
BW	Body weight (kg)	Adult: 70 Child: 15
RfD	Reference Dose (mg/kg/d)	Chemical-specific

Description

This equation calculates the hazard quotient for indirect exposure to noncarcinogenic chemicals. The body weight varies for the child.

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Appendix C

Selection of Surrogates and Pigment Waste Stream Constituents

Appendix C

Selection of Surrogates and Pigment Waste Stream Constituents

C.1 Selection of Surrogates for Organic Constituents

Because of the large number of constituents of concern, constituents were grouped based on subsurface fate and transport characteristics. Then one representative constituent from each category was modeled. The modeled constituent in each category is called a surrogate. The modeling results for the surrogate are then applied to each constituent in that category. The methodology for grouping the constituents and choosing the surrogates is described here.

C.1.1 Basis for Grouping of Organic Constituents

The constituent list for the Dyes and Pigments Deferred Wastes (Section 4, Table 4-2) contains a total of 53 organic and 11 inorganic constituents. The number of modeling runs required to model these constituents in the sensitivity analysis was minimized by exploiting the following features:

- For a given waste management scenario, if two organic constituents have the same waste and leaching concentrations and the same sorption and hydrolysis rate coefficients, the model will predict the same receptor well exposure concentration.

- If two organic constituents have the same receptor well exposure concentration, their waste and leachate concentration thresholds will be linearly proportional to their respective HBL values.

Combined, these two features make it possible to group constituents based on subsurface fate and transport characteristics, rather than requiring a separate modeling run for each individual constituent on the list.

For computational efficiency, average transformation rate, λ, is calculated for each constituent, constituents are categorized according to their λ and K_{OC} values, and then the modeling is conducted for one representative constituent in each category. The modeled

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constituent in each category is called a surrogate. The modeling results for the surrogate are then applied to each constituent in that category.

C.1.2 Calculation of Constituent-Specific Sorption and Decay Characteristics

The subsurface fate and transport of solute species is described by the advection-dispersion equation (U.S. EPA, 1996b):

$$\nabla D \nabla C - V \nabla C = \phi \lambda C + \phi R \frac{\partial C}{\partial t} \qquad \text{(C-1)}$$

where

∇ = divergence operator
D = dispersion tensor
C = chemical concentration
V = velocity tensor
ϕ = porosity
λ = first-order chemical decay coefficient
R = retardation coefficient.

The chemical decay coefficient, λ, and the retardation coefficient, R, represent the constituent-specific fate and transport characteristics that influence solute transport behavior. In other words, for the same modeling scenario, chemicals with similar values for R and λ are expected to have similar fate and transport behavior. Thus, the model-predicted exposure concentration of individual chemicals may be derived from the modeling results of chemicals with similar R and λ values.

The following sections describe how R and λ are determined from the chemical-specific organic carbon partition coefficient, K_{OC}, and the hydrolysis rate constants, $K_{a,n,b}$, respectively.

C.1.2.1 <u>Chemical Decay Coefficient (λ)</u>. The overall first-order chemical decay coefficient of an organic species in the subsurface as modeled by EPACMTP is a combination of dissolved phase and sorbed phase decay and is described by (U.S. EPA, 1996b):

$$\lambda = \frac{\lambda_1 \phi + \lambda_2 \rho_b k_d}{\phi + \rho_b k_d} \qquad \text{(C-2)}$$

where

λ_1 = dissolved phase decay coefficient (y^{-1})
ϕ = porosity (or average water content in the unsaturated zone)

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λ_2 = sorbed phase decay coefficient (y^{-1})
ρ_b = soil bulk density (gm/cm^3)
k_d = soil-water partition coefficient (cm^3/gm).

Note that the effect of sorbed phase decay is directly incorporated in the formulation of λ. The sorbed and dissolved phase decay coefficients are functions of the temperature-dependent chemical-specific hydrolysis rate constants K_a^T, K_n^T, and K_b^T (U.S. EPA, 1996b):

$$\lambda_1 = K_a^T \cdot 10^{-pH} + K_n^T + K_b^T \cdot 10^{-(14-pH)}$$
$$\lambda_2 = 10 \cdot K_a^T \cdot 10^{-pH} + K_n^T \qquad \text{(C-3)}$$

where

K_a^T = acid-catalyzed hydrolysis rate constant at temperature T (1/mol-yr)
pH = soil or aquifer pH
K_n^T = neutral hydrolysis rate constant at temperature T (1/yr)
K_b^T = base-catalyzed hydrolysis rate constant at temperature T (1/mol-yr).

The temperature dependence of $K_{a,n,b}$ is described by the Arrhenius equation:

$$K_{a,n,b}^T = K_{a,n,b}^{Tr} e^{\left[E_a/R_g\left(\frac{1}{Tr + 273} - \frac{1}{T + 273}\right)\right]} \qquad \text{(C-4)}$$

where

E_a/R_g = activation coefficient = 10,000
T_r = reference temperature (°C) = 25°
T = soil or aquifer temperature (°C).

C.1.2.2 <u>Parameters Used in the Calculation of Chemical-Specific Decay Rate</u>. Equations C-2 through C-4 indicate that the modeled decay rate depends not only on the chemical-specific hydrolysis rate constants but also on a number of soil and aquifer parameters. These parameters include the bulk density, porosity (water content in unsaturated zone), temperature, and pH.

These parameters are not constants, but depend on soil type and location; for Monte Carlo analyses, each is characterized by a distribution of values. However, for computational efficiency, an average λ value for each constituent is calculated so that constituents can be classified according to their K_{OC} and λ values. Modeling is conducted for one constituent in each category (called the surrogate) and modeling results for the surrogate are applied to each constituent in that category.

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In calculating the average chemical decay coefficient (l) for each of the 53 organic constituents, the median values of the soil parameters are used. These values for the unsaturated zone (rather than saturated zone) are used because the effect of contaminant sorption and degradation as modeled by EPACMTP is much more pronounced in the unsaturated zone than in the saturated zone. Although the unsaturated zone travel distance (from the base of the waste unit to the water table) is generally much shorter than the travel distance through the saturated zone to the receptor well, the flow rate through the unsaturated zone is several orders of magnitude smaller than the groundwater flow rate in the saturated zone. As a result, for a given constituent, most of the travel time from the source to the receptor well is spent in the unsaturated zone. Therefore, median values of unsaturated zone parameters (Table C-1) are used in calculating the overall λ value for the each constituent.

Table C-1. Median Parameters used to Derive λ

Soil Parameter	Value
Water content, ϕ	0.355
Bulk density, ρ_b	1.65 g/cm^3
Temperature, T	14.4°C
pH	6.8

C.1.2.3 Retardation Coefficient (R). The effect of equilibrium sorption is expressed in EPACMTP through the retardation coefficient, R, which is a function of the chemical-specific organic carbon partition coefficient, K_{OC} (U.S. EPA, 1996b):

$$R = 1 + \frac{\rho_b k_d}{\phi} \qquad \text{(C-5)}$$

where

ρ_b = soil bulk density (gm/cm^3)
ϕ = porosity (or average water content in the unsaturated zone)
k_d = soil-water partition coefficient (cm^3/gm).

$$k_d = f_{oc} \cdot k_{oc} \qquad \text{(C-6)}$$

where

f_{oc} = fraction organic carbon in the soil or aquifer
k_{oc} = organic carbon partition coefficient.

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C.1.3 Grouping of Constituents Based on K_{OC} and λ

Using the criteria described below, categories based on K_{OC} and λ values are developed for the organic constituents of concern. These categories are presented in Table C-2.

The value of 1.0×10^{-4} yr^{-1} (half-life of 6,931 years) is selected as the maximum value for the lowest λ category because constituents with a λ value less than or equal to 1.0×10^{-4} yr^{-1} are classified as nondegraders in the 1995 proposed Hazardous Waste Identification Rule (HWIR '95) (U.S. EPA, 1996b). This is done because the modeled result will be the same (essentially identical to that of a conservative constituent, i.e., λ value of 0.0 yr^{-1}) whether a constituent has a λ value of 1.0×10^{-4} yr^{-1} or a smaller number such as 1.0×10^{-6} yr^{-1}. The upper bound for the second λ category, 0.1 yr^{-1} is chosen as a value just slightly higher than the λ values of the three constituents in this category (see Tables C-2 and C-3).

Table C-2. Grouping of Constituents Based on K_{OC} and λ

	K_{OC} (mL/g)				
λ (yr^{-1})	<1	<100	<1,000	<10,000	>10,000
$<1.0 \times 10^{-4}$	Group 1	Group 2	Group 3	Group 4	Group 5
<0.1	Group 6	Group 7	Group 8	Group 9	Group 10
>0.1	Group 1	Group 12	Group 13	Group 14	Group 15

Table C-3. Distribution of λ and K_{OC} for Organic Chemicals

	K_{OC} (mL/g)					
λ (yr^{-1})	<1	<100	<1,000	<10,000	>10,000	Total
$<1.0 \times 10^{-4}$	7	24	9	9	4	53
<0.1	0	3	0	0	0	3
>0.1	0	1	0	0	0	1
Total	15	35	12	12	11	57

The upper bounds for each of the K_{OC} categories are chosen both to provide meaningful boundaries and to separate the nondegrading constituents into groups roughly equal in size.

The distribution of the organic chemicals within the chosen categories is shown in Table C-3. This table shows that the majority of the chemicals either do not or only slightly degrade (hydrolysis rate < 0.0001).

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Table C-4 lists the 53 organic constituents of concern from the wastes produced by dyes and pigments facilities. The last column of this table indicates the group to which each constituent was assigned.

The λ and K_{OC} value of the surrogate for each group of constituents is chosen as the lowest λ and lowest K_{OC} value of any constituents in that group. If the same constituent has both the lowest λ and lowest K_{OC} value, then that constituent is chosen as the surrogate. The surrogates chosen in this manner are highlighted in bold text on Table C-4.

Table C-4. Grouping of Organic Constituents[a]

Organic Constituents for Groundwater Pathway	CAS #	Koc (ml/g)	λ (1/yr)	Group
Acetone	67-64-1	0.28	0.00E+00	1
Formaldehyde	50-00-0	0.43	0.00E+00	1
p-Phenylenediamine	106-50-3	0.24	0.00E+00	1
o-Phenylenediamine	95-54-5	0.68	0.00E+00	1
_____[b]				**1**
Aniline	62-53-3	4.6	0.00E+00	2
Benzaldehyde	100-52-7	14	0.00E+00	2
Benzene	71-43-2	65	0.00E+00	2
Benzidine	92-87-5	22	0.00E+00	2
Chloroaniline, p-	106-47-8	34	0.00E+00	2
Cresol, p-	106-44-5	43	0.00E+00	2
Chloroform	67-66-3	40	7.46E-05	2
N-N-Dimethylaniline	121-69-7	98	0.00E+00	2
Dimethyoxybenzidine, 3,3'-	119-90-4	31	0.00E+00	2
Methyl isobutyl ketone	108-10-1	7.4	0.00E+00	2
Phenol	108-95-2	14	0.00E+00	2
Pyridine	110-86-1	2.2	0.00E+00	**2**
Toluidine, o-	95-53-4	10	0.00E+00	2
Toluidine, p-	106-49-0	12	0.00E+00	2
Chlorobenzene	108-90-7	347	0.00E+00	3

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Organic Constituents for Groundwater Pathway	CAS #	Koc (ml/g)	λ (1/yr)	Group
1,2-Diphenylhydrazine	122-66-7	417	0.00E+00	3
Ethylbenzene	100-41-4	661	0.00E+00	3
N-Nitrosodiphenylamine	86-30-6	692	0.00E+00	3
Toluene	108-88-3	269	0.00E+00	3
Xylenes (total)	1330-20-7	708	0.00E+00	3
_____[a]				**3**
Azobenzene	103-33-3	3162	0.00E+00	4
Diphenylamine	122-39-4	1445	0.00E+00	4
Naphthalene	91-20-3	1096	0.00E+00	**4**
Trichlorobenzene, 1,2,4-	120-82-1	4898	0.00E+00	4
Bis(2-ethylhexyl)phthalate	117-81-7	9549926	7.15E-10	5
_____[a]				**5**
Bromodichloromethane	75-27-4	60	7.91E-04	7
Methylene chloride	75-09-2	8.5	2.90E-04	7
_____[b]				**7**

[a] The complete list of constituents is not included at present because of business confidentiality concerns.

[b] These compounds were used in the original analysis but were later dropped from the list of constituents of concern evaluated for this analysis. They were nevertheless retained as surrogate constituents for the compounds assessed. They are not included at present because of business confidentiality concerns.

C.2 Selection of Surrogates for Inorganic Constituents

Inorganic constituents are assigned to the appropriate group based on their geochemical characteristics. In general, these compounds do not hydrolyze to a significant degree. Anionic compounds exhibit little or no sorption and therefore are grouped with the conservative organics ($K_{OC} < 1$ and $\lambda < 1.0 \times 10^{-4}$). Cationic compounds such as ammonia and the metals can be strongly sorbed and thus can be grouped with organic compounds that are adsorbed to a similar degree.

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For the metals listed in Table C-5, empirical (pH-dependent) isotherms are available for use in the sensitivity analysis (Loux et al., 1990; U.S. EPA, 1996c). Thus, the pH-dependent isotherm is used to assign a K_d value for each metal for the filter aid waste stream based on the central tendency pH value of the waste stream (pH = _____;* data supplied by SAIC). The K_d value is then divided by the fraction organic carbon in the waste (f_{oc} = _____;* data supplied by SAIC) to obtain an "effective K_{OC}" value for each metal. This effective K_{OC} value is then used to place each metal in one of the groups established for organics. The results of the sensitivity analysis for the surrogate assigned to each group are then applied to the metals in that group.

Table C-5. Assignment of Metals to Groups

Metal	K_d (L/kg) at pH ___[a]	Effective K_{oc} (L/kg)	λ (yr^{-1})	Group
As (III)	[a]	380	0.0	3
As (V)	[a]	625	0.0	3
Ba (II)	[a]	1451	0.0	4
Cr (VI)	[a]	195	0.0	3
Cu (II)	[a]	6383	0.0	4
Ni (II)	[a]	1311	0.0	4
Pb (II)	[a]	1677	0.0	4
V (V)	[a]	625	0.0	3
Zn (II)	[a]	2054	0.0	4

[a] Relevant data are not included at present because of business confidentiality concerns.

*Relevant data are not included at present because of business confidentiality concerns.

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C.3 References

Loux, N. T., C. R. Chafin, and S. M. Hassan. 1990. *Statistics of Aquifer Material Properties and Empirical pH-dependent Partitioning Relationships for As (III), As (V), Ba(II), Cd(II), Cr(VI), Cu(II), Hg(II), Ni(II), Pb(II), Sb(V), Se(IV), Tl(I), and Zn(II).* Office of Research and Development, U. S. Environmental Protection Agency, Athens GA.

U.S. EPA (Environmental Protection Agency). 1996a. *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) Background Document for the Finite Source Methodology*. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1996b. *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) Background Document for Metals*. Office of Solid Waste, Washington, DC.

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Appendix D

Chemical-Specific Inputs

Relevant data for some constituents are not included at present because of business confidentiality concerns

Table D-1. Chemical-Specific Inputs for Acetone

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	0.58	
Kow	Octanol-water partition coefficient (unitless)	5.8E-1	SCDM
VP	Vapor pressure (atm)	3.03E-1	SCDM
SOl	Water solubility (mL/g)	1E+6	SCDM
MW	Molecular weight (g/mol)	58.08	
H	Henry's law constant (atm-m^3/mol)	3.88E-5	SCDM
D_a	Diffusivity in air (cm^2/s)	1.2E-1	Water8
D_w	Diffusivity in water (cm^2/s)	1.1E-5	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	8E-2	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	8.4E-1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	5.3E+1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	1.4E-8	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	4.6E-9	Calc
	Skin permeability constant for water (cm/hr)	5.7E-4	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	1.7E-1	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	1E-1	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	3.1E+1	ATSDR

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Table D-2. Chemical-Specific Inputs for Aniline

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	9.2	
Kow	Octanol-water partition coefficient (unitless)	9.5E+0	SCDM
VP	Vapor pressure (atm)	6.45E-4	SCDM
SOl	Water solubility (mL/g)	3.6E+4	SCDM
MW	Molecular weight (g/mol)	93.13	
H	Henry's law constant (atm-m^3/mol)	1.9E-6	SCDM
D_a	Diffusivity in air (cm^2/s)	7E-2	Water8
D_w	Diffusivity in water (cm^2/s)	8.3E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	3.3E+1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	9.9E-1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	1.1E+1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	2.4E-7	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	7.6E-8	Calc
	Skin permeability constant for water (cm/hr)	2.6E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	1.6E+0	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	5.7E-3	IRIS
RfD	Reference dose (mg/kg/d)	N/A	
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	1E-3	IRIS

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Table D-3. Chemical-Specific Inputs for Azobenzene

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	0	
Koc	Soil adsorption coefficient (m/g)	5693	
Kow	Octanol-water partition coefficient (unitless)	6.6E+3	Vershueren
VP	Vapor pressure (atm)		
SOl	Water solubility (mL/g)		
MW	Molecular weight (g/mol)	182.22	
H	Henry's law constant (atm-m^3/mol)		
D_a	Diffusivity in air (cm^2/s)	8E-2	Water8
D_w	Diffusivity in water (cm^2/s)	8E-6	Water8
λ	GW degradation rate (1/yr)		
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])		
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	2.7E+1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.4E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	1.7E-4	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	5.2E-5	Calc
	Skin permeability constant for water (cm/hr)	7.6E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	N/A	
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	1.1E-1	IRIS
RfD	Reference dose (mg/kg/d)	N/A	
URF	Unit risk factor (per µg/m^3)	3.1E-5	IRIS
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-4. Chemical-Specific Inputs for Benzaldehyde

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	29	
Kow	Octanol-water partition coefficient (unitless)	3E+1	Vershueren
VP	Vapor pressure (atm)	1.24E-3	Vershueren
SOl	Water solubility (mL/g)	3.3E+3	Vershueren
MW	Molecular weight (g/mol)	106.13	
H	Henry's law constant (atm-m^3/mol)	3.98E-5	Calc
D_a	Diffusivity in air (cm^2/s)	7.3E-2	Water8
D_w	Diffusivity in water (cm^2/s)	9.1E-6	Water8
λ	GW degradation rate (1/yr)		
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.3E-1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.2E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	5.4E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	7.6E-7	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	2.4E-7	Calc
	Skin permeability constant for water (cm/hr)	4.8E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	N/A	
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	1E-1	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-5. Chemical-Specific Inputs for Benzene

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	124	
Kow	Octanol-water partition coefficient (unitless)	1.3E+2	SCDM
VP	Vapor pressure (atm)	1.25E-1	SCDM
SOl	Water solubility (mL/g)	1.75E+3	SCDM
MW	Molecular weight (g/mol)	78.11	
H	Henry's law constant (atm-m^3/mol)	5.58E-3	Calc
D_a	Diffusivity in air (cm^2/s)	8.8E-2	Water8
D_w	Diffusivity in water (cm^2/s)	9.8E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.9E-1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	2.1E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.3E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	3.4E-6	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.1E-6	Calc
	Skin permeability constant for water (cm/hr)	2.1E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	4.2E+0	Mackay,82
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	2.9E-2	IRIS
RfD	Reference dose (mg/kg/d)	N/A	
URF	Unit risk factor (per µg/m^3)	8.3E-6	IRIS
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-6. Chemical-Specific Inputs for Benzidine

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	0.193867	EPA,94
Koc	Soil adsorption coefficient (m/g)	43	
Kow	Octanol-water partition coefficient (unitless)	4.6E+1	SCDM
VP	Vapor pressure (atm)	1.05E-11	SCDM
SOl	Water solubility (mL/g)	5E+2	SCDM
MW	Molecular weight (g/mol)	184.24	
H	Henry's law constant (atm-m^3/mol)	3.88E-11	SCDM
D_a	Diffusivity in air (cm^2/s)	3.4E-2	Water8
D_w	Diffusivity in water (cm^2/s)	1.5E-9	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	8.4E+6	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.4E+0	Calc
$BCF_{Plant-Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	4.3E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	1.1E-6	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	3.6E-7	Calc
	Skin permeability constant for water (cm/hr)	2.2E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	5.4E+0	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	2.3E+2	IRIS
RfD	Reference dose (mg/kg/d)	3E-3	IRIS
URF	Unit risk factor (per µg/m^3)	6.7E-2	IRIS
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-7. Chemical-Specific Inputs for Bis(2-Ethylexyl) Phthalate

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	0.934485	EPA,94
Koc	Soil adsorption coefficient (m/g)	15003065	
Kow	Octanol-water partition coefficient (unitless)	2E+7	SCDM
VP	Vapor pressure (atm)	8.49E-9	SCDM
SOl	Water solubility (mL/g)	3.4E-1	SCDM
MW	Molecular weight (g/mol)	390.56	
H	Henry's law constant (atm-m^3/mol)	1.02E-7	SCDM
D_a	Diffusivity in air (cm^2/s)	3.5E-2	Water8
D_w	Diffusivity in water (cm^2/s)	3.7E-6	Water8
λ	GW degradation rate (1/yr)	7.15E-10	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	8.2E+7	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.3E+4	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.3E-3	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	5E-1	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.6E-1	Calc
	Skin permeability constant for water (cm/hr)	1.2E+0	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	1.2E+2	Stephan,93
BCF_{Fish}	Fish bioconcentration factor (L/kg)	N/A	
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	1.4E-2	IRIS
RfD	Reference dose (mg/kg/d)	2E-2	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	1E-3	Superfund

Table D-8. Chemical-Specific Inputs for Bromodichloromethane

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Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	116	
Kow	Octanol-water partition coefficient (unitless)	1.3E+2	SCDM
VP	Vapor pressure (atm)	6.58E-2	SCDM
SOl	Water solubility (mL/g)	6.74E+3	SCDM
MW	Molecular weight (g/mol)	163.83	
H	Henry's law constant (atm-m^3/mol)	1.6E-3	Calc
D_a	Diffusivity in air (cm^2/s)	3E-2	Water8
D_w	Diffusivity in water (cm^2/s)	1.1E-5	Water8
λ	GW degradation rate (1/yr)	7.91E-4	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	6E-1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	2.1E+0	Calc
$BCF_{Plant-Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.4E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	3.2E-6	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1E-6	Calc
	Skin permeability constant for water (cm/hr)	5.9E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	1.2E+1	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	6.2E-2	IRIS
RfD	Reference dose (mg/kg/d)	2E-2	IRIS
URF	Unit risk factor (per µg/m^3)	1.8E-5	EPA,98
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-9. Chemical-Specific Inputs for p-Chloroaniline

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	0.999992	EPA,94
Koc	Soil adsorption coefficient (m/g)	66	
Kow	Octanol-water partition coefficient (unitless)	7.1E+1	SCDM
VP	Vapor pressure (atm)	1.62E-5	SCDM
SOl	Water solubility (mL/g)	5.3E+3	SCDM
MW	Molecular weight (g/mol)	127.57	
H	Henry's law constant (atm-m^3/mol)	3.31E-7	SCDM
D_a	Diffusivity in air (cm^2/s)	4.8E-2	Water8
D_w	Diffusivity in water (cm^2/s)	1E-5	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.6E+3	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.6E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	3.3E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	1.8E-6	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	5.6E-7	Calc
	Skin permeability constant for water (cm/hr)	6.5E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	7.6E+0	EPA,1991
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	4E-3	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-10. Chemical-Specific Inputs for Chlorobenzene

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	648	
Kow	Octanol-water partition coefficient (unitless)	7.2E+2	SCDM
VP	Vapor pressure (atm)	1.58E-2	SCDM
SOl	Water solubility (mL/g)	4.72E+2	SCDM
MW	Molecular weight (g/mol)	112.56	
H	Henry's law constant (atm-m^3/mol)	3.7E-3	SCDM
D_a	Diffusivity in air (cm^2/s)	7.3E-2	Water8
D_w	Diffusivity in water (cm^2/s)	8.7E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.7E+0	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	5.6E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	8.6E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	1.8E-5	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	5.8E-6	Calc
	Skin permeability constant for water (cm/hr)	4.2E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	2.3E+1	Mackay, 82
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	2E-2	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	2E-2	HEAST

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Table D-11. Chemical-Specific Inputs for Chloroform

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	77	
Kow	Octanol-water partition coefficient (unitless)	8.3E+1	SCDM
VP	Vapor pressure (atm)	2.59E-1	SCDM
SOl	Water solubility (mL/g)	7.92E+3	SCDM
MW	Molecular weight (g/mol)	119.38	
H	Henry's law constant (atm-m^3/mol)	3.67E-3	SCDM
D_a	Diffusivity in air (cm^2/s)	1E-1	Water8
D_w	Diffusivity in water (cm^2/s)	1E-5	Water8
λ	GW degradation rate (1/yr)	7.46E-5	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.7E-1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.7E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	3E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	2.1E-6	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	6.6E-7	Calc
	Skin permeability constant for water (cm/hr)	8.2E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	2.6E+0	Mackay, 82
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	6.1E-3	IRIS
RfD	Reference dose (mg/kg/d)	1E-2	IRIS
URF	Unit risk factor (per µg/m^3)	2.3E-5	IRIS
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-12. Chemical-Specific Inputs for p-Cresol

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	83	
Kow	Octanol-water partition coefficient (unitless)	8.9E+1	SCDM
VP	Vapor pressure (atm)	1.45E-4	SCDM
SOl	Water solubility (mL/g)	2.15E+4	SCDM
MW	Molecular weight (g/mol)	108.14	
H	Henry's law constant (atm-m^3/mol)	7.92E-7	SCDM
D_a	Diffusivity in air (cm^2/s)	7.4E-2	Water8
D_w	Diffusivity in water (cm^2/s)	1E-5	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	8.4E+2	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.8E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.9E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	2.2E-6	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	7.1E-7	Calc
	Skin permeability constant for water (cm/hr)	1E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	9.1E+0	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	5E-3	HEAST
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-13. Chemical-Specific Inputs for 1,2-Dichlorobenzene

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	2355	
Kow	Octanol-water partition coefficient (unitless)	2.7E+3	SCDM
VP	Vapor pressure (atm)	1.79E-3	SCDM
SOl	Water solubility (mL/g)	1.56E+2	SCDM
MW	Molecular weight (g/mol)	147.00	
H	Henry's law constant (atm-m^3/mol)	1.9E-3	SCDM
D_a	Diffusivity in air (cm^2/s)	6.9E-2	Water8
D_w	Diffusivity in water (cm^2/s)	7.9E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.3E+1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.4E+1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	4E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	6.8E-5	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	2.1E-5	Calc
	Skin permeability constant for water (cm/hr)	6.6E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	2.3E+2	Oliver & Niimi,83
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	9E-2	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	2E-1	HEAST

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Table D-14. Chemical-Specific Inputs for 1,4-Dichlorobenzene

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	2302	
Kow	Octanol-water partition coefficient (unitless)	2.6E+3	SCDM
VP	Vapor pressure (atm)	1.32E-3	SCDM
SOl	Water solubility (mL/g)	7.38E+1	SCDM
MW	Molecular weight (g/mol)	147.00	
H	Henry's law constant (atm-m^3/mol)	2.43E-3	SCDM
D_a	Diffusivity in air (cm^2/s)	6.9E-2	Water8
D_w	Diffusivity in water (cm^2/s)	7.9E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1E+1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.4E+1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	4.1E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	6.6E-5	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	2.1E-5	Calc
	Skin permeability constant for water (cm/hr)	6.5E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	2.3E+2	Oliver& Niimi,83
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	2.4E-2	HEAST
RfD	Reference dose (mg/kg/d)	N/A	
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	8E-1	IRIS

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Table D-15. Chemical-Specific Inputs for 3,3'-Dimethoxybenzidine

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	0.905382	EPA,94
Koc	Soil adsorption coefficient (m/g)	60	
Kow	Octanol-water partition coefficient (unitless)	6.5E+1	SCDM
VP	Vapor pressure (atm)	2.79E-10	SCDM
SOl	Water solubility (mL/g)	6E+1	SCDM
MW	Molecular weight (g/mol)	244.29	
H	Henry's law constant (atm-m^3/mol)	1.81E-13	SCDM
D_a	Diffusivity in air (cm^2/s)	2.4E-2	Water8
D_w	Diffusivity in water (cm^2/s)	5.5E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	2.6E+9	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.6E+00	Calc
$BCF_{Plant-Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	3.5E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	1.6E-6	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	5.1E-7	Calc
	Skin permeability constant for water (cm/hr)	1.2E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	7E+0	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	1.4E-2	HEAST
RfD	Reference dose (mg/kg/d)	N/A	
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-16. Chemical-Specific Inputs for N-N-Dimethylaniline

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	187	
Kow	Octanol-water partition coefficient (unitless)	2E+2	Verschueren
VP	Vapor pressure (atm)	9.13E-4	Verschueren
SOl	Water solubility (mL/g)	1.1E+3	ASTER
MW	Molecular weight (g/mol)	121.18	
H	Henry's law constant (atm-m^3/mol)	9.96E-5	Calc
D_a	Diffusivity in air (cm^2/s)	1.5E-1	Water8
D_w	Diffusivity in water (cm^2/s)	1.4E-5	Water8
λ	GW degradation rate (1/yr)		
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.6E+1 4E-1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	2.6E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	1.8E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	5.1E-6	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.6E-6	Calc
	Skin permeability constant for water (cm/hr)	1.5E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	N/A	
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	2E-3	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-17. Chemical-Specific Inputs for Diphenylamine

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	0.999752	EPA,94
Koc	Soil adsorption coefficient (m/g)	2637	
Kow	Octanol-water partition coefficient (unitless)	3E+3	SCDM
VP	Vapor pressure (atm)	8.79E-7	SCDM
SOl	Water solubility (mL/g)	3.57E+1	SCDM
MW	Molecular weight (g/mol)	169.23	
H	Henry's law constant (atm-m^3/mol)	4.96E-7	SCDM
D_a	Diffusivity in air (cm^2/s)	5.8E-2	Water8
D_w	Diffusivity in water (cm^2/s)	6.3E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	5.7E+4	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.5E+1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	3.8E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	7.6E-5	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	2.4E-5	Calc
	Skin permeability constant for water (cm/hr)	5.2E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	9.5E+1	Mackay,82
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	2.5E-2	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-18. Chemical-Specific Inputs for 1,2-Diphenylhydrazine

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	0.999941	EPA,94
Koc	Soil adsorption coefficient (m/g)	777	
Kow	Octanol-water partition coefficient (unitless)	8.7E+2	SCDM
VP	Vapor pressure (atm)	5.67E-7	SCDM
SOl	Water solubility (mL/g)	6.8E+1	SCDM
MW	Molecular weight (g/mol)	184.24	
H	Henry's law constant (atm-m^3/mol)	1.54E-6	Calc
D_a	Diffusivity in air (cm^2/s)	3.2E-2	Water8
D_w	Diffusivity in water (cm^2/s)	7.4E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	4.9E+3 1.2E+2	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	6.4E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	7.7E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	2.2E-5	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	6.9E-6	Calc
	Skin permeability constant for water (cm/hr)	1.8E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	N/A	
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	8E-1	IRIS
RfD	Reference dose (mg/kg/d)	N/A	
URF	Unit risk factor (per µg/m^3)	2.2E-4	IRIS
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-19. Chemical-Specific Inputs for Ethylbenzene

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	1222	
Kow	Octanol-water partition coefficient (unitless)	1.4E+3	SCDM
VP	Vapor pressure (atm)	1.26E-2	SCDM
SOl	Water solubility (mL/g)	1.69E+2	SCDM
MW	Molecular weight (g/mol)	106.17	
H	Henry's law constant (atm-m^3/mol)	7.88E-3	SCDM
D_a	Diffusivity in air (cm^2/s)	7.5E-2	Water8
D_w	Diffusivity in water (cm^2/s)	7.8E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.6E+0	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	8.7E+0	Calc
$BCF_{Plant-Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	5.9E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	3.5E-5	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.1E-5	Calc
	Skin permeability constant for water (cm/hr)	7.3E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	7.9E+1	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	1E-1	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	1E+0	IRIS

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Table D-20. Chemical-Specific Inputs for Formaldehyde

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	.89	
Kow	Octanol-water partition coefficient (unitless)	8.9E-1	SCDM
VP	Vapor pressure (atm)	6.89E+0	SCDM
SOl	Water solubility (mL/g)	5.5E+5	SCDM
MW	Molecular weight (g/mol)	30.03	
H	Henry's law constant (atm-m^3/mol)	3.36E-7	SCDM
D_a	Diffusivity in air (cm^2/s)	1.8E-1	Water8
D_w	Diffusivity in water (cm^2/s)	2E-5	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.5E+1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	8.5E-1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	4.1E+1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	2.2E-8	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	7.1E-9	Calc
	Skin permeability constant for water (cm/hr)	1.2E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	2.4E-1	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	4.5E-2	HEAST
RfD	Reference dose (mg/kg/d)	2E-1	IRIS
URF	Unit risk factor (per µg/m^3)	1.3E-5	IRIS
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-21. Chemical-Specific Inputs for Methyl Isobutyl Ketone

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	15	
Kow	Octanol-water partition coefficient (unitless)	1.5E+1	SCDM
VP	Vapor pressure (atm)	2.62E-2	SCDM
SOl	Water solubility (mL/g)	1.9E+4	SCDM
MW	Molecular weight (g/mol)	100.16	
H	Henry's law constant (atm-m^3/mol)	1.38E-4	Calc
D_a	Diffusivity in air (cm^2/s)	7.5E-2	Water8
D_w	Diffusivity in water (cm^2/s)	7.8E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	7.5E-1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.1E+0	Calc
$BCF_{Plant-Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	7.9E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	3.9E-7	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.2E-7	Calc
	Skin permeability constant for water (cm/hr)	3.3E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	2.3E+0	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	8E-2	HEAST
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	8E-2	HEAST

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Table D-22. Chemical-Specific Inputs for Methylene Chloride

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	17	
Kow	Octanol-water partition coefficient (unitless)	1.8E+1	SCDM
VP	Vapor pressure (atm)	5.7E-1	SCDM
SOl	Water solubility (mL/g)	1.3E+4	SCDM
MW	Molecular weight (g/mol)	84.93	
H	Henry's law constant (atm-m^3/mol)	2.19E-3	SCDM
D_a	Diffusivity in air (cm^2/s)	1E-1	Water8
D_w	Diffusivity in water (cm^2/s)	1.2E-5	Water8
λ	GW degradation rate (1/yr)	2.9E-4	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	5.5E-2	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.1E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	7.3E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	4.5E-7	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.4E-7	Calc
	Skin permeability constant for water (cm/hr)	4.5E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	2.5E+0	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	7.5E-3	IRIS
RfD	Reference dose (mg/kg/d)	6E-2	IRIS
URF	Unit risk factor (per µg/m^3)	4.7E-7	IRIS
RfC	Reference concentration (mg/m^3)	3E+0	HEAST

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Table D-23. Chemical-Specific Inputs for Naphthalene

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	2010	
Kow	Octanol-water partition coefficient (unitless)	2.3E+3	SCDM
VP	Vapor pressure (atm)	1.12E-4	SCDM
SOl	Water solubility (mL/g)	3.1E+1	SCDM
MW	Molecular weight (g/mol)	128.17	
H	Henry's law constant (atm-m^3/mol)	4.83E-4	SCDM
D_a	Diffusivity in air (cm^2/s)	5.9E-2	Water8
D_w	Diffusivity in water (cm^2/s)	7.5E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	4.4E+1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.2E+1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	4.4E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	5.8E-5	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.8E-5	Calc
	Skin permeability constant for water (cm/hr)	7.7E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	7.2E+1	Mackay,82
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	2E-2	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	3E-3	IRIS

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Table D-24. Chemical-Specific Inputs for N-Nitrosodiphenylamine

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	0.999821	EPA,94
Koc	Soil adsorption coefficient (m/g)	1278	
Kow	Octanol-water partition coefficient (unitless)	1.4E+3	SCDM
VP	Vapor pressure (atm)	8.8E-7	SCDM
SOl	Water solubility (mL/g)	3.51E+1	SCDM
MW	Molecular weight (g/mol)	198.22	
H	Henry's law constant (atm-m^3/mol)	5E-6	SCDM
D_a	Diffusivity in air (cm^2/s)	2.9E-2	Water8
D_w	Diffusivity in water (cm^2/s)	6.9E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	2.6E+3	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	9E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	5.8E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	3.6E-5	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.1E-5	Calc
	Skin permeability constant for water (cm/hr)	2.1E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	9.8E+1	Veith et al,80
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	4.9E-3	IRIS
RfD	Reference dose (mg/kg/d)	N/A	
URF	Unit risk factor (per µg/m^3)	2.6E-6	CalEPA97
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-25. Chemical-Specific Inputs for Phenol

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	29	
Kow	Octanol-water partition coefficient (unitless)	3E+1	SCDM
VP	Vapor pressure (atm)	3.63E-4	SCDM
SOl	Water solubility (mL/g)	8.28E+4	SCDM
MW	Molecular weight (g/mol)	94.11	
H	Henry's law constant (atm-m^3/mol)	3.97E-7	SCDM
D_a	Diffusivity in air (cm^2/s)	8.2E-2	Water8
D_w	Diffusivity in water (cm^2/s)	9.1E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	5.3E+2	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.2E+0	Calc
$BCF_{Plant-Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	5.4E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	7.6E-7	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	2.4E-7	Calc
	Skin permeability constant for water (cm/hr)	5.7E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	1.7E+3	Stephan,93
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	6E-1	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	6E-3	EPA,98

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Table D-26. Chemical-Specific Inputs for o-Phenylenediamine

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	1.4	
Kow	Octanol-water partition coefficient (unitless)	1.4E+0	Verschueren
VP	Vapor pressure (atm)	6.76E-4	ASTDR
SOl	Water solubility (mL/g)	4.15E+4	Verschueren
MW	Molecular weight (g/mol)	108.15	
H	Henry's law constant (atm-m^3/mol)	1.76E-6	Calc
D_a	Diffusivity in air (cm^2/s)	6.6E-2	Water8
D_w	Diffusivity in water (cm^2/s)	9.9E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	4.6E+0 1.1E+0	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	8.6E-1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	3.2E+1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	3.5E-8	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.1E-8	Calc
	Skin permeability constant for water (cm/hr)	5.3E-4	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	N/A	
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	4.7E-2	HEAST
RfD	Reference dose (mg/kg/d)	N/A	
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-27. Chemical-Specific Inputs for p-Phenylenediamine

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	0.999996	EPA,94
Koc	Soil adsorption coefficient (m/g)	0.51	
Kow	Octanol-water partition coefficient (unitless)	5E-1	Hansch,95
VP	Vapor pressure (atm)	6.05E-6	EPA,96
SOl	Water solubility (mL/g)	3.8E+4	Verschueren
MW	Molecular weight (g/mol)	108.15	
H	Henry's law constant (atm-m^3/mol)	1.72E-8	Calc
D_a	Diffusivity in air (cm^2/s)	6.6E-2	Water8
D_w	Diffusivity in water (cm^2/s)	9.9E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	3.9E+0	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	8.4E-1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	5.8E+1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	1.3E-8	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	4E-9	Calc
	Skin permeability constant for water (cm/hr)	2.6E-4	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	N/A	
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	1.9E-1	HEAST
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-28. Chemical-Specific Inputs for Pyridine

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	4.6	
Kow	Octanol-water partition coefficient (unitless)	4.7E+0	SCDM
VP	Vapor pressure (atm)	2.74E-2	SCDM
SOl	Water solubility (mL/g)	1E+6	SCDM
MW	Molecular weight (g/mol)	79.10	
H	Henry's law constant (atm-m^3/mol)	8.88E-6	SCDM
D_a	Diffusivity in air (cm^2/s)	9.1E-2	Water8
D_w	Diffusivity in water (cm^2/s)	7.6E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	3.3E+0	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	9.2E-1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	1.6E+1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	1.2E-7	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	3.7E-8	Calc
	Skin permeability constant for water (cm/hr)	1.9E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	8.9E-1	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	1E-3	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	7E-3	EPA,98

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Table D-29. Chemical-Specific Inputs for Toluene

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	505	
Kow	Octanol-water partition coefficient (unitless)	5.6E+2	SCDM
VP	Vapor pressure (atm)	3.74E-2	SCDM
SOl	Water solubility (mL/g)	5.26E+2	SCDM
MW	Molecular weight (g/mol)	92.14	
H	Henry's law constant (atm-m^3/mol)	6.64E-3	SCDM
D_a	Diffusivity in air (cm^2/s)	8.7E-2	Water8
D_w	Diffusivity in water (cm^2/s)	8.6E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	7.1E-1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	4.8E+0	Calc
$BCF_{Plant-Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	1E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	1.4E-5	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	4.5E-6	Calc
	Skin permeability constant for water (cm/hr)	4.7E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	4.8E+1	Veith et al. 80
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	2E-1	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	4E-1	IRIS

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Table D-30. Chemical-Specific Inputs for o-Toluidine

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	21	
Kow	Octanol-water partition coefficient (unitless)	2.2E+1	SCDM
VP	Vapor pressure (atm)	4.21E-4	SCDM
SOl	Water solubility (mL/g)	1.66E+4	SCDM
MW	Molecular weight (g/mol)	107.16	
H	Henry's law constant (atm-m^3/mol)	2.72E-6	Calc
D_a	Diffusivity in air (cm^2/s)	7.1E-2	Water8
D_w	Diffusivity in water (cm^2/s)	9.1E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	5.5E+0	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.1E+0	Calc
$BCF_{Plant-Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	6.5E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	5.5E-7	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.7E-7	Calc
	Skin permeability constant for water (cm/hr)	3.8E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	3E+0	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	N/A	
URF	Unit risk factor (per µg/m^3)	6.9E-5	EPA,98
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-31. Chemical-Specific Inputs for p-Toluidine

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	24	
Kow	Octanol-water partition coefficient (unitless)	2.5E+1	SCDM
VP	Vapor pressure (atm)	2.34E-4	SCDM
SOl	Water solubility (mL/g)	7.82E+2	SCDM
MW	Molecular weight (g/mol)	107.16	
H	Henry's law constant (atm-m^3/mol)	3.21E-5	Calc
D_a	Diffusivity in air (cm^2/s)	7E-2	Water8
D_w	Diffusivity in water (cm^2/s)	9.4E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	5.4E+0	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.2E+0	Calc
$BCF_{Plant-Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	6.0E+0	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	6.3E-7	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	2E-7	Calc
	Skin permeability constant for water (cm/hr)	4.2E-3	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	3.3E+0	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	1.9E-1	HEAST
RfD	Reference dose (mg/kg/d)	N/A	
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	N/A	

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Table D-32. Chemical-Specific Inputs for 1,2,4-Trichlorobenzene

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	8752	
Kow	Octanol-water partition coefficient (unitless)	1E+4	SCDM
VP	Vapor pressure (atm)	5.67E-4	SCDM
SOl	Water solubility (mL/g)	3E+2	SCDM
MW	Molecular weight (g/mol)	181.45	
H	Henry's law constant (atm-m^3/mol)	1.42E-3	SCDM
D_a	Diffusivity in air (cm^2/s)	3E-2	Water8
D_w	Diffusivity in water (cm^2/s)	8.2E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	7.3E+1	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	3.8E+1	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	1.9E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	2.6E-4	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	8.1E-5	Calc
	Skin permeability constant for water (cm/hr)	1E-1	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	5.3E+2	Thomann,89
BCF_{Fish}	Fish bioconcentration factor (L/kg)	N/A	
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	1E-2	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	2E-1	HEAST

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Table D-33. Chemical-Specific Inputs for Xylenes (total)

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
Fv	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1	
Koc	Soil adsorption coefficient (m/g)	1307	
Kow	Octanol-water partition coefficient (unitless)	1.5E+3	
VP	Vapor pressure (atm)	1.06E-2	
SOl	Water solubility (mL/g)	1.86E+2	
MW	Molecular weight (g/mol)	106.17	
H	Henry's law constant (atm-m^3/mol)	6.04E-3	Calc
D_a	Diffusivity in air (cm^2/s)	7.1E-2	Water8
D_w	Diffusivity in water (cm^2/s)	9.3E-6	Water8
λ	GW degradation rate (1/yr)	0	
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	2.2E+0	Calc
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	9.2E+0	Calc
$BCF_{Plant\text{-}Soil}$	Plant-soil bioconcentration factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	5.7E-1	Calc
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef (d/kg)[1]	3.7E-5	Calc
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.2E-5	Calc
	Skin permeability constant for water (cm/hr)	7.6E-2	
BAF_{Fish}	Fish bioaccumulation factor (L/kg)	N/A	
BCF_{Fish}	Fish bioconcentration factor (L/kg)	8.4E+1	EPA,91
Other Parameters			
Fw	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/day)	N/A	
RfD	Reference dose (mg/kg/d)	2E+0	IRIS
URF	Unit risk factor (per µg/m^3)	N/A	
RfC	Reference concentration (mg/m^3)	4.3E-1	ATSDR

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References

All references cited in this appendix are cited as secondary sources from the following sources:

U.S. EPA (Environmental Protection Agency). 1997f. *Health Effects Assessment Summary Tables. FY 1997 Update*. Office of Emergency and Remedial Response and Office of Research and Development, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1998b. Integrated Risk Information System (IRIS) Database. Cincinnati, OH. August.

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Appendix E

Toxicological Profiles

Relevant data for some constituents are not included at present because of business confidentiality concerns

Acetone

Benchmark Status: Acetone has a reference dose (RfD) in the Integrated Risk Information System (IRIS) database but does not have a reference concentration (RfC), inhalation unit risk, oral cancer slope factor (CSF), or inhalation CSF. The RfD is 0.1 mg/kg-d.

The RfD was based on an oral no observed effects level (NOEL) of 100 mg/kg-d from a subchronic study (90 days) using rats (U.S. EPA, 1986). The NOEL was based on daily gavage of acetone. An uncertainty factor of 1,000 was applied (100 for inter- and intraspecies extrapolation, and 10 to extrapolate from subchronic to chronic exposure). Confidence in the study used to develop the RfD was medium, but low confidence was assigned to the overall database and the RfD estimate.

Acetone is not classifiable as to human carcinogenicity (Group D) based on the lack of human data and inadequate data from animal bioassays.

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Aniline

Benchmark Status: Aniline has an RfC and oral CSF in the IRIS database but does not have an RfD, inhalation unit risk factor, or inhalation CSF. The RfC is 1E-3 mg/m^3, and the oral CSF is 5.7E-3$(mg/kg-d)^{-1}$.

The RfC was based on an inhalation NOAEL of 19 mg/m^3 (5 ppm) from a subchronic study (20 to 26 weeks) using rats, guinea pigs, and mice (Oberst et al., 1956). The adjusted NOAEL of 3.4 mg/m^3 was based on exposure for 6 hours per day and 5 days per week. An uncertainty factor of 3,000 was applied (10 for sensitive human subpopulations, 10 for interspecies variation, 10 for use of a subchronic study, and 3 for a lack of reproductive studies). The modifying factor was 1. Confidence in the study used to develop the RfC and in the overall database were low; consequently, low confidence was assigned to the RfC estimate.

Aniline is classified as a probable human carcinogen (Group B2) based on inadequate data in humans and sufficient evidence in animals. The CSF was based on a 2-year study using CD-F rats. Aniline hydrochloride was given in the diet at dose levels of 0, 200, 600, and 2,000 ppm (CIIT, 1982). An increased incidence of splenic sarcomas was seen in male rats receiving the high dose. The CSF was derived using the linearized multistage procedure and correcting for differences in the molecular weight of aniline and aniline hydrochloride. The linearized multistage procedure may not be the most appropriate procedure for derivation of the slope factor since tumor incidence may be related to hemosiderosis and the subsequent fibrotic response in the spleen.

US EPA ARCHIVE DOCUMENT

Azobenzene

Benchmark Status: Azobenzene has an oral CSF and an inhalation unit risk factor in the IRIS database but does not have an RfD, RfC, or inhalation CSF. The oral CSF is 1.1E-1(mg/kg-d)$^{-1}$, and the inhalation unit risk factor is 3.1E-5µg/m^3. Azobenzene has an inhalation CSF in the Health Effects Assessment Summary Tables (HEAST) of 1.1E-01(mg/kg-d)$^{-1}$.

Azobenzene is classified as a probable human carcinogen (Group B2) based on its ability to induce invasive sarcomas in the spleen and other abdominal organs in rats following dietary administration. Also, it is genotoxic and may be converted to benzidine, a known human carcinogen, under the acidic conditions of the stomach. The oral CSF was based on a 105 to 106-week dietary study using F344 rats and B6C3F1 mice (NCI, 1979). Azobenzene was administered in feed at dose levels of 200 or 400 ppm (rats and male mice) and 208 or 505 ppm (female mice). An increased incidence of various types of sarcomas in the spleen and other abdominal organs was observed in rats of both sexes. The CSF was derived using the linearized multistage procedure.

The inhalation unit risk factor was calculated from the oral data listed above using the linearized multistage procedure. The unit risk should not be used if the air concentration exceeds 300 µg/m^3 since above this concentration the unit risk may not be appropriate.

The inhalation CSF was based on the same study as listed above for the oral CSF. No further information was given.

US EPA ARCHIVE DOCUMENT

Benzaldehyde

Benchmark Status: Benzaldehyde has an RfD in the IRIS database but does not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.1 mg/kg-d.

The RfD was based on a NOEL of 200 mg/kg-d from a subchronic study (13 weeks) using rats (Kluwe et al., 1983). The adjusted NOEL was based on oral gavage doses of benzaldehyde in corn oil for 5 days per week. An uncertainty factor of 1,000 was applied (10 for extrapolation from subchronic to chronic exposure, 10 for intraspecies extrapolation, and 10 for consideration of sensitive human subgroups). The modifying factor was 1. Confidence in the study used to develop the RfD was medium, but a low confidence rating was assigned to the overall database and the RfD estimate.

Benzaldehyde has not undergone a complete evaluation and determination under U.S. EPA's IRIS program for evidence of human carcinogenic potential.

US EPA ARCHIVE DOCUMENT

Benzene

Benchmark Status: Benzene has an oral CSF in the IRIS database but does not have an RfC, RfD, inhalation unit risk factor, or inhalation CSF. The oral CSF is $0.029(mg/kg\text{-}d)^{-1}$. Benzene has an inhalation CSF in HEAST of $0.029(mg/kg\text{-}d)^{-1}$.

Benzene is classified as a known human carcinogen (Group A) based on convincing human evidence as well as supporting evidence from animal studies. The oral CSF was based on inhalation occupational exposure data (Rinsky et al., 1981; Ott et al., 1978; Wong et al., 1983). The exposures to benzene varied with the studies. An increased evidence of leukemia was observed in the human workers exposed to benzene. The oral CSF was extrapolated using a one-hit (pooled data) process. The inhalation CSF was based on the same studies listed above for the oral CSF derivation.

US EPA ARCHIVE DOCUMENT

Benzidine

Benchmark Status: Benzidine has an RfD, inhalation unit risk factor, inhalation CSF, and oral CSF in the IRIS database but does not have an RfC. The RfD is 0.003 mg/kg-d, the inhalation unit risk factor is 0.067µg/m^3, the inhalation CSF is 230$(mg/kg\text{-}d)^{-1}$, and the oral CSF is 230$(mg/kg\text{-}d)^{-1}$.

The RfD was based on an oral LOAEL of 2.7 mg/kg-d from a chronic study (33 months) using mice (Littlefield et al., 1983). The LOAEL was based on daily exposure to benzidine in drinking water. An uncertainty factor of 1,000 was applied (10 for the extrapolation of dose levels from laboratory animals to humans, 10 for the threshold for sensitive humans, and 10 for the estimation of a NOAEL from a LOAEL). The modifying factor was 1. Confidence in the study used to develop the RfD was medium; consequently, a medium confidence rating was assigned to both the overall database and the RfD estimate.

Benzidine is classified as a human carcinogen (Group A) based on increased incidence of bladder cancer and bladder cancer-related deaths in exposed workers. The inhalation CSF was based on an occupational exposure of humans to benzidine over a mean time period of 11.46 years (Zavon, 1973). An increased incidence of bladder tumors was observed. The inhalation CSF was derived using a model taking into account observed tumor incidence, daily lifetime exposure, and average human life span in the U.S.

The inhalation unit risk factor was derived using a one-hit time factor using the data from the Zavon (1973) study. The inhalation unit risk should not be used if the air concentration exceeds 0.2 µg/m^3 because above this concentration the slope factor may differ from that stated.

The oral CSF was derived using a one-hit time factor using the data from the Zavon (1973) study.

US EPA ARCHIVE DOCUMENT

Bis(2-Ethylhexyl) Phthalate

Benchmark Status: Bis(2-ethylhexyl) phthalate has an RfD and an oral CSF in the IRIS database but does not have an RfC, inhalation unit risk factor, or inhalation CSF. The RfD is 0.02 mg/kg-d, and the oral CSF is $0.014(mg/kg\text{-}d)^{-1}$.

The RfD was based on a LOAEL of 19 mg/kg-d from a chronic study (1 year) using guinea pigs (Carpenter et al., 1953). The LOAEL was based on daily administration of bis(2-ethylhexyl) phthalate in the feed. An uncertainty factor of 1,000 was applied (10 for interspecies variation, 10 for protection of sensitive human subpopulations, and 10 because the study used was longer than subchronic but less than lifetime and the effect was considered minimally adverse). The modifying factor was 1. Confidence in the study used to develop the RfD, the overall database, and the RfC estimate was medium.

Bis(2-ethylhexyl) phthalate is classified as a probable human carcinogen (Group B2) based on dose-related increases in liver tumor responses in rats and mice of both sexes. The oral CSF was based on a 103-week study using Fisher 344 rats and B6C3F1 mice. Bis(2-ethylhexyl) phthalate was given in the diet at dose levels of 0, 6,000, or 12,000 ppm for rats and 0, 3,000, or 6,000 ppm for mice (NTP, 1982). An increased incidence of hepatocellular carcinomas and adenomas was observed in female rats and mice of both sexes. The oral CSF was derived using the linearized multistage procedure.

US EPA ARCHIVE DOCUMENT

Bromodichloromethane

Benchmark Status: Bromodichloromethane has an RfD and oral CSF in the IRIS database but does not have an RfC, inhalation unit risk factor, or inhalation CSF. The RfD is 0.02 mg/kg-d, and the oral CSF is 0.062/mg/kg-d.

The RfD was based on a LOAEL of 17.9 mg/kg-d from a chronic study (102 weeks) using F344/N rats and B6C3F1 mice (NTP, 1986). The adjusted LOAEL of 17.9 mg/kg-d was based on a gavage dose of bromodichloromethane in corn oil 5 days per week. An uncertainty factor of 1,000 was applied to the LOAEL (100 for extrapolation from animal data and for protection of sensitive human subpopulations, and 10 for basing the RfD on a LOAEL and to account for database deficiencies). The modifying factor was 1. Confidence in the study used to develop the RfD was medium; consequently, a medium confidence rating was assigned to both the overall database and the RfD estimate.

Bromodichloromethane is classified as a probable human carcinogen (Group B2) based on inadequate human data and sufficient evidence of carcinogenicity in two animal species (mice and rats). The oral CSF was based on a 102-week study using F344/N rats and B6C3F1 mice. The test animals were exposed by gavage to bromodichloromethane in corn oil at dose levels of 0, 50, or 100 mg/kg-d (rats) or 0, 25, or 50 mg/kg-d (mice) 5 days per week (NTP, 1987). An increased incidence of kidney tubular cell adenoma and adenocarcinomas was observed in male mice. The oral CSF was derived using the linearized multistage procedure.

US EPA ARCHIVE DOCUMENT

p-Chloroaniline

Benchmark Status: p-Chloroaniline has an RfD in the IRIS database but does not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.004 mg/kg-d.

The RfD was based on a LOAEL of 12.5 mg/kg-d from a chronic study (78 weeks) using rats (NCI, 1979). The LOAEL was based on daily doses of p-chloroaniline in their diet. An uncertainty factor of 3,000 was applied (10 to extrapolate from a LOAEL to a NOEL, 10 to extrapolate from rats to humans, 10 to protect sensitive humans, and 3 for lack of supporting reproductive and other toxicity data). The modifying factor was 1. Confidence in the study used to develop the RfD was low; consequently, a low confidence rating was assigned to the overall database and the RfD estimate.

p-Chloroaniline has not undergone a complete evaluation and determination under U.S. EPA's IRIS program for evidence of human carcinogenic potential.

US EPA ARCHIVE DOCUMENT

Chlorobenzene

Benchmark Status: Chlorobenzene has an RfD in the IRIS database but does not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.02 mg/kg-d. Chlorobenzene has an RfC in HEAST of 0.02 mg/m^3.

The RfD was based on a NOAEL of 27.25 mg/kg-d from a subchronic study (13 weeks) using dogs (Monsanto Company, 1967a; Knapp et al., 1971). The adjusted NOAEL was 19 mg/kg-d based on administration of chlorobenzene in capsule form for 5 days per week. An uncertainty factor of 1,000 was applied to the NOAEL of 19 mg/kg-d (10 for the extrapolation of dose levels from laboratory animals to humans, 10 for the threshold for sensitive humans, and 10 for the effect of duration when extrapolating from subchronic to chronic exposure). The modifying factor was 1. Confidence in the study used to develop the RfD, the overall database, and the RfD estimate was medium.

The RfC was based on a LOAEL of 75 ppm from a subchronic study (120 days) using rats (Dilley, 1977). The LOAEL was based on intermittent inhalation of chlorobenzene vapor. An uncertainty factor of 10,000 was applied, but no further explanation was given. The chronic RfC value was derived from methodology that is not current with the interim inhalation methodology used by the RfD/RfC work group.

Chlorobenzene is not classifiable as to human carcinogenicity (Group D) based on no data concerning carcinogenicity in human; inadequate data for animals; and predominantly negative genetic toxicity data in bacterial, yeast, and mouse lymphoma cells.

US EPA ARCHIVE DOCUMENT

Chloroform

Benchmark Status: Chloroform has an RfD, inhalation unit risk factor, and oral CSF in the IRIS database but does not have an RfC or inhalation CSF. The RfD is 1E-2 mg/kg-d, the inhalation unit risk factor is 2.3E-5 $\mu g/m^3$, and the CSF is 6.1E-3$(mg/kg-d)^{-1}$. Chloroform has an inhalation CSF in HEAST of 8.1E-2$(mg/kg-d)^{-1}$.

The RfD was based on a LOAEL of 15 mg/kg-d from a chronic study (7.5 years) using dogs (Heywood et al., 1979). The adjusted LOAEL was 12.9 mg/kg-d based on an oral dose of chloroform in a toothpaste base given 6 days a week. An uncertainty factor of 1,000 was applied to the LOAEL of 12.9 mg/kg-d (10 for the interspecies conversion, 10 for the protection of sensitive human subpopulations, and 10 for the concern that the effect seen was a LOAEL and not a NOEL). The modifying factor was 1. Confidence in the study used to develop the RfD was medium, and a medium-to-low confidence rating was assigned to both the overall database and the RfD estimate.

Chloroform is classified as a probable human carcinogen (Group B2) based on increased incidence of several tumor types in rats and mice. The inhalation unit risk factor was based on a 78-week study using Osborne-Mendel rats and B6C3F1 mice. The test animals were exposed by gavage to chloroform in corn oil at dose levels of 90 or 125 mg/kg-d (male rats), 90 or 180 mg/kg-d (female rats), 150 or 300 mg/kg-d (male mice), or 250 or 500 mg/kg-d (female mice) 5 times per week (NCI, 1976). An increased incidence of kidney epithelial tumors was observed in male rats and significant increases in hepatocellular carcinomas in mice of both sexes. The inhalation unit risk factor was derived using the linearized multistage procedure. The unit risk should not be used if the air concentration exceeds 400 $\mu g/m^3$ since above this concentration the unit risk may not be appropriate.

The oral CSF was based on a 104-week study using Osborne-Mendel rats and B6C3F1 mice. The test animals were administered chloroform in drinking water at concentrations of 200, 400, 900, or 1,800 mg/L (Jorgenson et al., 1985). A significant increase in renal tumors was observed in rats administered the highest dose level. The oral CSF was derived using a linearized multistage procedure.

The inhalation CSF was based on the 78-week study using B6C3F1 mice (NCI, 1976). The inhalation CSF was based on route-to-route extrapolation.

US EPA ARCHIVE DOCUMENT

p-Cresol

Benchmark Status: p-Cresol does not have an RfD, RfC, inhalation unit risk factor, oral CSF, or inhalation CSF in the IRIS database. An RfD was established in the IRIS database, but it was withdrawn in 1991. p-Cresol has an RfD in HEAST of 0.005 mg/kg-d.

The RfD was based on a NOAEL of 5 mg/kg-d from a developmental study (days 6-18 of gestation) using rabbits (CMA, 1988). The NOAEL was based on daily oral gavage of p-cresol. An uncertainty factor of 1,000 was applied. No further information was provided.

p-Cresol is classified as a possible human carcinogen (Group C) based on an increased incidence of skin papillomas in mice in an initiation-promotion study.

US EPA ARCHIVE DOCUMENT

1,2-Dichlorobenzene

Benchmark Status: 1,2-Dichlorobenzene has an RfD in the IRIS database but does not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.09 mg/kg-d. 1,2-Dichlorobenzene has an RfC in the HEAST of 0.2 mg/m^3.

The RfD was based on a NOAEL of 120 mg/kg-d from a chronic study (2 years) using rats (NTP, 1985). The adjusted NOAEL of 85.7 mg/kg-d was based on gavage of 1,2-dichlorobenzene in corn oil 5 days per week. An uncertainty factor of 1,000 was applied (10 for the extrapolation of dose levels from laboratory animals to humans, 10 for the threshold for sensitive humans, and 10 because of the lack of studies assessing reproductive effects and adequate chronic toxicity in a second species). The modifying factor was 1. Confidence in the study used to develop the RfD was medium, but a low confidence rating was assigned to both the overall database and the RfD estimate.

The chronic RfC was based on a NOAEL of 49 ppm from a subchronic study (up to 7 months) using rats (Hollingsworth et al., 1958). The NOAEL was based on intermittent inhalation exposure to 1,2-dichlorobenzene. An uncertainty factor of 1,000 was applied, but no further information was given.

1,2-Dichlorobenzene is not classifiable as to human carcinogenicity (Group D) based on no human data and evidence of both negative and positive trends for carcinogenic responses in rats and mice.

US EPA ARCHIVE DOCUMENT

1,4-Dichlorobenzene

Benchmark Status: 1,4-Dichlorobenzene has an RfC in the IRIS database but does not have an RfD, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfC is 0.8 mg/m^3. 1,4-Dichlorobenzene has an oral CSF in HEAST of $0.024(mg/kg\text{-}d)^{-1}$.

The RfC was based on a NOAEL of 301 mg/m^3 from a subchronic multi-generational study using rats (Chlorobenzene Producers Association, 1986). The adjusted NOAEL of 75 mg/m^3 was based on exposure to 1,4-dichlorobenzene vapor for 6 hours per day and 7 days per week. An uncertainty factor of 100 was applied (10 to account for sensitive human subpopulations, 3 for interspecies differences, 3 because the NOAEL was based on a subchronic rather than a chronic study). The modifying factor was 1. Confidence in the study used to develop the RfC was medium, and a medium confidence rating was assigned to the overall database and the RfC estimate.

1,4-Dichlorobenzene has not undergone a complete evaluation and determination under U.S. EPA's IRIS program for evidence of human carcinogenic potential; however, HEAST classifies 1,4-dichlorobenzene as a possible human carcinogen (Group C). The oral CSF was based on a 103-week oral gavage study using mice (NTP, 1986). An increased incidence of liver tumors was observed in the mice. The oral CSF derived by HEAST is under review and is subject to change.

US EPA ARCHIVE DOCUMENT

3,3'-Dimethoxybenzidine

Benchmark Status: 3,3'-Dimethoxybenzidine does not have a profile in the IRIS database. Benzenethiol has an oral CSF in HEAST but does not have an RfD, RfC, inhalation unit risk factor, or inhalation CSF. The oral CSF is $0.014(mg/kg\text{-}d)^{-1}$.

The oral CSF was based on a lifetime exposure study using hamsters (Sellakumar et al., 1969). The hamsters were exposed orally to 3,3'-dimethoxybenzidine through their diet. An increased incidence of forestomach papillomas was observed.

3,3'-Dimethoxybenzidine is classified as a probable human carcinogen (Group B2), but no further information was available.

US EPA ARCHIVE DOCUMENT

N-N-Dimethylaniline

Benchmark Status: N-N-Dimethylaniline has an RfD in the IRIS database but does not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.002 mg/kg-d.

The RfD was based on a LOAEL of 31.25 mg/kg-d from a subchronic study (13 weeks) using mice (Abdo et al., 1984). The adjusted LOAEL of 22.32 mg/kg-d was based on administration of N-N-dimethylaniline in corn oil by gavage 5 days per week. An uncertainty factor of 10,000 was applied (10 for interspecies extrapolation, 10 to protect sensitive individuals, 10 because the effect level was a LOAEL, and 10 because the study was subchronic). The modifying factor was 1. Confidence in the study used to develop the RfD was low; consequently, a low confidence rating was also applied to the overall database and the RfD estimate.

N-N-Dimethylaniline has not undergone a complete evaluation and determination under U.S. EPA's IRIS program for evidence of human carcinogenic potential.

US EPA ARCHIVE DOCUMENT

Diphenylamine

Benchmark Status: Diphenylamine has an RfD in the IRIS database but does not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.025 mg/kg-d.

The RfD was based on a NOEL of 2.5 mg/kg-d from a chronic study (2 years) using dogs (Thomas et al., 1967). The NOEL was based on administration of diphenylamine in feed. An uncertainty factor of 100 was applied (10 each for inter- and intraspecies differences). The modifying factor was 1. Confidence in the study used to develop the RfD was medium, and a confidence rating of medium was also applied to the overall database and the RfD estimate.

Information regarding evidence of human carcinogenic potential for diphenylamine is not available at this time.

US EPA ARCHIVE DOCUMENT

1,2-Diphenylhydrazine

Benchmark Status: 1,2-Diphenylhydrazine has an oral CSF and an inhalation unit risk factor in the IRIS database but does not have an RfD, RfC, or inhalation CSF. The oral CSF is 0.8/mg/kg-d and the inhalation unit risk factor is 0.00022µg/m^3. 1,2-Diphenylhydrazine has an inhalation CSF HEAST of 0.8$(mg/kg\text{-}d)^{-1}$.

1,2-Diphenylhydrazine is classified as a probable human carcinogen (Group B2) based on positive results of studies in both rats and mice. The oral CSF was based on a 78-week dietary study using F344 rats and B6C3F1 mice (NCI, 1978). 1,2-Diphenylhydrazine was administered in feed at concentrations of 0.008 or 0.03 percent (male rats), 0.004 or 0.01 percent (female rats), 0.008 or 0.04 percent (male mice), or 0.004 and 0.04 percent (female mice). An increased incidence of hepatocellular carcinomas and neoplastic liver nodules was observed in male rats. Also, increased incidence of neoplastic liver nodules and mammary adenocarcinomas was observed in female rats, and increased incidence of hepatocelluar carcinomas was observed in female mice. The oral CSF was derived using the linearized multistage procedure.

The inhalation unit risk factor was calculated from the oral data listed above using the linearized multistage procedure. The unit risk factor should not be used if the air concentration exceeds 50 µg/m^3 since above this concentration the unit risk may not be appropriate.

The inhalation CSF was based on the same study as listed above for the oral CSF (NCI, 1978), but no further information is available.

US EPA ARCHIVE DOCUMENT

Ethylbenzene

Benchmark Status: Ethylbenzene has an RfD and RfC in the IRIS database but does not have an inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.1 mg/kg-d, and the RfC is 1 mg/m^3.

The RfD was based on a NOEL of 136 mg/kg-d from a subchronic study (182 days) using rats (Wolf et al., 1956). The adjusted NOEL was 97.1 mg/kg-d based on exposure to gavage of ethylbenzene in olive oil for 5 days per week. An uncertainty factor of 1,000 was applied to the adjusted NOEL (10 for interspecies variability, 10 for intraspecies variability, and 10 for extrapolation of a subchronic effect level to its chronic equivalent). The modifying factor was 1. Confidence in the study used to develop the RfD was low; consequently, a low confidence rating was assigned to the overall database and the RfD estimate.

The RfC was based on a NOAEL of 434 mg/m^3 from a developmental study (days 1-19 of gestation) using rats or (days 1-24 of gestation) using rabbits (Andrew et al., 1981; Hardin et al., 1981). The NOAEL was based on inhalation of ethylbenzene vapor for 6 to 7 hours per day and 7 days per week. An uncertainty factor of 300 was applied (10 for protection of unusually sensitive individuals, 3 for interspecies conversion, and 10 to adjust for the absence of multigenerational reproductive and chronic studies). The modifying factor was 1. Confidence in the study used to develop the RfC was low; consequently, a low confidence rating was assigned to the overall database and the RfC estimate.

Ethylbenzene is not classifiable as to human carcinogenicity (Group D) based on lack of animal bioassays and human studies.

US EPA ARCHIVE DOCUMENT

Formaldehyde

Benchmark Status: Formaldehyde has an RfD and inhalation unit risk factor in the IRIS database but does not have an RfC, oral CSF, or inhalation CSF. The RfD is 2E-1 mg/kg-d and the inhalation unit risk factor is 1.3E-5µg/m^3. Formaldehyde has an inhalation CSF in HEAST of 4.5E-2$(mg/kg-d)^{-1}$.

The RfD was based on an oral NOAEL of 15 mg/kg-d from a chronic study (2 years) using rats (Til et al., 1989). The NOAEL was based on daily doses in drinking water. An uncertainty factor of 100 was applied to account for the inter- and intraspecies differences. The modifying factor was 1. Confidence in the study used to develop the RfD was high, but medium confidence was assigned to the overall database and the RfD estimate.

Formaldehyde is classified as a probable human carcinogen (Group B1) based on limited evidence in humans and sufficient evidence in animals. The inhalation unit risk factor was based on a 2-year study using Fischer 344 rats and B6C3F1 mice. The test animals were exposed to formaldehyde at dose levels of 0, 2, 5.6, or 14.3 ppm for 6 hours per day and 5 days per week (Kerns et al., 1983). An increased incidence of squamous cell carcincomas was seen in both male and female rats receiving the high dose. The inhalation unit risk factor was derived using the linearized multistage procedure. The unit risk should not be used if the air concentration exceeds 800 µg/m^3 since above this concentration the unit risk may not be appropriate.

The CSF was based on the Kerns et al. (1983) study used by IRIS to calculate the inhalation unit risk factor. The CSF was based on the incidence of nasal cavity tumors in the rats. No other information was given.

US EPA ARCHIVE DOCUMENT

Methyl Isobutyl Ketone

Benchmark Status: Methyl isobutyl ketone (MIK) does not have an RfC, RfD, inhalation unit risk factor, oral CSF, or inhalation CSF in the IRIS database. MIK has an RfD of 0.08 and an RfC of 0.08 mg/m^3 in HEAST.

The RfD was based on a NOAEL of 250 mg/kg-d from a subchronic study (13 weeks) using rats (Microbiological Associates, 1986). The NOAEL was based on oral gavage of MIK. An uncertainty factor of 3,000 was applied, but no other information was given. A chronic RfD had been developed by IRIS, but the value was withdrawn in 1993.

The RfC was based on a NOEL of 50 ppm from a subchronic study (90 days) using rats (Union Carbide Corp., 1983). The NOEL was based on intermittent inhalation exposure. An uncertainty factor of 1,000 was applied. The chronic RfC value was derived from methodology that is not current with the interim inhalation methodology used by the RfC/RfC work group.

Information regarding evidence of human carcinogenic potential for MIK is not available at this time.

US EPA ARCHIVE DOCUMENT

Methylene Chloride

Benchmark Status: Methylene chloride has an RfD, inhalation unit risk factor, and oral CSF in the IRIS database but does not have an RfC or inhalation CSF. The RfD is 6E-2 mg/kg-d, the inhalation unit risk factor is 4.7E-7µg/m^3, and the oral CSF is 7.5E-3$(mg/kg-d)^{-1}$. Methylene chloride has an RfC in HEAST of 3E+0 mg/m^3.

The RfD was based on a NOAEL of 5.85 mg/kg-d (males) and 6.47 mg/kg-d (females) from a chronic study (2 years) using rats (National Coffee Association, 1982). The NOAEL was based on daily oral doses of methylene chloride in drinking water. An uncertainty factor of 100 was applied to account for both the expected intra- and interspecies variability to the toxicity of methylene chloride in lieu of specific data. The modifying factor was 1. Confidence in the study used to develop the RfD was high, but a medium confidence rating was assigned to both the overall database and the RfD estimate.

The RfC in HEAST was based on a NOAEL of 6.94.8 mg/m^3 from a chronic study (2 years) using rats, (Nitschke et al., 1988). The NOAEL was based on intermittent inhalation exposure to methylene chloride. An uncertainty factor of 100 was applied, but no further information was given.

Methylene chloride is classified as a probable human carcinogen (Group B2) based on inadequate human data and sufficient evidence of carcinogenicity in animals. The inhalation unit risk factor was based on a study using B6C3F1 mice (NTP, 1986). An increased incidence of combined adenomas and carcinomas was observed in female mice. The inhalation unit risk factor was derived using the linearized multistage procedure. The unit risk should not be used if the air concentration exceeds 2,000 µg/m^3 since above this concentration the unit risk may differ from that stated.

The oral CSF was based on two studies using B6C3F1 mice. The test animals were administered methylene chloride in either drinking water (National Coffee Association, 1983) or via inhalation of varying concentrations (NTP, 1986). A significant increase in hepatocellular adenomas or carcinomas was observed in female mice, and an increase in hepatocellular cancer and neoplastic nodules was observed in male mice. The CSF was derived using a linearized multistage procedure.

US EPA ARCHIVE DOCUMENT

Naphthalene

Benchmark Status: Naphthalene has an RfD and an RfC in the IRIS database but does not have an inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.02 mg/kg-d and the RfC is 0.003 mg/m^3.

The RfD was based on a oral NOAEL of 100 mg/kg-d from a subchronic study (13 weeks) using rats (Battelle's Columbus Laboratories, 1980). The adjusted NOAEL was 71 mg/kg-d based on a gavage of naphthalene in corn oil 5 days per week. An uncertainty factor of 3000 was applied to the adjusted NOAEL (10 to extrapolate from rats to humans, 10 for the protection of sensitive humans; 10 to extrapolate from subchronic to chronic exposure; and 3 for database deficiencies, including the lack of chronic oral exposure studies and two-generation reproductive toxicity studies). The modifying factor was 1. Confidence in the study used to develop the RfD was high; however, a low confidence rating was assigned to both the overall database and the RfD estimate.

The RfC was based on an adjusted inhalation LOAEL (HEC) of 9.3 mg/m^3 from a chronic study (103 weeks) using mice. The LOAEL was based on exposure for 6 hours per day and 5 days per week. An uncertainty factor of 3,000 was applied (10 to extrapolate from mice to humans; 10 for the protection of sensitive humans; 10 to extrapolate from LOAEL to a NOAEL; and 3 for database deficiencies, including the lack of a two-generation reproductive toxicity study and chronic inhalation data for other animal species). The modifying factor was 1. Confidence in the study used to develop the RfC was medium, but a low to medium confidence rating was assigned to the overall database, and a medium confidence rating was assigned to the RfC estimate.

Naphthalene is classified as a possible human carcinogen (Group C) based on the inadequate data of carcinogenicity in humans via the oral and inhalation routes and the limited evidence of carcinogenicity in animals via the inhalation route.

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N-Nitrosodiphenylamine

Benchmark Status: N-Nitrosodiphenylamine has an oral CSF in the IRIS database but does not have an RfD, RfC, inhalation unit risk, or inhalation CSF. The oral CSF is $0.0049(mg/kg\text{-}d)^{-1}$.

N-Nitrosodiphenylamine is classified as a probable human carcinogen (Group B2) based on increased incidence of bladder tumors in male and female rats, increased incidence of reticulum cell sarcomas in mice, and its structural relationship to carcinogenic nitrosamines. The oral CSF was based on a drinking water study using F344 rats (NCI, 1979). N-Nitrosodiphenylamine was administered in the diet at dose levels of 0, 1,000, or 4,000 ppm. An increased incidence of urinary bladder transitional cell carcinomas was observed in female rats. The CSF was derived using the linearized multistage procedure.

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Phenol

Benchmark Status: Phenol has an RfD in the IRIS database but does not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.6 mg/kg-d. EPA developed a provisional RfC of 0.006 mg/m^3 for the final listing rule for solvents (63 FR 64376).

The RfD was based on a NOAEL of 60 mg/kg-d from a developmental study using rats (NTP, 1983). The NOAEL was based on administration of phenol by gavage on gestational days 6 through 15. An uncertainty factor of 100 was applied (10 for interspecies extrapolation and 10 for sensitive human populations). The modifying factor was 1. Confidence in the study used to develop the RfD and the RfD estimate was low; however, a confidence rating of medium was applied to the overall database.

The RfC is based on a NOAEL of 5 ppm (19 mg/m^3) in rats, mice, and monkeys (Sandage, 1961). Sandage (1961) exposed Sprague-Dawley rats, mice, and rhesus monkeys continuously to 0 or 5 ppm phenol (19 mg/m^3) for 90 days. No significant effects in body weight, hematological or biochemical tests (i.e., liver or kidney function), organ pathology (lungs, liver, kidneys), or the stress test were seen in any of the species when compared to controls; no deaths occurred. An uncertainty factor of 3,000 (10 each for extrapolating from animals to humans, human variability, and use of subchronic data, and 3 to account for an incomplete database) was applied and a modifying factor of 1 was used.

Phenol is not classifiable as to human carcinogenicity (Group D) based on no data concerning carcinogenicity in humans and inadequate data for animals.

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o-Phenylenediamine

Benchmark Status: o-Phenylenediamine does not have a profile in the IRIS database. o-Phenylenediamine has an oral CSF in HEAST but does not have an RfD, RfC, inhalation unit risk factor, or inhalation CSF. The oral CSF is 0.047/mg/kg-d.

o-Phenylenediamine is classified as a probable human carcinogen (Group B2). The oral CSF was based on a 548-day study using rats (Weisburger et al., 1978). The test animals were exposed to o-phenylenediamine dihydrochloride in their diet. An increased incidence of liver tumors was observed in rats treated with o-phenylenediamine dihydrochloride.

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p-Phenylenediamine

Benchmark Status: p-Phenylenediamine does not have a profile in the IRIS database. p-Phenylenediamine has an RfD in HEAST but does not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.19 mg/kg-d.

The RfD was based on a NOAEL of 18.7 mg/kg-d from a chronic study (2 years) using rats (EPA, 1985). The NOAEL was based on administration of p-phenylenediamine in the diet. An uncertainty factor of 100 was applied to the NOAEL.

No information is available regarding the potential carcinogenicity of p-phenylenediamine to either humans or animals.

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Pyridine

Benchmark Status: Pyridine has an RfD in the IRIS database but does not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.001 mg/kg-d.

The RfD was based on a NOAEL of 1 mg/kg-d from a subchronic study (90 days) using rats (EPA, 1986). The NOAEL was based on daily gavage of varying concentrations of pyridine. An uncertainty factor of 1000 was applied (10 each for interspecies and intraspecies variability and 10 for extrapolation from a subchronic to a chronic effect level). The modifying factor was 1. Confidence is the study used to develop the RfC, the overall database, and the RfC estimate was medium.

Pyridine has not undergone a complete evaluation and determination under U.S. EPA's IRIS program for evidence of human carcinogenic potential.

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Toluene

Benchmark Status: Toluene has an RfD and RfC in the IRIS database but does not have an inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 0.2 mg/kg-d, and the RfC is 0.4 mg/m^3.

The RfD was based on a NOAEL of 312 mg/kg-d from a subchronic study (13 weeks) using rats (NTP, 1989). The adjusted NOAEL was 223 mg/kg-d based on gavage exposure to toluene in corn oil for 5 days per week. An uncertainty factor of 1,000 was applied (10 for inter- and intraspecies extrapolations, 10 for subchronic-to-chronic extrapolation, and 10 for limited reproductive and developmental toxicity data). The modifying factor was 1. Confidence in the study used to develop the RfD was high, but a medium confidence rating was assigned to the overall database and the RfD estimate.

The RfC was based on LOAELs from two studies. The first LOAEL was 332 mg/m^3 from a chronic occupational exposure study of females. The adjusted LOAEL of 119 mg/m^3 was based on inhalation of toluene vapor for an 8-hour time-weighted average per day and 5 days per week. The second LOAEL was 2,261 mg/m^3 from a chronic study (2 years) using rats. The adjusted LOAEL was 437 mg/m^3, and the LOAEL (HEC or human equivalent concentration) of 79 mg/m^3 was based on inhalation of toluene vapor for 6.5 hours per day and 5 days per week. This LOAEL was calculated for a gas:respiratory effect in the extrathoracic region. An uncertainty factor of 300 was applied (10 for the intraspecies variability, 10 for the use of a LOAEL, and 3 for database deficiencies). The modifying factor was 1. Confidence in the studies used to develop the RfC, the overall database, and the RfC estimate was medium.

Toluene is not classifiable as to human carcinogenicity (Group D) based on no human data and inadequate animal data.

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o-Toluidine

Benchmark Status: o-Toluidine does not have a profile in the IRIS database. o-Toluidine has an oral CSF in HEAST, but does not have an RfD, RfC, inhalation unit risk factor, or inhalation CSF. The oral CSF is $0.24(mg/kg\text{-}d)^{-1}$.

o-Toluidine is classified as a probable human carcinogen (Group B2). The oral CSF was based on a 93-week study using rats (Hecht et al., 1982). The test animals were exposed orally to o-toluidine in their diet. An increased incidence of skin fibromas was observed in treated rats.

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p-Toluidine

Benchmark Status: p-Toluidine does not have a profile in the IRIS database. p-Toluidine has an oral CSF in HEAST but does not have an RfD, RfC, inhalation unit risk factor, or inhalation CSF. The oral CSF is $0.19(mg/kg\text{-}d)^{-1}$.

p-Toluidine is classified as a possible human carcinogen (Group C). The oral CSF was based on a 18-month study using mice (Weisburger et al., 1978). The test animals were administered p-toluidine in their diet. An increase in liver tumors was observed in the mice. No further information was provided.

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1,2,4-Trichlorobenzene

Benchmark Status: 1,2,4-Trichlorobenzene has an RfD in the IRIS database of 0.01 mg/kg-d but does not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The 1,2,4-trichlorobenzene RfC in HEAST is 0.2 mg/m^3.

The RfD was based on a NOAEL of 14.8 mg/kg-d from a chronic multigeneration study using rats (Robinson et al., 1981). The NOAEL was based on exposure to 1,2,4-trichlorobenzene administered in the drinking water. An uncertainty factor of 1,000 was applied (10 for extrapolation from laboratory studies to humans, 10 for sensitive human subpopulations, and 10 for a lack of chronic studies). The modifying factor was 1. Confidence in the study used to develop the RfD, the overall database, and the RfD estimate was medium.

The RfC was based on a NOAEL of 104 ppm from a subchronic study (6 and 26 weeks) using rats, rabbits, dogs, and monkeys (Kociba et al., 1981; Coate et al., 1977; Cote et al., 1988). The NOAEL was based on inhalation of 1,2,4-trichlorobenzene. An uncertainty factor of 1,000 was applied.

1,2,4-Trichlorobenzene is not classifiable as to human carcinogenicity (Group D) based on inadequate studies for drawing conclusions as to carcinogenicity in humans.

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Xylenes (Total)

Benchmark Status: Total xylenes have an RfD in the IRIS database but do not have an RfC, inhalation unit risk factor, oral CSF, or inhalation CSF. The RfD is 2 mg/kg-d.

The RfD was based on a NOAEL of 250 mg/kg-d from a chronic study (103 weeks) using rats (NTP, 1986). The adjusted NOAEL was 179 mg/kg-d based on an oral gavage of a xylene mixture for 5 days per week. An uncertainty factor of 100 was applied to the adjusted NOAEL (10 for species-to-species extrapolation and 10 to protect sensitive individuals). The modifying factor was 1. Confidence in the study used to develop the RfD was medium; consequently, a medium confidence rating was assigned to both the overall database and the RfD estimate.

Total xylenes are not classifiable as to human carcinogenicity (Group D) based on the fact that orally administered technical xylene mixtures did not result in significant increases in incidences in tumor responses in rats or mice of both sexes.

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References

All references cited in this appendix are cited as secondary sources from the following sources (with one exception for phenol):

U.S. EPA (Environmental Protection Agency). 1997f. *Health Effects Assessment Summary Tables. FY 1997 Update*. Office of Emergency and Remedial Response and Office of Research and Development, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1998b. Integrated Risk Information System (IRIS) Database. Cincinnati, OH. August.

Exception:

Sandage, C. 1961. As cited in *Tolerance Criteria for Continuous Inhalation Exposure to Toxic Material. I. Effects on Animals of 90-Day Exposure to Phenol, CCl_4 and a Mixture of Indole, Skatole, H_2S and Methyl Mercaptan.* Wright-Patterson Air Force Base, OH. U.S. Air Force Systems Command, Aeronautical Systems Division, ASD technical report 61-519(I).

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Appendix F

Results

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Table F-1. Risk-Based Waste Concentrations for TAM Sludge Waste (mg/kg)*

Chemical	CAS Number	Group Number	90% Waste Concentration			95% Waste Concentration			Deterministic Waste Concentration (mg/kg)
			Concentration (mg/kg)	Receptor	Pathway	Concentration (mg/kg)	Receptor	Pathway	
1,2-Diphenylhydrazine	122667	4	31	Adult	Oral	16	Adult	Oral	11
Acetone	67641	1	3333	Child	Oral	2000	Child	Oral	5500
Aniline	62533	2	17	Adult/Child	Inhalation	11	Adult/Child	Inhalation	18
Azobenzene	103333	4	716	Adult	Oral	360	Adult	Oral	257
Benzaldehyde	100527	2	5000	Child	Oral	2500	Child	Oral	3800
Benzene	71432	2	365	Child	Inhalation	167	Adult/Child	Inhalation	97
Benzidine	92875	2	0.03	Adult	Oral	0.01	Adult	Oral	0.01
Bis(2-ethylhexyl)phthalate	117817	5	NA	NA	NA	NA	NA	NA	120000
Bromodichloromethane	75274	6	156	Adult/Child	Inhalation	70	Adult	Inhalation	46
Chloroaniline, p-	106478	2	250	Child	Oral	143	Child	Oral	160
Chlorobenzene	108907	3	36	Adult/Child	Inhalation	17	Adult/Child	Inhalation	24
Chloroform	67663	2	102	Child	Inhalation	47	Adult/Child	Inhalation	27
Cresol, p-	106445	2	333	Child	Oral	200	Child	Oral	230
Dichlorobenzene, 1,2-	95501	4	1109	Adult/Child	Inhalation	665	Adult/Child	Inhalation	708
Dichlorobenzene, 1,4-	106467	4	2607	Adult	Oral	1276	Adult	Oral	935
Dimethoxybenzidine, 3,3'-	119904	2	518	Adult	Oral	238	Adult	Oral	140
Diphenylamine	122394	4	26524	Adult	Oral	12352	Adult	Oral	18000
Ethylbenzene	100414	3	3429	Adult/Child	Inhalation	1664	Adult/Child	Inhalation	2200
Formaldehyde	50000	1	7000	Child	Oral	2500	Child	Oral	7143
Methyl isobutyl ketone	108101	2	42	Adult/Child	Inhalation	27	Adult/Child	Inhalation	40
Methylene chloride	75092	6	927	Adult	Oral	414	Adult	Oral	325
Naphthalene	91203	4	17	Adult/Child	Inhalation	9	Adult/Child	Inhalation	40
N-N-Dimethylaniline	121697	2	300	Child	Oral	143	Child	Oral	167
N-nitrosodiphenylamine	86306	4	7393	Adult	Oral	3686	Adult	Oral	2657
Phenol	108952	2	833	Adult/Child	Inhalation	416	Adult/Child	Inhalation	
Phenylenediamine, o-	95545	1	61	Adult	Oral	30	Adult	Oral	36
Phenylenediamine, p-	106503	1	5000	Child	Oral	2500	Child	Oral	6200

* The complete list of constituents is not included at present because of business confidentiality concerns

(continued)

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Table F-1. (continued)

Chemical	CAS Number	Group Number	90% Waste Concentration			95% Waste Concentration			Deterministic Waste Concentration (mg/kg)
			Concentration (mg/kg)	Receptor	Pathway	Concentration (mg/kg)	Receptor	Pathway	
Pyridine	110861	2	29	Adult/Child	Inhalation	17	Adult/Child	Inhalation	31
Toluene	108883	3	665	Adult/Child	Inhalation	333	Adult/Child	Inhalation	400
Toluidine, o-	95534	2	13	Adult	Oral	10	Adult	Oral	7
Toluidine, p-	106490	2	23	Adult	Oral	15	Adult	Oral	10
Trichlorobenzene, 1,2,4-	120821	4	3840	Adult/Child	Inhalation	1997	Adult/Child	Inhalation	2628
Xylenes (total)	1330207	3	1247	Adult/Child	Inhalation	713	Adult/Child	Inhalation	907

NA - Not Applicable because the concentration was > 1,000,000 mg/kg. Note - shading indicates risk-limiting exposure route

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Table F-2. Risk-Based Leachate Concentrations for TAM Sludge Waste (mg/L)*

Chemical	CAS Number	Group Number	90% Leachate Concentration			95% Leachate Concentration			Deterministic Leachate Concentration (mg/L)
			Concentration (mg/L)	Receptor	Pathway	Concentration (mg/L)	Receptor	Pathway	
1,2-Diphenylhydrazine	122667	4	0.0042	Adult	Oral	0.003	Adult	Oral	0.038
Acetone	67641	1	5.6	Child	Oral	3.7	Child	Oral	8.6
Aniline	62533	2	0.029	Adult/Child	Inhalation	0.02	Adult/Child	Inhalation	0.045
Azobenzene	103333	4	0.013	Adult	Oral	0.0086	Adult	Oral	0.012
Benzaldehyde	100527	2	5.6	Child	Oral	3.7	Child	Oral	8.3
Benzene	71432	2	0.11	Adult/Child	Inhalation	0.69	Adult/Child	Inhalation	0.083
Benzidine	92875	2	0.000023	Adult	Oral	0.000013	Adult	Oral	0.00002
Bis(2-ethylhexyl)phthalate	117817	5	0.17	Adult	Oral	0.048	Adult	Oral	0.0019
Bromodichloromethane	75274	6	0.060	Adult	Inhalation	0.037	Adult	Inhalation	0.048
Chloroaniline, p-	106478	2	0.25	Child	Oral	0.15	Child	Oral	0.32
Chlorobenzene	108907	3	0.0036	Adult/Child	Inhalation	0.0025	Adult/Child	Inhalation	0.0065
Chloroform	67663	2	0.042	Adult/Child	Inhalation	0.026	Adult/Child	Inhalation	0.031
Cresol, p-	106445	2	0.33	Child	Oral	0.2	Child	Oral	0.41
Dichlorobenzene, 1,2-	95501	4	0.043	Adult/Child	Inhalation	0.03	Adult/Child	Inhalation	0.075
Dichlorobenzene, 1,4-	106467	4	0.11	Adult	Oral	0.066	Adult	Oral	0.098
Dimethoxybenzidine, 3,3'-	119904	2	0.38	Adult	Oral	0.22	Adult	Oral	0.29
Diphenylamine	122394	4	1.1	Adult	Oral	0.78	Adult	Oral	1.9
Ethylbenzene	100414	3	0.17	Adult/Child	Inhalation	0.12	Adult/Child	Inhalation	0.32
Formaldehyde	50000	1	11	Child	Oral	10	Child	Oral	18
Methyl isobutyl ketone	108101	2	0.042	Adult/Child	Inhalation	0.029	Adult/Child	Inhalation	0.068
Methylene chloride	75092	6	0.067	Adult	Oral	0.41	Adult	Oral	0.53
Naphthalene	91203	4	0.0028	Adult/Child	Inhalation	0.0021	Adult/Child	Inhalation	0.0053
N-N-Dimethylaniline	121697	2	0.11	Child	Oral	0.10	Child	Oral	0.16
N-nitrosodiphenylamine	86306	4	0.62	Adult	Oral	0.37	Adult	Oral	0.55
Phenol	108952	2	0.8	Adult/Child	Inhalation	0.57	Adult/Child	Inhalation	
Phenylenediamine, o-	95545	1	0.11	Adult	Oral	0.070	Adult	Oral	0.09
Phenylenediamine, p-	106503	1	10	Child	Oral	7.0	Child	Oral	16
Pyridine	110861	2	0.042	Adult/Child	Inhalation	0.030	Adult/Child	Inhalation	0.066
Toluene	108883	3	0.071	Adult/Child	Inhalation	0.053	Adult/Child	Inhalation	0.12
Toluidine, o-	95534	2	0.022	Adult	Oral	0.013	Adult	Oral	0.017
Toluidine, p-	106490	2	0.029	Adult	Oral	0.016	Adult	Oral	0.021

* The complete list of constituents is not included at present because of business confidentiality concerns

(continued)

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Table F-2. (continued)

Chemical	CAS Number	Group Number	90% Leachate Concentration			95% Leachate Concentration			Deterministic Leachate Concentration (mg/L)
			Concentration (mg/L)	Receptor	Pathway	Concentration (mg/L)	Receptor	Pathway	
Trichlorobenzene, 1,2,4-	120821	4	0.046	Adult/Child	Inhalation	0.034	Adult/Child	Inhalation	0.081
Xylene, m-	108383	3	100	Child	Oral	63	Child	Oral	
Xylene, o-	95476	3	100	Child	Oral	63	Child	Oral	
Xylenes (total)	1330207	3	0.071	Adult/Child	Inhalation	0.051	Adult/Child	Inhalation	0.13

NA - Not Applicable because the concentration was > 1,000,000 mg/kg. Note - shading indicates risk-limiting exposure route

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Table F-3. Risk Limiting Waste Concentrations for TAM Sludge Stream*
90th Percentile
Adult

Chemical	CAS Number	Group Number	New Waste Concentration (mg/kg)	Drinking Water Ingestion HQ or Risk for the ADULT	Inhalation Hazard Quotient or Risk for Shower - ADULT	Inhalation Hazard Quotient or Risk for Bathroom - ADULT	Inhalation Hazard Quotient or Risk for Whole House - ADULT	Summed Inhalation Hazard Quotient or Risk - ADULT	Dermal Hazard Quotient or Risk - ADULT	Summed Drinking Water Ingestion & Dermal HQ or Risk for the ADULT
1,2-Diphenylhydrazine	122667	4	31	3E-06	5E-08	1E-08	2E-09	7E-08	7E-06	**1E-05**
Acetone	67641	1	3333	0.4	0.09	0.02	0.0001	0.1101	0.0020	0.40
Aniline	62533	2	17	3E-07	0.9	0.1	0.0009	**1**	1E-08	3E-07
Azobenzene	103333	4	716	6E-06	3E-08	9E-09	9E-10	4E-08	4E-06	**1E-05**
Benzaldehyde	100527	2	5000	0.5	NA	NA	NA	NA	0.032	0.52
Benzene	71432	2	365	5E-06	5E-06	4E-06	4E-07	9E-06	1E-06	7E-06
Benzidine	92875	2	0.03	9E-06	2E-12	4E-13	4E-14	2E-12	8E-07	**1E-05**
Bis(2-ethylhexyl)phthalate	117817	5	NA	NA	NA	NA	NA	NA	NA	NA
Bromodichloromethane	75274	6	156	8E-06	7E-06	3E-06	4E-07	**1E-05**	9E-07	8E-06
Chloroaniline, p-	106478	2	250	0.4	NA	NA	NA	NA	0.062	0.47
Chlorobenzene	108907	3	36	0.002	0.8	0.3	0.002	**1**	0.00098	0.0028
Chloroform	67663	2	102	4E-07	5E-06	4E-06	4E-07	9E-06	5E-08	5E-07
Cresol, p-	106445	2	333	0.4	NA	NA	NA	NA	0.081	0.47
Dichlorobenzene, 1,2-	95501	4	1109	0.004	0.8	0.3	0.002	**1**	0.0049	0.0095
Dichlorobenzene, 1,4-	106467	4	2607	5E-06	0.5	0.2	0.001	0.70	5E-06	**1E-05**
Dimethoxybenzidine, 3,3'-	119904	2	518	9E-06	NA	NA	NA	NA	6E-07	**1E-05**
Diphenylamine	122394	4	26524	0.4	NA	NA	NA	NA	0.59	**1**
Ethylbenzene	100414	3	3429	0.02	0.8	0.3	0.002	**1**	0.017	0.036
Formaldehyde	50000	1	7000	0.6	2E-06	5E-07	6E-08	2E-06	0.0050	0.60
Methyl isobutyl ketone	108101	2	42	0.004	0.8	0.2	0.0009	**1**	0.00017	0.0042
Methylene chloride	75092	6	927	9E-06	2E-06	1E-06	1E-07	3E-06	5E-07	**1E-05**
Naphthalene	91203	4	17	0.0004	0.8	0.2	0.001	**1**	0.00041	0.00081
N-N-Dimethylaniline	121697	2	300	0.5	NA	NA	NA	NA	0.10	0.58
N-Nitrosodiphenylamine	86306	4	7393	5E-06	2E-07	5E-08	5E-09	2E-07	4E-06	**1E-05**

*** The complete list of constituents is not included at present because of business confidentiality concerns**

(continued)

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Table F-3. (continued)

Chemical	CAS Number	Group Number	New Waste Concentration (mg/kg)	Drinking Water Ingestion HQ or Risk for the ADULT	Inhalation Hazard Quotient or Risk for Shower - ADULT	Inhalation Hazard Quotient or Risk for Bathroom - ADULT	Inhalation Hazard Quotient or Risk for Whole House - ADULT	Summed Inhalation Hazard Quotient or Risk - ADULT	Dermal Hazard Quotient or Risk - ADULT	Summed Drinking Water Ingestion & Dermal HQ or Risk for the ADULT
Phenol	108952	2	833	0.01	0.91	0.2	0.001	**1**	0.001	0.01
Phenylenediamine, o-	95545	1	61	1E-05	NA	NA	NA	NA	1E-07	**1E-05**
Phenylenediamine, p-	106503	1	5000	0.5	NA	NA	NA	NA	0.0024	0.50
Pyridine	110861	2	29	0.3	0.9	0.2	0.00091	**1**	0.0069	0.31
Toluene	108883	3	665	0.004	0.8	0.3	0.002	**1**	0.0019	0.0056
Toluidine, o-	95534	2	13	9E-06	1E-07	3E-08	3E-09	1E-07	7E-07	**1E-05**
Toluidine, p-	106490	2	23	9E-06	NA	NA	NA	NA	5E-07	**1E-05**
Trichlorobenzene, 1,2,4-	120821	4	3840	0.04	0.8	0.2	0.001	**1**	0.089	0.13
Xylenes (total)	1330207	3	1247	0.0003	0.7	0.3	0.002	**1**	0.00031	0.00066

NA - Not Applicable because the waste concentration is > 1,000,000 mg/kg.
*Shading indicates risk-limiting exposure route.

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Table F-4. Risk Limiting Waste Concentrations for TAM Sludge Stream*
90th Percentile
Child

Chemical	CAS Number	Group Number	New Waste Concentration (mg/kg)	Drinking Water Ingestion HQ or Risk for the CHILD	Inhalation Hazard Quotient or Risk for Shower - CHILD	Inhalation Hazard Quotient or Risk for Bathroom - CHILD	Inhalation Hazard Quotient or Risk for Whole House - CHILD	Summed Inhalation Hazard Quotient or Risk - CHILD
1,2-Diphenylhydrazine	122667	4	31	5E-06	4E-08	1E-08	1E-09	5E-08
Acetone	67641	1	3333	**1**	0.09	0.02	0.0001	0.11
Aniline	62533	2	17	2E-07	0.9	0.1	0.0009	**1**
Azobenzene	103333	4	716	2E-06	6E-08	2E-08	2E-09	7E-08
Benzaldehyde	100527	2	5000	**1**	NA	NA	NA	NA
Benzene	71432	2	365	5E-06	6E-06	4E-06	5E-07	**1E-05**
Benzidine	92875	2	0.03	9E-06	2E-12	4E-13	5E-14	2E-12
Bis(2-ethylhexyl)phthalate	117817	5	NA	NA	NA	NA	NA	NA
Bromodichloromethane	75274	6	156	6E-06	6E-06	3E-06	3E-07	**1E-05**
Chloroaniline, p-	106478	2	250	**1**	NA	NA	NA	NA
Chlorobenzene	108907	3	36	0.004	0.8	0.3	0.002	**1**
Chloroform	67663	2	102	4E-07	6E-06	4E-06	5E-07	**1E-05**
Cresol, p-	106445	2	333	**1**	NA	NA	NA	NA
Dichlorobenzene, 1,2-	95501	4	1109	0.01	0.8	0.3	0.002	**1**
Dichlorobenzene, 1,4-	106467	4	2607	4E-06	0.5	0.2	0.001	0.70
Dimethoxybenzidine, 3,3'-	119904	2	518	9E-06	NA	NA	NA	NA
Diphenylamine	122394	4	26524	0.8	NA	NA	NA	NA
Ethylbenzene	100414	3	3429	0.04	0.8	0.3	0.002	**1**
Formaldehyde	50000	1	7000	**1**	2E-06	6E-07	7E-08	2E-06
Methyl isobutyl ketone	108101	2	42	0.01	0.8	0.2	0.0009	**1**
Methylene chloride	75092	6	927	9E-06	2E-06	1E-06	1E-07	3E-06
Naphthalene	91203	4	17	0.00081	0.8	0.2	0.001	**1**
N-N-Dimethylaniline	121697	2	300	**1**	NA	NA	NA	NA
N-Nitrosodiphenylamine	86306	4	7393	5E-06	2E-07	5E-08	6E-09	3E-07

(continued)

Note - Shading indicates risk-limiting exposure route. *The complete list of consituents is not included at present because of business confidentiality concerns

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Table F-4. (continued)

Chemical	CAS Number	Group Number	New Waste Concentration (mg/kg)	Drinking Water Ingestion HQ or Risk for the CHILD	Inhalation Hazard Quotient or Risk for Shower - CHILD	Inhalation Hazard Quotient or Risk for Bathroom - CHILD	Inhalation Hazard Quotient or Risk for Whole House - CHILD	Summed Inhalation Hazard Quotient or Risk - CHILD
Phenol	108952	2	833	0.03	0.91	0.2	0.001	**1**
Phenylenediamine, o-	95545	1	61	9E-06	NA	NA	NA	NA
Phenylenediamine, p-	106503	1	5000	**1**	NA	NA	NA	NA
Pyridine	110861	2	29	0.8	0.9	0.2	0.00091	**1**
Toluene	108883	3	665	0.008	0.8	0.3	0.002	**1**
Toluidine, o-	95534	2	13	8E-06	1E-07	3E-08	4E-09	1E-07
Toluidine, p-	106490	2	23	9E-06	NA	NA	NA	NA
Trichlorobenzene, 1,2,4-	120821	4	3840	0.09	0.8	0.2	0.001	**1**
Xylenes (total)	1330207	3	1247	0.0008	0.7	0.3	0.002	**1**

NA - Not Applicable because the waste concentration is > 1,000,000 mg/kg.
*Shading indicates risk-limiting exposure route.

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Table F-5. Risk Limiting Waste Concentrations for TAM Sludge Stream*
95th Percentile
Adult

Chemical	CAS Number	Group Number	New Waste Concentration (mg/kg)	Drinking Water Ingestion HQ or Risk for the ADULT	Inhalation Hazard Quotient or Risk for Shower - ADULT	Inhalation Hazard Quotient or Risk for Bathroom - ADULT	Inhalation Hazard Quotient or Risk for Whole House - ADULT	Summed Inhalation Hazard Quotient or Risk - ADULT	Dermal Hazard Quotient or Risk - ADULT	Summed Drinking Water Ingestion & Dermal HQ or Risk for the ADULT
1,2-Diphenylhydrazine	122667	4	16	6E-06	3E-08	8E-09	9E-10	4E-08	4E-06	**1E-05**
Acetone	67641	1	2000	0.5	0.1	0.02	0.0001	0.12	0.0024	0.50
Aniline	62533	2	11	3E-07	0.805	0.1	0.0009	**1**	2E-08	3E-07
Azobenzene	103333	4	360	3E-06	5E-08	1E-08	2E-09	7E-08	7E-06	**1E-05**
Benzaldehyde	100527	2	2500	0.4	NA	NA	NA	NA	0.024	0.42
Benzene	71432	2	167	5E-06	6E-06	4E-06	5E-07	**1E-05**	1E-06	7E-06
Benzidine	92875	2	0.01	9E-06	2E-12	4E-13	4E-14	2E-12	8E-07	**1E-05**
Bis(2-ethylhexyl)phthalate	117817	5	NA	NA	NA	NA	NA	NA	NA	NA
Bromodichloromethane	75274	6	70	7E-06	7E-06	3E-06	4E-07	**1E-05**	8E-07	8E-06
Chloroaniline, p-	106478	2	143	0.4	NA	NA	NA	NA	0.072	0.51
Chlorobenzene	108907	3	17	0.002	0.7	0.3	0.002	**1**	0.00084	0.0024
Chloroform	67663	2	47	4E-07	6E-06	4E-06	4E-07	**1E-05**	5E-08	5E-07
Cresol, p-	106445	2	200	0.4	NA	NA	NA	NA	0.096	0.54
Dichlorobenzene, 1,2-	95501	4	665	0.005	1	0.3	0.002	**1**	0.0060	0.012
Dichlorobenzene, 1,4-	106467	4	1276	5E-06	0.5	0.2	0.001	0.70	5E-06	**1E-05**
Dimethoxybenzidine, 3,3'-	119904	2	238	9E-06	NA	NA	NA	NA	7E-07	**1E-05**
Diphenylamine	122394	4	12352	0.4	NA	NA	NA	NA	0.59	**1**
Ethylbenzene	100414	3	1664	0.02	0.7	0.3	0.002	**1**	0.015	0.031
Formaldehyde	50000	1	2500	0.4	1E-06	4E-07	4E-08	2E-06	0.0036	0.40
Methyl isobutyl ketone	108101	2	27	0.005	0.9	0.2	0.001	**1**	0.00020	0.0053
Methylene chloride	75092	6	414	1E-05	2E-06	1E-06	1E-07	3E-06	4E-07	**1E-05**
Naphthalene	91203	4	9	0.0004	0.8	0.2	0.001	**1**	0.00045	0.00086
N-N-Dimethylaniline	121697	2	143	0.4	NA	NA	NA	NA	0.095	0.52
N-Nitrosodiphenylamine	86306	4	3686	5E-06	2E-07	5E-08	5E-09	2E-07	4E-06	**1E-05**

(continued)

Note - Shading indicates risk-limiting exposure route. *The complete list of constituents is not included at present because of business confidentiality concerns

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Table F-5. (continued)

Chemical	CAS Number	Group Number	New Waste Concentration (mg/kg)	Drinking Water Ingestion HQ or Risk for the ADULT	Inhalation Hazard Quotient or Risk for Shower - ADULT	Inhalation Hazard Quotient or Risk for Bathroom - ADULT	Inhalation Hazard Quotient or Risk for Whole House - ADULT	Summed Inhalation Hazard Quotient or Risk - ADULT	Dermal Hazard Quotient or Risk - ADULT	Summed Drinking Water Ingestion & Dermal HQ or Risk for the ADULT
Phenol	108952	2	416	0.01	0.9	0.2	0.0009	**1**	0.001	0.01
Phenylenediamine, o-	95545	1	30	1E-05	NA	NA	NA	NA	1E-07	**1E-05**
Phenylenediamine, p-	106503	1	2500	0.5	NA	NA	NA	NA	0.0024	0.50
Pyridine	110861	2	17	0.4	0.80	0.105	0.0009	**1**	0.0076	0.41
Toluene	108883	3	333	0.003	0.8	0.3	0.002	**1**	0.0018	0.0050
Toluidine, o-	95534	2	10	9E-06	1E-07	3E-08	3E-09	1E-07	8E-07	**1E-05**
Toluidine, p-	106490	2	15	1E-05	NA	NA	NA	NA	6E-07	**1E-05**
Trichlorobenzene, 1,2,4-	120821	4	1997	0.04	0.9	0.2	0.001	**1**	0.097	0.14
Xylenes (total)	1330207	3	713	0.00030	0.8	0.3	0.002	**1**	0.00035	0.00065

NA - Not Applicable because the waste concentration is > 1,000,000 mg/kg.
*Shading indicates risk-limiting exposure route.

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Table F-6. Risk Limiting Waste Concentrations for TAM Sludge Stream*
95th Percentile
Child

Chemical	CAS Number	Group Number	New Waste Concentration (mg/kg)	Drinking Water Ingestion HQ or Risk for the CHILD	Inhalation Hazard Quotient or Risk for Shower - CHILD	Inhalation Hazard Quotient or Risk for Bathroom - CHILD	Inhalation Hazard Quotient or Risk for Whole House - CHILD	Summed Inhalation Hazard Quotient or Risk - CHILD
1,2-Diphenylhydrazine	122667	4	16	6E-06	4E-08	1E-08	1E-09	5E-08
Acetone	67641	1	2000	**1**	0.1	0.02	0.0001	0.12
Aniline	62533	2	11	3E-07	0.80	0.1	0.0009	**1**
Azobenzene	103333	4	360	3E-06	6E-08	2E-08	2E-09	9E-08
Benzaldehyde	100527	2	2500	**1**	NA	NA	NA	NA
Benzene	71432	2	167	4E-06	5E-06	4E-06	4E-07	**1E-05**
Benzidine	92875	2	0.01	9E-06	2E-12	4E-13	5E-14	2E-12
Bis(2-ethylhexyl)phthalate	117817	5	NA	NA	NA	NA	NA	NA
Bromodichloromethane	75274	6	70	6E-06	6E-06	3E-06	3E-07	9E-06
Chloroaniline, p-	106478	2	143	**1**	NA	NA	NA	NA
Chlorobenzene	108907	3	17	0.004	0.7	0.3	0.002	**1**
Chloroform	67663	2	47	4E-07	6E-06	4E-06	5E-07	**1E-05**
Cresol, p-	106445	2	200	**1**	NA	NA	NA	NA
Dichlorobenzene, 1,2-	95501	4	665	0.01	1	0.3	0.002	**1**
Dichlorobenzene, 1,4-	106467	4	1276	5E-06	0.5	0.2	0.001	0.701
Dimethoxybenzidine, 3,3'-	119904	2	238	8E-06	NA	NA	NA	NA
Diphenylamine	122394	4	12352	0.8	NA	NA	NA	NA
Ethylbenzene	100414	3	1664	0.04	0.7	0.3	0.002	**1**
Formaldehyde	50000	1	2500	**1**	1E-06	4E-07	5E-08	2E-06
Methyl isobutyl ketone	108101	2	27	0.01	0.9	0.2	0.001	**1**

(continued)

Note - Shading indicates risk-limiting exposure route. * The complete list of constituents is not included at present because of business confidentiality concerns

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Table F-6. (continued)

Chemical	CAS Number	Group Number	New Waste Concentration (mg/kg)	Drinking Water Ingestion HQ or Risk for the CHILD	Inhalation Hazard Quotient or Risk for Shower - CHILD	Inhalation Hazard Quotient or Risk for Bathroom - CHILD	Inhalation Hazard Quotient or Risk for Whole House - CHILD	Summed Inhalation Hazard Quotient or Risk - CHILD
Methylene chloride	75092	6	414	8E-06	2E-06	1E-06	1E-07	3E-06
Naphthalene	91203	4	9	0.0009	0.8	0.2	0.001	**1**
N-N-Dimethylaniline	121697	2	143	**1**	NA	NA	NA	NA
N-Nitrosodiphenylamine	86306	4	3686	6E-06	2E-07	6E-08	6E-09	3E-07
Phenol	108952	2	416	0.03	0.9	0.2	0.0009	**1**
Phenylenediamine, o-	95545	1	30	9E-06	NA	NA	NA	NA
Phenylenediamine, p-	106503	1	2500	**1**	NA	NA	NA	NA
Pyridine	110861	2	17	0.9	0.80	0.10	0.0009	**1**
Toluene	108883	3	333	0.008	0.8	0.3	0.002	**1**
Toluidine, o-	95534	2	10	9E-06	1E-07	3E-08	4E-09	1E-07
Toluidine, p-	106490	2	15	**1E-05**	NA	NA	NA	NA
Trichlorobenzene, 1,2,4-	120821	4	1997	0.1	0.9	0.2	0.001	**1**
Xylenes (total)	1330207	3	713	0.00080	0.8	0.3	0.002	**1**

NA - Not Applicable because the waste concentration is > 1,000,000 mg/kg.
*Shading indicates risk-limiting exposure route.

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Table F-7. Risk Limiting Waste Concentrations for TAM Sludge Stream*
Deterministic
Adult

Chemical	CAS Number	Group Number	New Waste Concentration (mg/kg)	Drinking Water Ingestion HQ or Risk for the ADULT	Inhalation Hazard Quotient or Risk for Shower - ADULT	Inhalation Hazard Quotient or Risk for Bathroom - ADULT	Inhalation Hazard Quotient or Risk for Whole House - ADULT	Summed Inhalation Hazard Quotient or Risk - ADULT	Dermal Hazard Quotient or Risk - ADULT	Summed Drinking Water Ingestion & Dermal HQ or Risk for the ADULT
1,2-Diphenylhydrazine	122667	4	11	6E-06	4E-08	1E-08	1E-09	5E-08	4E-06	1E-05
Acetone	67641	1	5500	0.4	0.1	0.02	0.0001	0.12	0.0023	0.40
Aniline	62533	2	18	2E-07	0.9	0.1	0.0009	1	8E-09	2E-07
Azobenzene	103333	4	257	3E-06	6E-08	2E-08	2E-09	8E-08	7E-06	1E-05
Benzaldehyde	100527	2	3800	0.4	NA	NA	NA	NA	0.027	0.43
Benzene	71432	2	97	4E-06	5E-06	3E-06	4E-07	8E-06	1E-06	5E-06
Benzidine	92875	2	0.01	8E-06	1E-12	3E-13	4E-14	2E-12	6E-07	8E-06
Bis(2-ethylhexyl)phthalate	117817	5	120000	6E-08	0.002	0.0003	0.000002	0.0023	1E-05	1E-05
Bromodichloromethane	75274	6	46	6E-06	6E-06	2E-06	3E-07	8E-06	6E-07	6E-06
Chloroaniline, p-	106478	2	160	0.4	NA	NA	NA	NA	0.066	0.47
Chlorobenzene	108907	3	24	0.002	0.7	0.3	0.002	1	0.0009	0.0029
Chloroform	67663	2	27	3E-07	5E-06	3E-06	4E-07	8E-06	4E-08	4E-07
Cresol, p-	106445	2	230	0.4	NA	NA	NA	NA	0.092	0.49
Dichlorobenzene, 1,2-	95501	4	708	0.004	0.8	0.2	0.002	1	0.0046	0.0086
Dichlorobenzene, 1,4-	106467	4	935.000	3E-06	0.24	0.10	0.00069	0.35000	7E-06	1E-05
Dimethoxybenzidine, 3,3'-	119904	2	140	8E-06	NA	NA	NA	NA	5E-07	8E-06
Diphenylamine	122394	4	18000	0.4	NA	NA	NA	NA	0.61	1
Ethylbenzene	100414	3	2200	0.02	0.7	0.3	0.002	1	0.015	0.035
Formaldehyde	50000	1	7143	0.5	8E-07	3E-07	3E-08	1E-06	0.0040	0.50

(continued)

Note - Shading indicates risk-limiting exposure route. * The complete list of constituents is not included at present because of business confidentiality concerns

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Table F-7. (continued)

Chemical	CAS Number	Group Number	New Waste Concentration (mg/kg)	Drinking Water Ingestion HQ or Risk for the ADULT	Inhalation Hazard Quotient or Risk for Shower - ADULT	Inhalation Hazard Quotient or Risk for Bathroom - ADULT	Inhalation Hazard Quotient or Risk for Whole House - ADULT	Summed Inhalation Hazard Quotient or Risk - ADULT	Dermal Hazard Quotient or Risk - ADULT	Summed Drinking Water Ingestion & Dermal HQ or Risk for the ADULT
Methyl isobutyl ketone	108101	2	40	0.005	0.8	0.2	0.001	1	0.00018	0.0052
Methylene chloride	75092	6	325	7E-06	2E-06	1E-06	1E-07	3E-06	4E-07	8E-06
Naphthalene	91203	4	40	0.0007	0.8	0.2	0.001	1	0.00074	0.0014
N-N-Dimethylaniline	121697	2	167	0.4	NA	NA	NA	NA	0.093	0.49
N-Nitrosodiphenylamine	86306	4	2657	6E-06	2E-07	5E-08	6E-09	3E-07	4E-06	1E-05
Phenol	108952	2								
Phenylenediamine, o-	95545	1	36	7E-06	NA	NA	NA	NA	8E-08	8E-06
Phenylenediamine, p-	106503	1	6200	0.4	NA	NA	NA	NA	0.0023	0.40
Pyridine	110861	2	31	0.4	0.9	0.1	0.0009	1	0.0070	0.41
Toluene	108883	3	400	0.003	0.7	0.3	0.002	1	0.0016	0.0046
Toluidine, o-	95534	2	7	7E-06	9E-08	2E-08	3E-09	1E-07	6E-07	8E-06
Toluidine, p-	106490	2	10	7E-06	NA	NA	NA	NA	4E-07	8E-06
Trichlorobenzene, 1,2,4-	120821	4	2628	0.04	0.8	0.2	0.001	1	0.091	0.13
Xylenes (total)	1330207	3	907	0.0003	0.7	0.3	0.002	1	0.00032	0.0062

NA - Not Applicable because the waste concentration is > 1,000,000 mg/kg.
*Shading indicates risk-limiting exposure route.

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Table F-8. Risk Limiting Leachate Concentrations for TAM Sludge Stream*
90th Percentile
Adult

Chemical	CAS Number	Group Number	Leachate Concentration (mg/L)	Drinking Water Ingestion HQ or Risk for the ADULT	Inhalation Hazard Quotient or Risk for Shower - ADULT	Inhalation Hazard Quotient or Risk for Bathroom - ADULT	Inhalation Hazard Quotient or Risk for Whole House - ADULT	Summed Inhalation Hazard Quotient or Risk - ADULT	Dermal Hazard Quotient or Risk - ADULT	Summed Drinking Water Ingestion & Dermal HQ or Risk for the ADULT
1,2-Diphenylhydrazine	122667	4	0.0042	6E-06	3E-08	8E-09	9E-10	4E-08	4E-06	**1E-05**
Acetone	67641	1	5.6	0.5	0.1	0.02	0.0001	0.12	0.0025	0.50
Aniline	62533	2	0.029	0.0000003	0.9	0.11	0.0009	**1**	1E-08	3E-07
Azobenzene	103333	4	0.013	3E-06	5E-08	1E-08	2E-09	6E-08	7E-06	**1E-05**
Benzaldehyde	100527	2	5.6	0.4	NA	NA	NA	NA	0.030	0.45
Benzene	71432	2	0.11	6E-06	6E-06	4E-06	5E-07	**1E-05**	1E-06	7E-06
Benzidine	92875	2	0.000023	9E-06	1E-12	4E-13	4E-14	2E-12	7E-07	**1E-05**
Bis(2-ethylhexyl)phthalate	117817	5	0.17	5E-08	0.004	0.0006	0.000004	0.0046	1E-05	**1E-05**
Bromodichloromethane	75274	6	0.060	7E-06	7E-06	3E-06	4E-07	**1E-05**	8E-07	8E-06
Chloroaniline, p-	106478	2	0.25	0.5	NA	NA	NA	NA	0.084	0.57
Chlorobenzene	108907	3	0.0036	0.002	0.7	0.3	0.002	**1**	0.00094	0.0026
Chloroform	67663	2	0.042	4E-07	6E-06	4E-06	5E-07	**1E-05**	5E-08	5E-07
Cresol, p-	106445	2	0.33	0.5	NA	NA	NA	NA	0.12	0.65
Dichlorobenzene, 1,2-	95501	4	0.043	0.004	0.8	0.21	0.002	**1**	0.0045	0.0087
Dichlorobenzene, 1,4-	106467	4	0.11	5E-06	0.5	0.2	0.001	0.70	5E-06	**1E-05**
Dimethoxybenzidine, 3,3'-	119904	2	0.38	9E-06	NA	NA	NA	NA	6E-07	**1E-05**
Diphenylamine	122394	4	1.1	0.4	NA	NA	NA	NA	0.61	**1**
Ethylbenzene	100414	3	0.17	0.01	0.7	0.3	0.002	**1**	0.015	0.029
Formaldehyde	50000	1	11	0.5	1E-06	4E-07	5E-08	2E-06	4E-03	0.50
Methyl isobutyl ketone	108101	2	0.042	0.004	0.8	0.2	0.001	**1**	0.00018	0.0042
Methylene chloride	75092	6	0.67	1E-05	2E-06	1E-06	2E-07	4E-06	5E-07	**1E-05**
Naphthalene	91203	4	0.0028	0.0006	0.8	0.2	0.001	**1**	0.00068	0.0013
N-N-Dimethylaniline	121697	2	0.11	0.4	NA	NA	NA	NA	0.10	0.55
N-Nitrosodiphenylamine	86306	4	0.62	6E-06	2E-07	5E-08	5E-09	2E-07	5E-06	**1E-05**

(continued)

*Shading indicates risk-limiting exposure route.

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Table F-8. (continued)

Chemical	CAS Number	Group Number	Leachate Concentration (mg/L)	Drinking Water Ingestion HQ or Risk for the ADULT	Inhalation Hazard Quotient or Risk for Shower - ADULT	Inhalation Hazard Quotient or Risk for Bathroom - ADULT	Inhalation Hazard Quotient or Risk for Whole House - ADULT	Summed Inhalation Hazard Quotient or Risk - ADULT	Dermal Hazard Quotient or Risk - ADULT	Summed Drinking Water Ingestion & Dermal HQ or Risk for the ADULT
Phenol	108952	2	0.8	0.01	0.9	0.2	0.0009	1	0.001	0.01
Phenylenediamine, o-	95545	1	0.11	1E-05	NA	NA	NA	NA	1E-07	1E-05
Phenylenediamine, p-	106503	1	10	0.4	NA	NA	NA	NA	0.0024	0.40
Pyridine	110861	2	0.042	0.3	0.9	0.2	0.001	1	0.0072	0.31
Toluene	108883	3	0.071	0.003	0.7	0.3	0.002	1	0.0018	0.0050
Toluidine, o-	95534	2	0.022	9E-06	1E-07	3E-08	3E-09	1E-07	8E-07	1E-05
Toluidine, p-	106490	2	0.029	1E-05	NA	NA	NA	NA	5E-07	1E-05
Trichlorobenzene, 1,2,4-	120821	4	0.046	0.04	0.8	0.2	0.001	1	0.088	0.13
Xylene, m-	108383	3	100	0.4	NA	NA	NA	NA	0.48	0.94
Xylene, o-	95476	3	100	0.4	NA	NA	NA	NA	0.43	0.88
Xylenes (total)	1330207	3	0.071	0.0003	0.7	0.3	0.002	1	0.00033	0.00065

Note - Shading indicates risk-limiting exposure route. NA - Not Applicable because the concentration was > 1,000,000 mg/kg.

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Table F-9. Risk Limiting Leachate Concentrations for TAM Sludge Stream*
90th Percentile
Child

Chemical	CAS Number	Group Number	Leachate Concentration (mg/L)	Drinking Water Ingestion HQ or Risk for the CHILD	Inhalation Hazard Quotient or Risk for Shower - CHILD	Inhalation Hazard Quotient or Risk for Bathroom - CHILD	Inhalation Hazard Quotient or Risk for Whole House - CHILD	Summed Inhalation Hazard Quotient or Risk - CHILD
1,2-Diphenylhydrazine	122667	4	0.0042	5E-06	4E-08	9E-09	1E-09	5E-08
Acetone	67641	1	5.6	**1**	0.1	0.02	0.0001	0.1201
Aniline	62533	2	0.029	2E-07	0.9	0.11	0.0009	**1**
Azobenzene	103333	4	0.013	2E-06	5E-08	1E-08	2E-09	7E-08
Benzaldehyde	100527	2	5.6	**1**	NA	NA	NA	NA
Benzene	71432	2	0.11	5E-06	6E-06	4E-06	5E-07	**1E-05**
Benzidine	92875	2	0.000023	8E-06	1E-12	4E-13	4E-14	2E-12
Bis(2-ethylhexyl)phthalate	117817	5	0.17	5E-08	0.004	0.0006	0.000004	0.0046
Bromodichloromethane	75274	6	0.060	6E-06	6E-06	3E-06	3E-07	9E-06
Chloroaniline, p-	106478	2	0.25	**1**	NA	NA	NA	NA
Chlorobenzene	108907	3	0.0036	0.004	0.7	0.3	0.002	**1**
Chloroform	67663	2	0.042	4E-07	6E-06	4E-06	5E-07	**1E-05**
Cresol, p-	106445	2	0.33	**1**	NA	NA	NA	NA
Dichlorobenzene, 1,2-	95501	4	0.043	0.008	0.8	0.21	0.002	**1**
Dichlorobenzene, 1,4-	106467	4	0.11	4E-06	0.5	0.2	0.001	0.70
Dimethoxybenzidine, 3,3'-	119904	2	0.38	8E-06	NA	NA	NA	NA
Diphenylamine	122394	4	1.1	0.8	NA	NA	NA	NA
Ethylbenzene	100414	3	0.17	0.03	0.7	0.3	0.002	**1**
Formaldehyde	50000	1	11	**1**	1E-06	4E-07	5E-08	2E-06
Methyl isobutyl ketone	108101	2	0.042	0.009	0.8	0.2	0.001	**1**
Methylene chloride	75092	6	0.67	8E-06	2E-06	1E-06	1E-07	3E-06
Naphthalene	91203	4	0.0028	0.001	0.8	0.2	0.001	**1**
N-N-Dimethylaniline	121697	2	0.11	**1**	NA	NA	NA	NA
N-Nitrosodiphenylamine	86306	4	0.62	4E-06	2E-07	5E-08	6E-09	3E-07

(continued)

Note - Shading indicates risk-limiting exposure route. *Not all constituents are included at present because of business confidentiality concerns

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Table F-9. (continued)

Chemical	CAS Number	Group Number	Leachate Concentration (mg/L)	Drinking Water Ingestion HQ or Risk for the CHILD	Inhalation Hazard Quotient or Risk for Shower - CHILD	Inhalation Hazard Quotient or Risk for Bathroom - CHILD	Inhalation Hazard Quotient or Risk for Whole House - CHILD	Summed Inhalation Hazard Quotient or Risk - CHILD
P henol	108952	2	0.8	0.02	0.9	0.2	0.0009	**1**
Phenylenediamine, o-	95545	1	0.11	8E-06	NA	NA	NA	NA
Phenylenediamine, p-	106503	1	10	**1**	NA	NA	NA	NA
Pyridine	110861	2	0.042	0.7	0.9	0.2	0.001	**1**
Toluene	108883	3	0.071	0.007	0.7	0.3	0.002	**1**
Toluidine, o-	95534	2	0.022	8E-06	1E-07	3E-08	3E-09	1E-07
Toluidine, p-	106490	2	0.029	8E-06	NA	NA	NA	NA
Trichlorobenzene, 1,2,4-	120821	4	0.046	0.08	0.8	0.2	0.001	**1**
Xylene, m-	108383	3	100	**1**	NA	NA	NA	NA
Xylene, o-	95476	3	100	**1**	NA	NA	NA	NA
Xylenes (total)	1330207	3	0.071	0.0007	0.7	0.3	0.002	**1**

*Shading indicates risk-limiting exposure route. NA - Not Applicable because the concentration was > 1,000,000 mg/kg.

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Table F-10. Risk Limiting Leachate Concentrations for TAM Sludge Stream*
95th Percentile
Adult

Chemical	CAS Number	Group Number	Leachate Concentration (mg/L)	Drinking Water Ingestion HQ or Risk for the ADULT	Inhalation Hazard Quotient or Risk for Shower - ADULT	Inhalation Hazard Quotient or Risk for Bathroom - ADULT	Inhalation Hazard Quotient or Risk for Whole House - ADULT	Summed Inhalation Hazard Quotient or Risk - ADULT	Dermal Hazard Quotient or Risk - ADULT	Summed Drinking Water Ingestion & Dermal HQ or Risk for the ADULT
1,2-Diphenylhydrazine	122667	4	0.003	7E-06	3E-08	9E-09	1E-09	4E-08	4E-06	**1E-05**
Acetone	67641	1	3.7	0.5	0.1	0.02	0.0001	0.12	0.0023	0.50
Aniline	62533	2	0.02	3E-07	0.9	0.1	0.0009	**1**	2E-08	4E-07
Azobenzene	103333	4	0.0086	3E-06	5E-08	1E-08	2E-09	7E-08	7E-06	**1E-05**
Benzaldehyde	100527	2	3.7	0.5	NA	NA	NA	NA	0.028	0.52
Benzene	71432	2	0.69	6E-06	5E-06	4E-06	5E-07	**1E-05**	1E-06	7E-06
Benzidine	92875	2	0.000013	9E-06	1E-12	3E-13	4E-14	2E-12	7E-07	**1E-05**
Bis(2-ethylhexyl)phthalate	117817	5	0.048	5E-08	0.003	0.0005	0.000003	0.0035	1E-05	**1E-05**
Bromodichloromethane	75274	6	0.037	7E-06	7E-06	3E-06	4E-07	**1E-05**	8E-07	8E-06
Chloroaniline, p-	106478	2	0.15	0.5	NA	NA	NA	NA	0.072	0.55
Chlorobenzene	108907	3	0.0025	0.002	0.7	0.3	0.002	**1**	0.00088	0.0026
Chloroform	67663	2	0.026	5E-07	6E-06	4E-06	5E-07	**1E-05**	5E-08	5E-07
Cresol, p-	106445	2	0.2	0.5	NA	NA	NA	NA	0.10	0.61
Dichlorobenzene, 1,2-	95501	4	0.030	0.004	0.8	0.205	0.002	**1**	0.0044	0.0085
Dichlorobenzene, 1,4-	106467	4	0.066	5E-06	0.4	0.1	0.001	0.50	5E-06	**1E-05**
Dimethoxybenzidine, 3,3'-	119904	2	0.22	9E-06	NA	NA	NA	NA	6E-07	**1E-05**
Diphenylamine	122394	4	0.78	0.4	NA	NA	NA	NA	0.61	**1**
Ethylbenzene	100414	3	0.12	0.010	0.7	0.3	0.002	**1**	0.014	0.029
Formaldehyde	50000	1	10	0.6	2E-06	6E-07	7E-08	2E-06	0.0052	0.61
Methyl isobutyl ketone	108101	2	0.029	0.005	0.8	0.2	0.001	**1**	0.00018	0.0051
Methylene chloride	75092	6	0.41	1E-05	2E-06	1E-06	2E-07	3E-06	5E-07	**1E-05**
Naphthalene	91203	4	0.0021	0.0007	0.8	0.2	0.001	**1**	0.00071	0.0014
N-N-Dimethylaniline	121697	2	0.1	0.6	NA	NA	NA	NA	0.13	0.75

(continued)

Note - Shading indicates risk-limiting exposure route. * Not all constituents are included at present because of business confidentiality concerns

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Table F-10. (continued)

Chemical	CAS Number	Group Number	Leachate Concentration (mg/L)	Drinking Water Ingestion HQ or Risk for the ADULT	Inhalation Hazard Quotient or Risk for Shower - ADULT	Inhalation Hazard Quotient or Risk for Bathroom - ADULT	Inhalation Hazard Quotient or Risk for Whole House - ADULT	Summed Inhalation Hazard Quotient or Risk - ADULT	Dermal Hazard Quotient or Risk - ADULT	Summed Drinking Water Ingestion & Dermal HQ or Risk for the ADULT
N-nitrosodiphenylamine	86306	4	0.37	6E-06	2E-07	4E-08	5E-09	2E-07	4E-06	**1E-05**
Phenol	108952	2	0.57	0.01	0.9	0.2	0.0009	**1**	0.001	0.01
Phenylenediamine, o-	95545	1	0.07	1E-05	NA	NA	NA	NA	1E-07	**1E-05**
Phenylenediamine, p-	106503	1	7	0.5	NA	NA	NA	NA	0.0024	0.50
Pyridine	110861	2	0.03	0.4	0.9	0.2	0.001	**1**	0.0073	0.41
Toluene	108883	3	0.053	0.003	0.70	0.3	0.002	**1**	0.0018	0.0052
Toluidine, o-	95534	2	0.013	9E-06	9E-08	3E-08	3E-09	1E-07	7E-07	**1E-05**
Toluidine, p-	106490	2	0.016	9E-06	NA	NA	NA	NA	5E-07	**1E-05**
Trichlorobenzene, 1,2,4-	120821	4	0.034	0.04	0.8	0.2	0.001	**1**	0.091	0.13
Xylene, m-	108383	3	63	0.4	NA	NA	NA	NA	0.40	0.80
Xylene, o-	95476	3	63	0.4	NA	NA	NA	NA	0.36	0.75
Xylenes (total)	1330207	3	0.051	0.0003	0.7	0.3	0.002	**1**	0.00031	0.00063

Note - Shading indicates risk-limiting exposure route. NA - Not Applicable because the concentration was > 1,000,000 mg/kg.

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Table F-11. Risk Limiting Leachate Concentrations for TAM Sludge Stream*
95th Percentile
Child

Chemical	CAS Number	Group Number	Leachate Concentration (mg/L)	Drinking Water Ingestion HQ or Risk for the CHILD	Inhalation Hazard Quotient or Risk for Shower - CHILD	Inhalation Hazard Quotient or Risk for Bathroom - CHILD	Inhalation Hazard Quotient or Risk for Whole House - CHILD	Summed Inhalation Hazard Quotient or Risk - CHILD
1,2-Diphenylhydrazine	122667	4	0.003	5E-06	4E-08	1E-08	1E-09	5E-08
Acetone	67641	1	3.7	**1**	0.1	0.02	0.0001	0.12
Aniline	62533	2	0.02	3E-07	0.9	0.1	0.0009	**1**
Azobenzene	103333	4	0.0086	2E-06	6E-08	2E-08	2E-09	8E-08
Benzaldehyde	100527	2	3.7	**1**	NA	NA	NA	NA
Benzene	71432	2	0.69	5E-06	6E-06	4E-06	5E-07	**1E-05**
Benzidine	92875	2	0.000013	7E-06	1E-12	3E-13	4E-14	2E-12
Bis(2-ethylhexyl)phthalate	117817	5	0.048	4E-08	0.003	0.0005	0.000003	0.0035
Bromodichloromethane	75274	6	0.037	6E-06	6E-06	3E-06	3E-07	9E-06
Chloroaniline, p-	106478	2	0.15	**1**	NA	NA	NA	NA
Chlorobenzene	108907	3	0.0025	0.004	0.7	0.3	0.002	**1**
Chloroform	67663	2	0.026	4E-07	6E-06	4E-06	5E-07	**1E-05**
Cresol, p-	106445	2	0.2	**1**	NA	NA	NA	NA
Dichlorobenzene, 1,2-	95501	4	0.030	0.009	0.8	0.20	0.002	**1**
Dichlorobenzene, 1,4-	106467	4	0.066	4E-06	0.4	0.1	0.001	0.50
Dimethoxybenzidine, 3,3'-	119904	2	0.22	7E-06	NA	NA	NA	NA
Diphenylamine	122394	4	0.78	0.9	NA	NA	NA	NA
Ethylbenzene	100414	3	0.12	0.04	0.7	0.3	0.002	**1**
Formaldehyde	50000	1	10	**1**	2E-06	6E-07	7E-08	3E-06
Methyl isobutyl ketone	108101	2	0.029	0.01	0.8	0.2	0.001	**1**
Methylene chloride	75092	6	0.41	8E-06	2E-06	1E-06	1E-07	3E-06
Naphthalene	91203	4	0.0021	0.001	0.8	0.2	0.001	**1**
N-N-Dimethylaniline	121697	2	0.1	**1**	NA	NA	NA	NA
N-nitrosodiphenylamine	86306	4	0.37	4E-06	2E-07	5E-08	6E-09	3E-07

(continued)

Note - Shading indicates risk-limiting exposure route. Not all constituents are included at present because of business confidentiality concerns

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Table F-11. (continued)

Chemical	CAS Number	Group Number	Leachate Concentration (mg/L)	Drinking Water Ingestion HQ or Risk for the CHILD	Inhalation Hazard Quotient or Risk for Shower - CHILD	Inhalation Hazard Quotient or Risk for Bathroom - CHILD	Inhalation Hazard Quotient or Risk for Whole House - CHILD	Summed Inhalation Hazard Quotient or Risk - CHILD
Phenol	108952	2	.057	0.03	0.9	0.2	0.0009	**1**
Phenylenediamine, o-	95545	1	0.07	8E-06	NA	NA	NA	NA
Phenylenediamine, p-	106503	1	7	**1**	NA	NA	NA	NA
Pyridine	110861	2	0.03	0.8	0.9	0.2	0.001	**1**
Toluene	108883	3	0.053	0.008	0.70	0.3	0.002	**1**
Toluidine, o-	95534	2	0.013	7E-06	1E-07	3E-08	3E-09	1E-07
Toluidine, p-	106490	2	0.016	7E-06	NA	NA	NA	NA
Trichlorobenzene, 1,2,4-	120821	4	0.034	0.1	0.8	0.2	0.001	**1**
Xylene, m-	108383	3	63	**1**	NA	NA	NA	NA
Xylene, o-	95476	3	63	**1**	NA	NA	NA	NA
Xylenes (total)	1330207	3	0.051	0.0008	0.7	0.3	0.002	**1**

Note - Shading indicates risk-limiting exposure route. NA - Not Applicable because the concentration was > 1,000,000 mg/kg.

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Appendix H

Sensitivity Analysis for the Groundwater Pathway

Appendix H

Sensitivity Analysis for the Groundwater Pathway

H.1 Introduction

The purpose of the groundwater pathway sensitivity analysis is to identify the most sensitive parameters in the exposure and risk calculations, and their corresponding high-end and central tendency values for the subsequent deterministic analysis. The sensitivity of individual parameters is defined as the difference, or ratio, in predicted health risk when the parameter is set to its high-end value compared to the risk corresponding to the central tendency value of that parameter. The high-end value of a parameter corresponds to its 90^{th} percentile value or its 10^{th} percentile value, depending on whether a high or a low value of that parameter results in a more conservative (higher) predicted risk. If data are limited to define the probability distribution of a parameter, the high-end may be set to either the maximum or minimum measured value. The central tendency value corresponds to the 50^{th} percentile (median) value of the parameter.

Section H.2 identifies and examines important parameters in the exposure and risk calculations. Section H.3 describes the surrogate selection process. Section H.4 describes the approach for the sensitivity analysis. Section H.5 presents and discusses the sensitivity analysis results.

H.1.1 Identification and Description of Important Parameters

The various parameters can be grouped into constituent-related parameters, waste- and WMU-related parameters, pathway-related parameters, and intake-related parameters. This discussion does not include all parameters in the groundwater model or in the exposure and risk equations, but is restricted to those that are expected to be among the most sensitive parameters.

H.1.1.1 <u>Constituent-Related Parameters</u>. The most important parameters in this group are

- Concentration of constituent in the waste
- Concentration of constituent in the leachate

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- **#** Organic carbon partition coefficient (for organics) or the solid-liquid partition coefficient (for metals and inorganics)

- **#** Transformation (hydrolysis) half-life.

In this analysis, the constituent-specific waste concentration is not an independent variable; rather, it is the quantity that is backcalculated. Under conditions of linear equilibrium partitioning, the leachate concentration is directly related to the waste concentration, as described in the methodology for the screening analysis. As a result, the leachate concentration is also not an independent parameter and is not considered in the sensitivity analysis. This leaves partition coefficient (k_d) or organic carbon partition coefficient (k_{oc}), and the hydrolysis half-life as the constituent-specific parameters to be considered in the sensitivity analysis.

For organic constituents, the product of the constituent-specific k_{oc} and the fraction organic carbon in the waste equals the solid-liquid partition coefficient, k_d, which determines the relative amount of constituent that is sorbed to the solid fraction of the waste, relative to the amount present in the leachate. For inorganic constituents, including metals, the effective k_d may more strongly depend on factors other than organic carbon, including groundwater pH.

H.1.1.2 <u>Waste and Landfill-Related Parameters</u>. The significant parameters in this category are

- **#** Landfill surface area
- **#** Infiltration rate through the landfill
- **#** Landfill operating life
- **#** Annual waste amount
- **#** Fraction of landfill occupied by dye and pigment industry wastes.

The product of landfill area and infiltration rate equals the annual volumetric leachate flux through the landfill. The product of leachate flux times leachate concentration equals the annual mass of constituent that is released into the subsurface. For a given landfill area, a higher infiltration rate will mean a higher loading of contaminant into the soil and groundwater, but also a more rapid depletion of the constituent in the landfill. Assuming a uniform landfill design (earthen cover, no liner), the infiltration rate is controlled by climatic factors (i.e., it will vary depending on the geographic location of the waste management unit).

The landfill operating life, the annual quantity of filter aid waste, and the fraction of landfill volume that is occupied by wastes from the dye and pigment industry affect the total amount of waste that accumulates in the waste unit. Landfill operating life is not varied in the sensitivity analysis because 30 years has been defined as the average operating life for municipal landfills (U.S. EPA, 1988). Conversely, there is considerable uncertainty and variation in the annual waste quantity; therefore, this parameter is examined in the sensitivity analysis. The fraction of the landfill volume that is occupied by dye and pigment industry wastes is calculated using the 30-year waste amount, waste density, landfill area, and landfill depth.

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H.1.1.3 <u>Groundwater Pathway-Related Parameters</u>. The most important parameters affecting dilution and attenuation in the soil and groundwater include:

- **#** Soil type and soil characteristics (including saturated conductivity and water content)
- **#** Depth to groundwater
- **#** Saturated zone thickness
- **#** Aquifer hydraulic conductivity
- **#** Hydraulic gradient
- **#** Distance to nearest receptor well
- **#** Depth of well intake point
- **#** Position of well relative to plume centerline.

In support of the 1995 HWIR proposal, a methodology and database were developed to relate a number of the most important soil and groundwater parameters to waste unit location (U.S. EPA, 1997a and 1997b). These location-dependent parameters are: (1) depth to groundwater, (2) saturated zone thickness, (3) aquifer hydraulic conductivity, and (4) hydraulic gradient. These data will be used for this modeling analysis to determine the value of each of these parameters at each facility location modeled. Whereas distance to nearest receptor well and position of the well relative to plume centerline are examined in the sensitivity analysis, depth of well intake point is not included. There can be significant differences in groundwater concentration at different depths below the water table. However, the depth at which the maximum concentration occurs varies according to well location and the hydrogeologic setting being modeled. Therefore, for the sensitivity analysis, the well is placed at the vertical midpoint of the plume (determined by the EPACMTP model).

It is important to note that the dilution-attenuation of waste constituents in the groundwater pathway depends strongly on the pathway-related parameters identified above and on the constituent-specific sorption (k_d or k_{oc}) parameters and hydrolysis transformation rate. The effect of sorption (high k_{oc} or k_d) will be to retard the movement of constituents relative to the rate of groundwater movement, thereby increasing the travel time through both the unsaturated zone (from the base of the landfill to the water table) and the saturated zone to the receptor well.

For constituents that do not hydrolyze, the primary effect of this retardation will be to delay the time of maximum exposure. For relatively large waste volumes (in which contaminant transport approaches steady-state conditions), the magnitude of the exposure at the receptor well is less affected. For smaller waste volumes, such as those being examined in this analysis, the magnitude of the exposure at the receptor well may be significantly affected by retardation. For constituents that do hydrolyze, increased travel time means that a greater proportion of the

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constituent mass will have transformed before it reaches the receptor well, which may result in lower exposure and risk (although the risk associated with toxic transformation daughter products may be increased). Thus, the relative sensitivity of depth-to-groundwater and distance-to-receptor well may be markedly different for different constituents.

H.1.1.4 Intake-Related Parameters. Parameters in this category include:

- Exposure duration (for carcinogens only)
- Exposure frequency
- Groundwater intake (ingestion) rate
- Body weight.

The intake equation is a linear algebraic equation that allows the evaluation of the effect of variations in the above parameters directly without requiring a sensitivity analysis. For instance, if all other factors remain constant, a doubling of the ingestion rate will lead to a doubling of the risk. Moreover, the parameters in this group act independently of any of the other parameters discussed before (all of which affect the exposure concentration) and are also independent of the constituent being analyzed (with the exception of exposure duration, which is applicable for carcinogens only).

H.2 Selection of Surrogates for Organic Constituents

Because of the large number of constituents of concern, constituents are grouped based on subsurface fate and transport characteristics. Then one representative constituent from each category is modeled. The modeled constituent in each category is called a surrogate. Thus, the modeling results for the surrogate can then be applied to each constituent in that category. The methodology for grouping the constituents and choosing the surrogates is described briefly below and in greater detail in Appendix C.

H.2.1 Basis for Grouping of Organic Constituents

The constituent list for the Dyes and Pigments Deferred Wastes (Table C1 in Appendix C, Selection of Surrogates) contains a total of 53 organic constituents and 11 inorganics. The number of modeling runs required to model these constituents in the sensitivity analysis was minimized by exploiting the following features:

- For a given waste management scenario, if two organic constituents have the same waste and leaching concentrations and the same sorption and hydrolysis rate coefficients, the model will predict the same receptor well exposure concentration.

- If two organic constituents have the same receptor well exposure concentration, their waste and leachate concentration thresholds will be linearly proportional to their respective health-based level (HBL) values.

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Combined, these two features make it possible to group constituents based on subsurface fate and transport characteristics rather than requiring a separate modeling run for each individual constituent on the list.

For computational efficiency, average transformation rate, λ, is calculated for each constituent, constituents are categorized according to their λ and K_{OC} values, and then the modeling is conducted for one representative constituent in each category. The modeled constituent in each category is called a surrogate. The modeling results for the surrogate can then be applied to each constituent in that category.

H.3 Modeling Methodology

The following sections present the technical approach used to identify the pertinent high-end parameters for each surrogate. The approach is based on the fact that constituents that have the same or similar sorption (K_{OC} or K_d) and transformation (hydrolysis) characteristics will show the same or similar parameter sensitivity.

H.3.1 Modeling Methodology for Sensitivity Analysis

The selection of a surrogate for each group is described in Appendix C. Once a representative compound from each group was selected, a separate sensitivity analysis was performed for each of these surrogates. Only the spent filter aids waste stream was evaluated in this analysis; that is, a separate sensitivity analysis was not performed for the TAM sludges waste stream. Because of the similarity between these two waste streams, the sensitivity analysis results for the filter aids waste stream can be applied to the TAM sludges waste stream. However, in the next phase of modeling—the deterministic analysis—the modeling was performed separately for filter aids and TAM sludges.

The following waste, landfill, and groundwater pathway-related parameters were included in the sensitivity analysis for each surrogate:

- Annual waste amount
- Landfill area
- Waste unit location, which includes:
  - Infiltration and recharge rate
  - Soil type and properties
  - Depth to groundwater
  - Saturated zone thickness
  - Aquifer hydraulic conductivity
  - Hydraulic gradient
- Distance to receptor well (X-well)
- Distance of receptor well from the plume centerline (Y-well).

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These parameters were varied between high-end and central tendency values to determine the parameter sensitivity. EPACMTP input parameters other than those identified above were set to their respective central tendency values in all modeling runs.

The waste unit location, treated as one parameter in the analysis, defines a number of climatic and hydrogeologic model parameters that are all correlated to the geographic location of the waste unit. The high-end and central tendency waste unit locations for the filter aid waste stream were determined by evaluating the geographic distribution of the existing facilities. Under the assumption that wastes would be sent to a nearby municipal landfill, the climatic (infiltration rate), soil, and hydrogeologic characteristics for each waste site location were then determined using the methodology and databases developed in support of the 1995 HWIR groundwater pathway analysis (U.S. EPA, 1997a and 1997b).

For the filter aids waste stream, the high-end waste unit location corresponds to a landfill located in the vicinity of _____*. Conversely, the central tendency location corresponds to a landfill in the vicinity of _____*. For the TAM sludges waste stream, there is only one facility, which is located in Jersey City, NJ.

In all analyses, the initial waste concentration was set to an arbitrary value of 10,000 mg/kg. It is assumed that the operational life of the landfill is 30 years (U.S. EPA, 1988). Based on preliminary modeling using RTI's landfill partitioning model, the leaching profile for each of the surrogates approximates a square pulse of approximately 40 years. Thus, the EPACMTP modeling is conducted by assuming that the waste in the landfill leaches out in uniform fashion over 40 years, with a constant leachate concentration that is determined based on mass balance considerations and so that all the waste constituent mass is leached out after 40 years. No hydrolysis transformation inside the landfill is considered.

In the EPACMTP model, receptor well concentration is defined as the concentration at the well intake point, not an average concentration over the screened interval of the well. Because of the three-dimensional nature of the transport problem, the concentration varies in the vertical direction as well in the horizontal directions. Figure H-1 shows the concentration at the receptor intake point versus the distance from water table (Z-well) for the filter aids surrogate 1 (K_{OC} = 0, λ = 0.0). Note that the aquifer thickness is 18.6 m. This figure shows that the receptor well concentration for the high-end X-well case (X-well = 102 m, Y-well = 94 m) could be either smaller or larger than the central tendency X-well case (X=430 m, Y=118 m) depending on the value chosen for Z-well. However, by definition, the receptor well concentration for the high-end case should be larger than that for the central tendency case. Additionally, domestic drinking water wells are generally relatively shallow due to the increased cost of drilling a deeper well. Therefore, for these reasons and to be protective when performing the risk assessment, the receptor well intake point is set equal to vertical midpoint of the plume. For the sensitivity analysis, Z-well = 1.8 m below the water table for the high-end location and Z-well = 8.65 m for the central tendency case. In other runs in the sensitivity analysis, the well varies between

approximately 5 and 10 m below the water table depending on well location and landfill characteristics.

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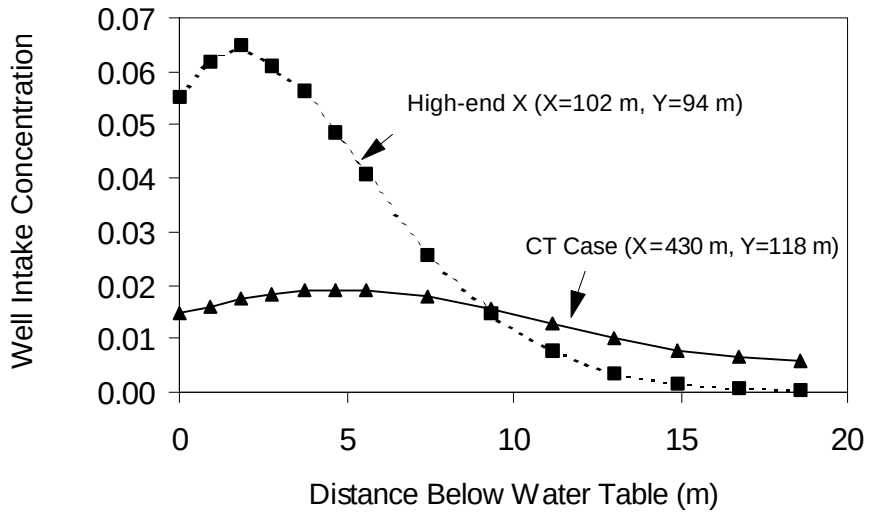

Figure H-1. Concentration profile throughout the aquifer thickness.

The modeling for the sensitivity analysis is evaluated in terms of the predicted receptor well exposure concentration, which is calculated as the peak receptor well concentration and maximum 9- and 30-year average receptor well concentrations. For constant intake parameters, the health risk is directly proportional to the exposure concentration. The sensitivity to other intake parameters (exposure duration, exposure frequency, ingestion rate, body weight) can be determined directly, as discussed previously, and these parameters do not need to be considered in the EPACMTP modeling runs.

H.3.2 Summary of Simulation Procedure

The sensitivity of individual parameters is defined as the difference, or ratio, in predicted health risk when the parameter is set to its high-end value, compared to the risk corresponding to the central tendency value of that parameter. The high-end value of a parameter corresponds to its 90th percentile value or its 10th percentile value, depending on whether a high or a low value of that parameter results in a more conservative (higher) predicted risk. If there is limited data to define the probability distribution of a parameter, the high end may be set to either the maximum or minimum measured value. The central tendency value corresponds to the 50th percentile (median) value of the parameter.

The sensitivity analysis is conducted by performing a number of modeling runs for each chosen surrogate. First, all parameters were set to their central tendency values. Then, one at a time, each parameter was set to its high-end value while all the other parameters remained at their central tendency values. These values and the data sources are presented in Table H-1. These modeling results are tabulated, and the parameters evaluated, including intake parameters, are ranked in order of sensitivity for each group of constituents. Additionally, the two most sensitive parameters are identified for use in the subsequent deterministic analysis.

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H.4 Modeling Results of Sensitivity Analysis

Following the procedures outlined above, the sensitivity analysis was conducted for the filter aids waste stream. The modeling results are presented in terms of the DAF^{WASTE}, which is defined as follows:

$$DAF^{WASTE} = \frac{C_W}{C_{RW}} \qquad \text{(H-1)}$$

where

DAF^{WASTE}	=	waste dilution-attenuation factor (L/kg)
C_W	=	waste concentration (mg/kg)
C_{RW}	=	receptor well concentration (mg/L)

The exit levels for the dyes and pigments industry wastes are defined in terms of initial waste concentration. Therefore, the DAF is also formulated in terms of waste concentration (rather than leachate concentration, as is usually done). Thus, the DAF^{WASTE}, when multiplied by the constituent-specific Health-Based Number (HBN), produces the desired threshold waste concentration.

The DAF^{WASTE} can be defined for the peak receptor well concentration or for the maximum 9-year or 30-year average well concentration; depending upon whether a constituent is a carcinogen or noncarcinogen, the peak or the average receptor well concentration will be of interest. Because for all the surrogates for the filter aid waste stream the leachate concentration profiles follow a square pulse with a duration of 40 years and dispersion is not strong compared to advection, there is negligible difference between the peak, the maximum 9-year average, and the maximum 30-year average receptor well concentrations. This is confirmed by the breakthrough curves, presented in Figures H-2 and H-3, recorded at the receptor well for the central tendency case of surrogates 1 and 5, respectively. The difference between the two surrogates lies solely in their K_{OC} values, which control the retardation factor for each constituent. Surrogate 1 has a K_{OC} value of ___* L/kg, whereas surrogate 5 has a K_{OC} value of ____* L/kg, the highest among the seven surrogates. Figure H-2 shows that, for a constituent with a low K_{OC} value, the peak and "T"-year average receptor well concentrations are almost identical for values of "T" less than or equal to 30 years.

*Relevant data are not included at present because of business confidentiality concerns.

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Table H-1. Values for EPACMTP Input Parameters

EPACMTP Input Parameter	High-End Value	Central Tendency Value	Data Source
Waste Management Scenario:			
C_W/C_L ratio	Constituent-specific	Constituent-specific	Derived from C_W and C_L (C_W = 10,000 mg/kg)
Landfill Area (m^2)	HE1 = 420,888 HE2 = 8,090	60,705	EPA Survey of municipal landfills HE1 = 90th %; HE2 = 10th %
Initial Leachate Concentration (C_L) (mg/L)	Derived [b]	Derived [b]	U.S. EPA, 1988
Regional Recharge Rate (m/yr)	[b]	[b]	Determined from source partitioning model
Infiltration Rate through Landfill (m/yr)			Set equal to infiltration
Landfill Depth (m)	2.63	2.63	HELP modeling analysis for HWIR 1995
Fraction	Derived [b]	Derived [b]	EPA OSW survey, 50% for Industrial LF
Waste density (kg/L)	____	____	Derived from waste amt, LF area, depth, density
Chemical-Specific Parameters:			
Hydrolysis rate (yr^{-1})	Constituent-specific	Constituent-specific	Kollig et al., 1993
K_{oc} (L/kg)	Constituent-specific	Constituent-specific	Kollig et al., 1993
Exposure duration (yr)	30	9	U.S. EPA, 1997

Note: Parameters in **bold face** are varied in Sensitivity and High-End Deterministic Analyses.

(continued)

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Table H-1. (continued)

EPACMTP Input Parameter	High-End Value	Central Tendency Value	Data Source
Unsaturated Zone Parameters:			
Sat. hydraulic conductivity (cm/h)	[b]	[b]	Carsel & Parrish, 1988
Hydraulic parameter, (cm^{-1})	[b]	[b]	Carsel & Parrish, 1988
Hydraulic parameter,	[b]	[b]	Carsel & Parrish, 1988
Residual water content	[b]	[b]	Carsel & Parrish, 1988
Saturated water content	[b]	[b]	Carsel & Parrish, 1988
Depth to groundwater (m)	[b]	[b]	U.S. EPA, 1997a and 1997b
Organic matter content (%)	[b]	[b]	Carsel et al., 1988
Bulk density (g/cm^3)	1.60	1.60	Carsel et al., 1988
Saturated Zone Parameters:			
Particle diameter (cm)	0.025	0.025	U.S. EPA, 1997a and 1997b
Saturated thickness (m)	[b]	[b]	U.S. EPA, 1997a and 1997b
Hydraulic conductivity (m/y)	[b]	[b]	U.S. EPA, 1997a and 1997b
Hydraulic gradient (m/m)	[b]	[b]	U.S. EPA, 1997a and 1997b
Longitudinal dispersivity (a_L)	Derived	Derived	Gelhar distribution, U.S. EPA, 1997a and 1997b
Transverse dispersivity (a_T)	Derived	Derived	Derived from a_L
Vertical dispersivity (a_V)	Derived	Derived	Derived from a_L
Groundwater temperature (°C)	14.4	14.4	U.S. EPA, 1997a and 1997b
Groundwater pH	6.8	6.8	U.S. EPA, 1997a and 1997b
Fraction organic carbon	0.000432	0.000432	EPA STORET database
Receptor Well Location:			
X-well distance (m)	102	430	U.S. EPA, 1997a and 1997b
Y-well distance from plume center-line (m)	0.0	117.75	HE = 0
Z-well distance below water table (m)	1.8	8.65	CT = calculated from estimated plume width vertical center of plume (determined by EPACMTP)

[a]High-end location corresponds to a waste unit located in _____[b]; central tendency location corresponds to a waste unit located in _____[b].
[b]Relevant data are not included at present because of business confidentiality concerns.

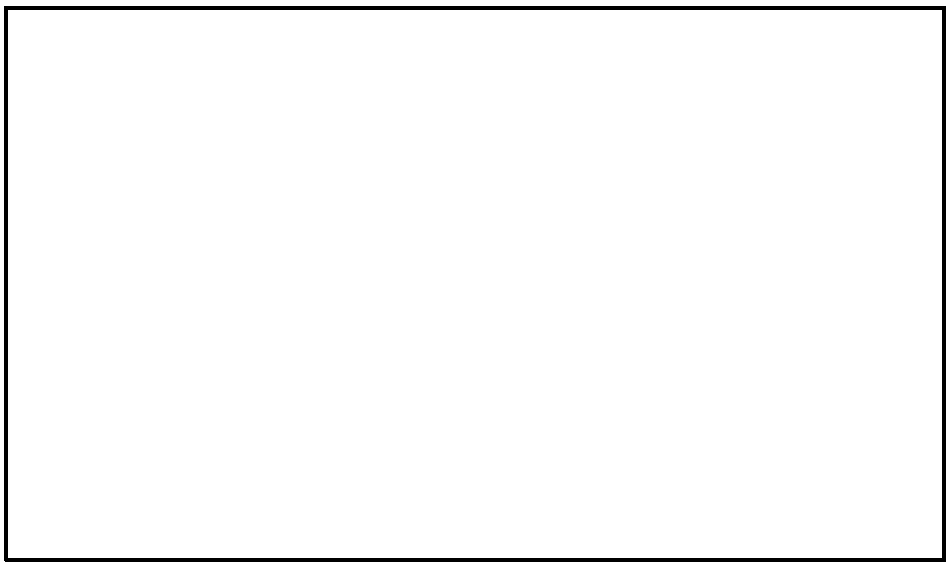

Figure H-2. Breakthrough curve at receptor well: surrogate 1 (K_{OC}=___ *, λ =0), central tendency case.

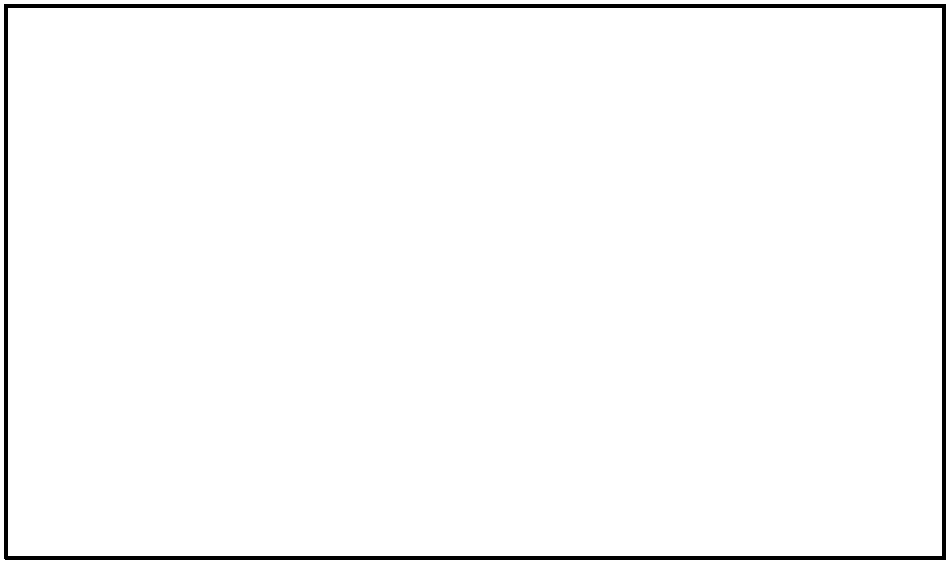

Figure H-3. Breakthrough curve at receptor well: surrogate 5 (KOC=_____*, λ =0), central tendency case.

*Relevant data are not included at present because of business confidentiality concerns.

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Figure H-2 illustrates that, for a constituent with a high K_{OC} value, the peak and 9-year average concentrations are still identical, although the 30-year average concentration may differ slightly. Similar conclusions can be drawn concerning other surrogates and high-end parameter cases. For this reason, only the DAF^{WASTE} results associated with the 9-year average receptor well concentrations are presented here, with the implicit assumption that the DAF^{WASTE} associated with peak and 30-year average receptor well concentrations is the same as that associated with the 9-year average receptor well concentration.

The chemical-specific values and the results of the central tendency analysis are presented in Table H-2. All parameters examined in the sensitivity analysis are set to their median values for the central tendency case. For each surrogate, one parameter at a time is set to its high-end value. The central tendency DAF^{WASTE} values are then compared to each high-end case. Each high-end run should result in a higher receptor well concentration, and thus a lower DAF^{WASTE}, than the central tendency case for that surrogate. The two most sensitive modeling parameters are the parameters whose high-end runs result in the lowest DAF^{WASTE} values. The DAF^{WASTE} values from the high-end runs are presented in Table H-3, and the DAF^{WASTE} values for the two most sensitive parameters are highlighted in bold text. A list of the two most sensitive modeling parameters for each surrogate is presented in Table H-4.

Table H-2. Surrogate Characteristics and Resulting DAF^{WASTE} for Central Tendency Case

Group	Surrogate	K_{OC} (L/kg)	l (yr^{-1})	DAF^{WASTE} (L/kg) Central Tendency Case
1	1	_____[a]	_____[a]	_____[a]
2	2	_____[a]	_____[a]	_____[a]
3	3	_____[a]	_____[a]	_____[a]
4	4	_____[a]	_____[a]	_____[a]
5	5	_____[a]	_____[a]	_____[a]
7	6	_____[a]	_____[a]	_____[a]
12	7	_____[a]	_____[a]	_____[a]

[a]Relevant data are not included at present because of business confidentiality concerns.

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Table H-3. Resulting DAF^{WASTE} (L/kg) for One-Parameter High-End Cases

Surrogate	10% Landfill Area	90% Landfill Area	Waste Amount	Location	X-well	Y-well
1	[a]	[a]	[a]	[a]	[a]	[a]
2	[a]	[a]	[a]	[a]	[a]	[a]
3	[a]	[a]	[a]	[a]	[a]	[a]
4	[a]	[a]	[a]	[a]	[a]	[a]
5	[a]	[a]	[a]	[a]	[a]	[a]
6	[a]	[a]	[a]	[a]	[a]	[a]
7	[a]	[a]	[a]	[a]	[a]	[a]

[a]Relevant data are not included at present because of business confidentiality concerns.

Table H-4. Most Sensitive Modeling Parameters

Surrogate	First Most Sensitive Modeling Parameter	Second Most Sensitive Modeling Parameter
1	Waste amount	X-well
2	Waste amount	X-well
3	Waste amount	X-well
4	Waste amount	X-well
5	Waste amount	X-well
6	Waste amount	X-well

Note that two values of landfill area were examined in the sensitivity analysis. A larger landfill area usually results in higher receptor well concentrations; however, for this analysis, only a small fraction of the waste in the landfill is from filter aids. Using the 90th percentile value for landfill area results in increased dilution of the leachate plume from the filter aid wastes with leachate from the rest of the landfill, thus resulting in a lower receptor well concentration. Using the 10th area actually produces higher receptor well concentrations because the fixed amount of filter aid waste added to the landfill results in more concentrated source plume. This is also partly

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due to the choice of Y-well location. Except for the high-end Y-well case, Y-well is always set midway between plume centerline and the estimated lateral boundary of the plume. The smaller the landfill area is, the closer the receptor well is to the plume centerline where groundwater concentrations are generally higher.

For surrogates 1 through 6, waste amount is the most sensitive modeling parameter and the downgradient distance of the receptor well is the second most sensitive modeling parameter. Varying the waste amount to its high-end value resulted in decreasing the DAF^{WASTE} by a factor of about 10, and varying X-well to its high-end value resulted in a decrease in the DAF^{WASTE} by a factor of almost 3. There is an inverse linear relationship between DAF^{WASTE} and exposure risk, so when the DAF is decreased by a factor of 10, risk is increased by a factor of 10.

However, the sensitivity analysis must include evaluation of both modeling parameters and intake-related parameters. Since the risk equation is linear, these intake parameters can be evaluated directly without the use of groundwater modeling. The most sensitive of the intake-related parameters is exposure duration, but this parameter is applicable only to carcinogens. Increasing the exposure duration (from 9 to 30 years) for carcinogens increases risk by slightly more than a factor of 3. Because increasing the waste amount increases risk by a factor of 10, this modeling parameter is, overall, the most sensitive. However, increasing the exposure duration results in a slightly higher increase in risk than using the high-end value for X-well. Thus, for carcinogens, the two most sensitive parameters are waste amount and exposure duration; for noncarcinogens, the most sensitive parameters are waste amount and X-well. Note that these results were taken to apply to both the spent filter aids waste stream and the TAM sludges waste stream.

For surrogate 7, the hydrolysis rate (λ) is so high that even in the central tendency case, all of this constituent is transformed before it reaches the receptor well. For this reason, surrogate 7 was not included in the rest of the sensitivity analysis modeling.

H.5 References

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Carsel, Robert and Rudolph Parrish. 1988. Developing joint probability distributions of soil water retention characteristics. *Water Resources Research*, 25, (5):755-769.

Carsel, Robert, et al. 1988. Characterizing the uncertainty of pesticide leaching in agricultural soils. *Journal of Contaminant Hydrology*, 2:111-124.

Kollig, Heinz, editor. 1993. *Environmental Fate Constants for Organic Chemicals under Consideration for EPA's Hazardous Waste Identification Projects*. Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, GA.

Loux, N. T., C. R. Chafin, and S. M. Hassan. 1990. *Statistics of Aquifer Material Properties and Empirical pH-dependent Partitioning Relationships for As (III), As (V), Ba(II), Cd(II), Cr(VI), Cu(II), Hg(II), Ni(II), Pb(II), Sb(V), Se(IV), Tl(I), and Zn(II)*. Office of Research and Development, U.S. Environmental Protection Agency, Athens GA.

U.S. EPA (Environmental Protection Agency). 1997a. *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) User's Guide*. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1997b. *Analysis of Subtitle D Waste Management Units Databases Used in the Groundwater Pathway Analysis for HWIR*. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1996a. *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) Background Document*. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1996b. *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) Background Document for the Finite Source Methodology*. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1996c. *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) Background Document for Metals*. Office of Solid Waste, Washington, DC.

U.S. EPA, 1993. *Parameter Values for EPA's Composite Model for Landfills (EPACML) Used in Developing Nationwide Regulations: Toxicity Characteristic Rule*. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1988. *National Survey of Solid Waste (Municipal) Landfill Facilities*, EPA/530-SW-88-034. Office of Solid Waste, Washington, DC.

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Appendix I

Groundwater Pathway Deterministic Analysis for Metals

I.1 Introduction

The U. S. Environmental Protection Agency (EPA) analyzed samples from a few facilities for metals, but dropped metals from its list of constituents of concern due to the inability to link them directly to production of organic dyes and pigments. EPA found no reported use of metals in any significant quantity in the production process for the organic dyes and pigments under investigation, except for three metals (the identities are not included due to business confidentiality concerns). The metal of most potential concern (the identity is not included due to business confidentiality concerns) has limited use in the production of organic dyes and pigments. However, the metal is also widely found in wastewaters and wastewater treatment sludges due to its many and varied industrial uses. Nevertheless, a preliminary deterministic risk analysis for selected metals has been conducted to confirm that these metals are not likely to be of concern in these wastes. The deterministic analysis of metals is described in this section.

In the sensitivity analysis, the metals evaluated were assigned to the appropriate organic surrogate group based on their respective calculated "effective" K_{oc} values (Appendix D). For the deterministic analysis, results of the sensitivity analysis are applied to the metals and the deterministic modeling for metals was conducted in a manner similar to the sensitivity analysis for organics.

I.2 Modeling Methodology

I.2.1 Geochemical Characteristics of Metals

The fate of metals in the subsurface is governed by a number of transport mechanisms such as advection, dispersion, and retardation due to sorption. Advection and dispersion are mechanical processes that do not generally depend on the type of solute. However, the adsorption of metals onto the subsurface soil and aquifer matrix is metal-specific and is expressed, in EPACMTP modeling, in terms of an adsorption distribution coefficient (K_d). The metals modeling methodology in EPACMTP assumes that the rate of adsorption reactions is fast relative to transport rate and that the result of the adsorption process can be described by equilibrium adsorption isotherms.

The metals modeling methodology in EPACMTP incorporates two options to specify the K_d for a given metal. Adsorption isotherms for metals with nonlinear sorption behavior are computed using U.S. EPA's geochemical speciation model, MINTEQA2 (Allison et al., 1991); and the isotherms for metals with linear adsorption behavior are pH-dependent and defined by empirical relationships (Loux et al., 1990). The two approaches for calculating the K_d values are described briefly below; more detailed information can be found in U.S. EPA (1996c and 1997a).

In the first approach, the purpose of using a speciation model is to capture the variation in K_d due to variability in geochemical conditions in the soil and due to the changing dissolved metal concentrations. The four geochemical parameters on which adsorption primarily depends are: groundwater pH, concentration of hydrous ferric oxide adsorption sites, concentration of dissolved and particulate natural organic matter, and concentration of leachate organic acids. For the MINTEQA2 modeling, the natural variability of these parameters is divided into three ranges:

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low, medium, and high. Each parameter is then assigned three possible values that correspond approximately to the midpoint of each range. For each metal with nonlinear adsorption, the MINTEQA2 model is then run over a range of total metal concentrations to produce an isotherm for each combination of the three possible values for the four geochemical parameters. For each metal, the 162 isotherms produced in this way are then written to a data file that must accompany the input file when conducting EPACMTP modeling. EPACMTP then selects the appropriate isotherm based on the input values specified for the four geochemical parameters.

To perform geochemical modeling with MINTEQA2, one must know the adsorption reactions describing the interaction of the metal with the adsorbing surface. For several metals of concern, primarily those that behave as anions in aqueous solution, these reactions are not reliably known. Because the MINTEQA2 model cannot be used due to this lack of data, empirical linear relationships describing the adsorption distribution coefficient as a function of pH are used instead. The pH-dependent isotherms are determined through statistical analysis of laboratory measurements of soil and aquifer materials and corresponding groundwater and leachate samples (Loux et al., 1990). These isotherms are included in the EPACMTP code, and the appropriate K_d value is calculated based on the input value specified for groundwater pH.

Table I-1 provides a summary of the geochemical characteristics of each metal to be considered in the deterministic modeling. Note that all metals are noncarcinogens except arsenic, which is a carcinogen. Figure I-1 illustrates the sorption isotherms for the metals with nonlinear isotherms. It shows that lead, vanadium, copper, and zinc are the metals that are most strongly sorbed. Shown here are graphs of K_d versus dissolved concentration for six metals with nonlinear adsorption with the geochemical parameters set to the values used in the deterministic analysis.

I.2.2 Leachate Profiles for Metals

Figures I-2 and I-3 show variations of leachate concentrations with time for the eight metals in the spent filter aids waste stream for the central tendency case and high-end waste amount case, respectively. Figure I-4 illustrates the variations of leachate concentrations with time for the eight metals in the TAM sludges waste stream. No high-end waste amount is applicable to the TAM sludges because only one waste volume was modeled. In these figures, the leachate concentration increases during the first 30 years, which is equal to the landfill operational life, and then gradually decreases after that.

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Table I-1. Geochemical Characteristics of Metals

Metal	EPACMTP Metal ID	Type of Sorption Isotherm	Type of Health Impact
As	13	Linear	Carcinogen
Ba	1	Nonlinear	Noncarcinogen
Cr(VI)	3	Linear	Noncarcinogen
Cu	9	Nonlinear	Noncarcinogen
Ni	5	Nonlinear	Noncarcinogen
Pb	6	Nonlinear	Noncarcinogen
V	10	Nonlinear	Noncarcinogen
Zn	8	Nonlinear	Noncarcinogen

I.2.3 Construction of Effective Finite Leachate Source Models

The modified EPACMTP model used to simulate organic constituents with arbitrary leachate history cannot be applied to modeling of metals with nonlinear isotherms. For these metals, the EPACMTP model cannot simulate a depleting source; the available options are continuous or finite pulse source leaching. Thus, an "effective" finite leachate source is used for the metals depicted in Figures I-2, I-3, and I-4.

Because metals are highly adsorbed, the travel time to the receptor well is expected to be much longer than that for the organic constituents. Figures I-2, I-3, and I-4 show that the initial period of 30 years in which the leachate concentration increases is small compared to the entire leaching period (typically hundreds of years). Additionally, these figures show that the leaching after 30 years follows an exponential decay curve. This observation is confirmed by Figures I-5 and I-6 in which the leachate profiles (after 30 years) for lead and copper (filter aids waste stream, central tendency waste amount) have been plotted on a logarithmic scale. These figures show that the log (C_L) versus time falls on a straight line. Lead and copper were chosen because they represent two extreme cases in Figure I-2.

To use the existing metals finite source option in the EPACMTP model, two critical parameters need to be specified: (1) the finite source ratio C_w/C_L^0 (waste concentration over initial leachate concentration), and (2) the initial leachate concentration, C_L^0. The value of C_L^0 was chosen to be the leachate concentration 1 year after the end of the landfill operational life; that is at a time of 31 years. This C_L^0 would correspond to the initial value in Figures I-5 and I-6 or the initial concentration in the decaying part of the curve in Figures I-2, I-3, and I-4. To

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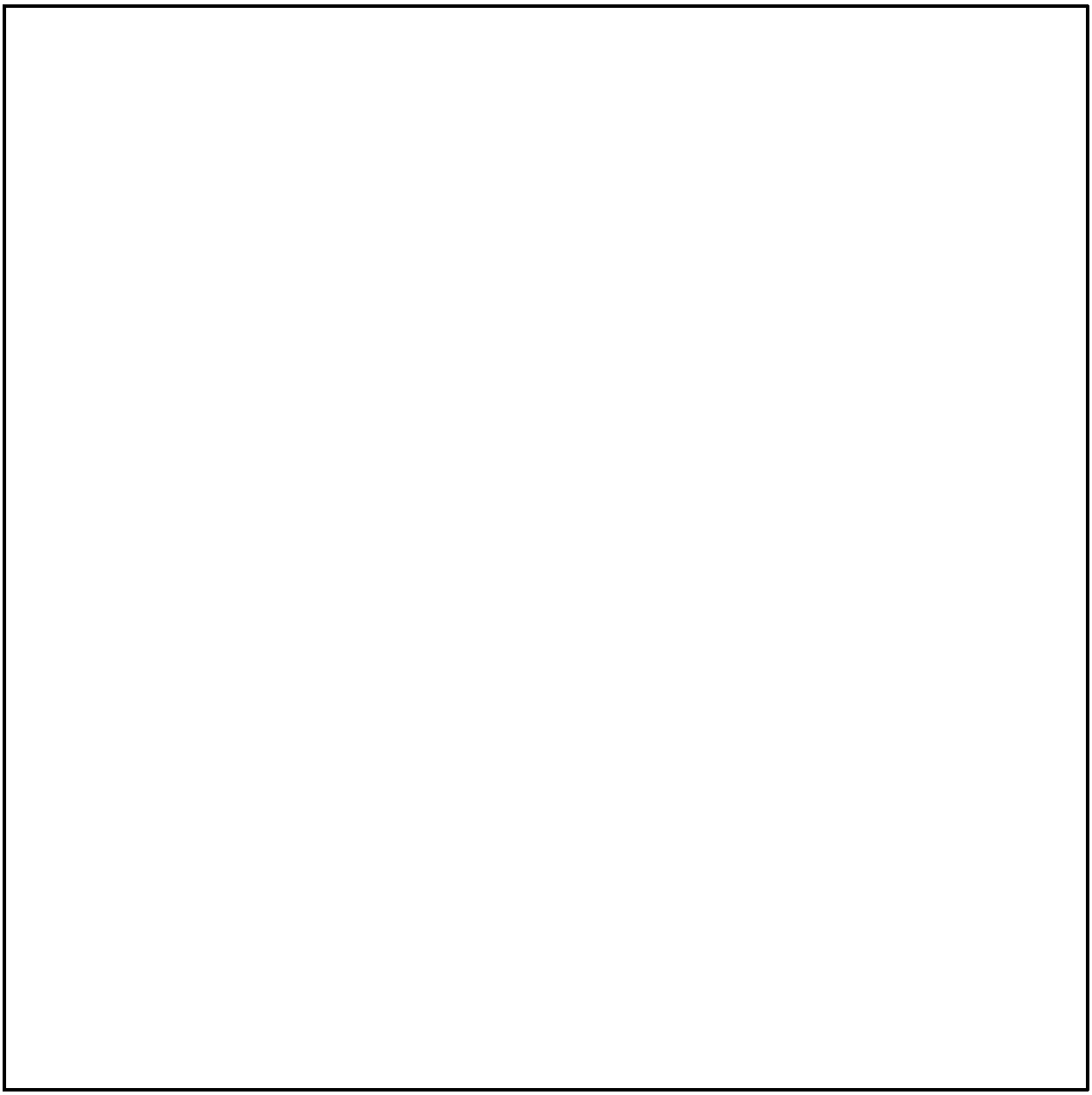

Figure I-1. Nonlinear isotherms for metals.*

*Relevant data are not included at present because of business confidentiality concerns.

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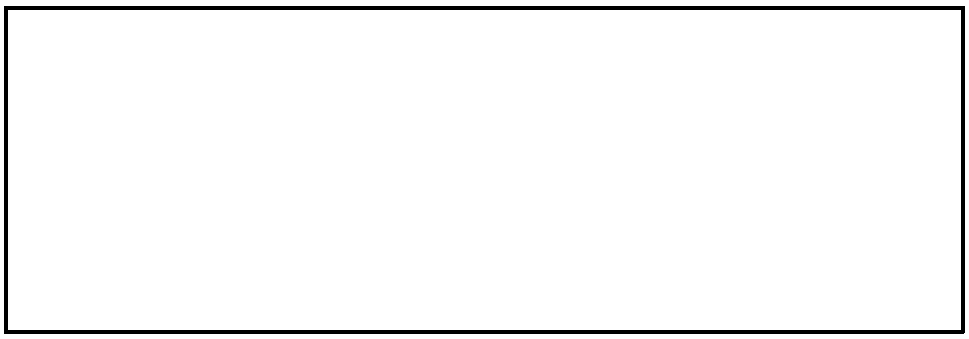

Figure I-2. CT leachate concentration for metals in filter aids waste stream.*

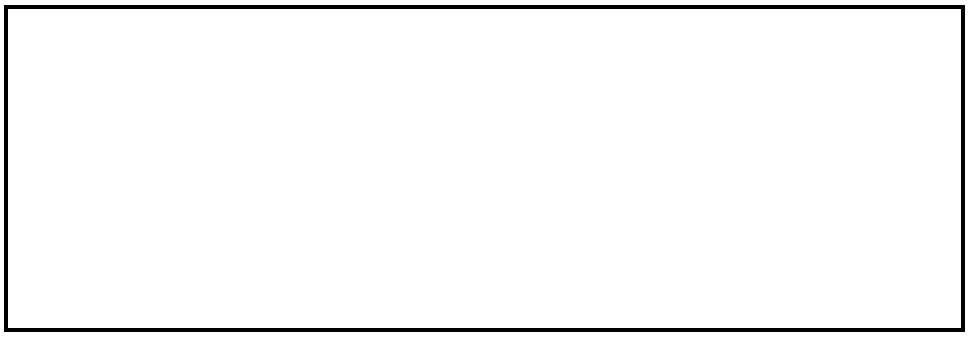

Figure I-3. HE leachate concentration for metals in filter aids waste stream.*

Figure I-4. CT leachate concentration for metals in filter aids waste stream.*

*Relevant data are not included at present because of business confidentiality concerns.

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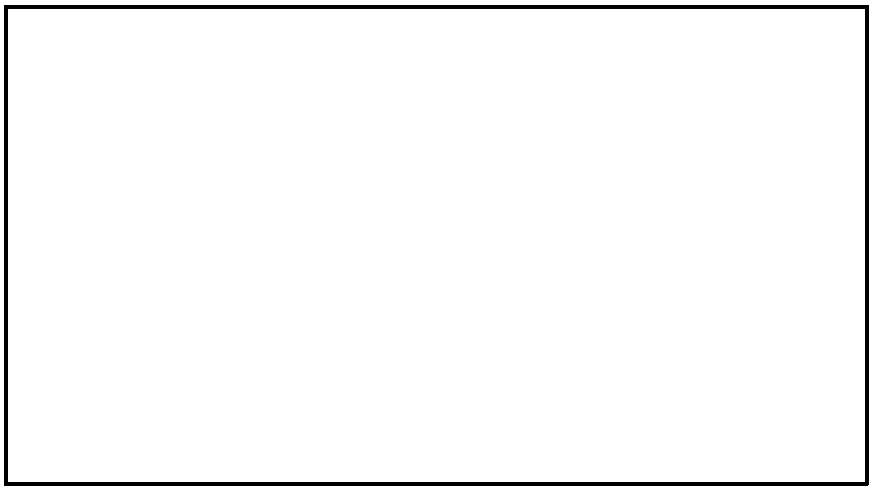

Figure I-5. Leachate concentration for lead on a semi-log scale.*
(initial 30-year period omitted)

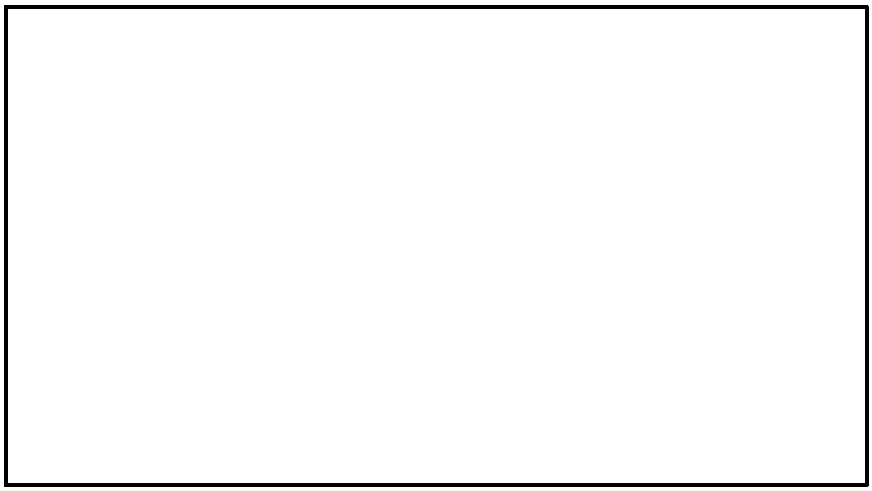

Figure I-6. Leachate concentration for lead on a semi-log scale.*
(initial 30-year period omitted)

*Relevant data are not included at present because of business confidentiality concerns.

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evaluate the ratio C_w/C_L^0, a comparison is made between the log C_L versus time with the physical depletion model (U.S. EPA, 1996a):

$$C_L = C_L^0 \exp\left[- \frac{I}{dF_h P_{hw} (C_w / C_L^0)} t \right] \quad \text{(I-1)}$$

where

I	=	infiltration rate (m/yr)
d	=	depth of waste unit (m)
F_h	=	volume fraction of waste unit that contains the waste of concern
P_{hw}	=	density of waste (g/cm^3).

The slope, *b*, in the graph of log C_L versus time should be equal to the bracketed term above:

$$b = - \frac{I}{dF_h P_{hw} (C_w / C_L^0)} \quad \text{(I-2)}$$

Thus, the ratio C_w/C_L^0 can be calculated by rearranging Equation I-2:

$$\frac{C_w}{C_L} = - \frac{I}{d F_h P_{hw} b} \quad \text{(I-3)}$$

where *b* (< 0.0) can be readily found from the leachate data, and the other parameters are all known a priori. The C_L^0 and C_w/C_L^0 values obtained in this manner guarantee that the finite source modeling preserves the total leachate mass in the original leachate data, assuming that the mass leached out during the first 30 years is negligible.

For arsenic and chromium, the two metals with linear sorption isotherms, the modeling methodology is the same as for organic constituents. The C_L^0 and C_w/C_L^0 calculated above are used as the initial leachate concentration and finite source ratio. For these two metals with linear adsorption, the landfill depleting source option is employed instead of finite square pulse, which is used for metals with nonlinear isotherms.

Table I-2 presents the resulting C_L^0 and C_w/C_L^0 values for both the central tendency waste amount and high-end waste amount cases for the filter aids waste stream. Table I-3 shows the C_L^0 and C_w/C_L^0 values for the central tendency waste amount for the TAM sludges waste stream.

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Table I-2. Effective C_L^0 and C_w/C_L^0 for Metals in Filter Aids Waste Stream

Metal	Isotherm Type	CT Waste Amount		High-End Waste Amount	
		C_L^0 (mg/L)	C_w/C_L	C_L^0 (mg/L)	C_w/C_L
Relevant data are not included at present because of business confidentiality concerns.					

Table I-3. Effective C_L^0 and C_w/C_L^0 for Metals in TAM Sludges Waste Stream

Metal	Isotherm Type	CT Waste Amount	
		C_L^0 (mg/L)	C_w/C_L
As	Linear	0.2670	29,933
Ba	Nonlinear	0.0877	8,988
Cr(VI)	Linear	0.0631	127,180
Cu	Nonlinear	0.8250	8,755
Ni	Nonlinear	0.3552	22,453
Pb	Nonlinear	0.0596	134,660
V	Nonlinear	0.0537	149,620
Zn	Nonlinear	1.3018	5,996

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I.2.4 Summary of Simulation Procedure for Metals

The deterministic analysis for metals consists of two modeling runs for each constituent: a central tendency run and a two-parameter high-end run. This modeling is conducted as follows:

For each metal, input parameters are set to their appropriate values; these parameter values are listed in Table I-4. For the central tendency scenario, all input parameters are set to their central tendency (median) values. For the high-end scenario, the two most sensitive parameters are set to their high-end values and the remaining input parameters are set to their central tendency values. Note that the depth of the receptor well intake point (Z-well) is set equal to the smaller of 5.0 m and half the aquifer thickness. This treatment of Z-well is the same as is used for the deterministic analysis for organics.

For each metal, the appropriate values for C_L^0 and C_w/C_L^0 (as listed in Tables I-2 and I-3) were specified and the leaching duration (TSOURC) is specified to be derived by EPACMTP; that is, leaching continues until all contaminant mass has been depleted. For metals with a linear isotherm, IBAT is set to 2 (physical depletion); this is the same setting as is used for the deterministic analysis conducted for organics. For metals with nonlinear isotherm, IBAT is set to 0 (finite pulse leaching). EPACMTP is then run to obtain the desired receptor well concentrations (peak and 9-year or 30-year averages).

The peak and appropriate time-averaged groundwater DAF^{GW} are then calculated for each metal. For metals that are noncarcinogens, the DAF^{GW} is defined as the ratio of peak leachate concentration and the peak receptor well concentration. For metals that are carcinogens, the DAF^{GW} is generally defined as ratio of the maximum 9-year average leachate concentration and the corresponding maximum 9-average receptor well concentration. However, when exposure duration is one of the high-end parameters, the DAF^{GW} is defined as the ratio of the maximum 30-year average leachate concentration and the corresponding maximum 30-average receptor well concentration.

1.3 Deterministic Modeling Results and Discussion

Tables I-5 and I-6 summarize the results of deterministic analysis of metals for the filter aids waste stream for the central tendency scenario and the two-parameter high-end scenarios, respectively. Because of the nonlinear nature of the isotherms for many of the metals included in this analysis, the leachate concentration, receptor well concentration, leaching duration (TSOURC), and peak arrival time are listed in addition to the DAF^{GW} values. Tables I-7 and I-8 present these results for the TAM sludges.

After careful examination of Tables I-5 through I-8, one can draw the following conclusions:

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Table I-4. EPACMTP Input Parameters for Deterministic Modeling of Metals

	Filter Aids	TAM Sludges

Relevant data are not included at present because of business confidentiality concerns.

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Table I-5. Results from Central Tendency Analysis for Metals in Filter Aids Waste Stream

Metal	Type	C_L[a] (mg/L)	C_{RW} (mg/L)	DAF_{GW}	Source Duration (years)	Time to Peak (years)

Relevant data are not included at present because of business confidentiality concerns.

Table I-6. Results From Two-Parameter High-End Modeling for Metals in Filter Aids

Metal	Type	2 High-End Parameters	C_L[a] (mg/L)	C_{RW}[a] (mg/L)	DAF_{GW}	Source Duration (Years)	Time to Peak (Years)

Relevant data are not included at present because of business confidentiality concerns.

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Table I-7. Results from Central Tendency Analysis for Metals in TAM Sludges Waste Stream

Metal	Type	C_L[a] (mg/L)	C_{RW}[a] (mg/L)	DAF_{GW}	Source Duration (years)	Time to Peak (years)
Pb	NC	5.96E-02	0.00E+00	1.E+30	13,001	10,000[b]
Ni	NC	3.55E-01	2.14E-03	166	2,168	4,354
Ba	NC	8.77E-01	6.04E-03	145	868	978
V	NC	5.37E-02	0.00E+00	1.E+30	14,445	10,000[b]
Cu	NC	1.48E+00	0.00E+00	1.E+30	516	10,000[b]
Zn	NC	1.30E+00	2.81E-04	4,639	579	8,786
As	C	2.67E-01	1.18E-03	227	2,890	3,751
Cr (VI)	NC	6.31E-02	3.84E-04	165	12,278	2,973

[a] C_{Leach} and C_{RW} refer to time average for carcinogen (C) and peak values for noncarcinogen (NC).

[b] Plume never reached receptor well during the 10,000-year simulation period.

Table I-8. Results from Two-Parameter High-End Modeling for Metals in TAM Sludges

Metal	Type	2 High-End Parameters	C_L[a] (mg/L)	C_{RW}[a] (mg/L)	DAF_{GW}	Source Duration (years)	Time to Peak (years)
Pb	NC	X-well and Y-well	5.96E-02	0.00E+00	1.E+30	13,001	10,000[b]
Ni	NC	X-well and Y-well	3.55E-01	9.62E-02	3.7	2,168	3,476
Ba	NC	X-well and Y-well	8.77E-01	2.38E-01	3.7	868	659
V	NC	X-well and Y-well	5.37E-02	0.00E+00	1.E+30	14,445	10,000[b]
Cu	NC	X-well and Y-well	1.48E+00	0.00E+00	1.E+30	516	10,000[b]

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Zn	NC	X-well and Y-well	1.30E+00	2.28E-02	57.2	579	6,906
As	C	X-well and exposure duration	2.67E-01	7.07E-02	3.8	2,890	3,710
Cr (VI)	NC	X-well and Y-well	6.31E-02	1.63E-02	3.9	12,278	1,992

[a]C_L and C_{RW} refer to time average for carcinogen (C), and peak values for noncarcinogen (NC).

[b]Plume never reached receptor well during the 10,000-year simulation period.

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- For the given input parameters, lead, vanadium, and copper are strongly adsorbed under both central tendency and two parameter high-end cases regardless of the waste stream considered. None of these three metals reached the receptor well within the 10,000-year simulation period.

- All metals are characterized by long travel times that are directly proportional to the magnitude of the effective K_d for each metal (compare Figure I-1).

- For a given scenario, the DAF^{GW} values do not vary much with metals except for lead, vanadium, copper, and zinc. Furthermore, for a given scenario, the DAF^{GW} values of most metals are comparable to those of organics.

- The DAF^{GW} for zinc is always greater than the corresponding DAF^{GW} values for nickel, barium, arsenic, and chromium. This may be explained by the relatively shorter leaching duration and longer travel time for zinc as compared to that of nickel, barium, arsenic, and chromium. A longer travel time and shorter leaching duration lead to more rapid dilution of the plume, resulting in larger DAF^{GW} for zinc.

I.4 Risk-Based Concentrations for Metals

Tables I-9 and I-10 present the results from the high-end deterministic analysis.

Table I-9. TAM Results

Constituent	CAS No.	K_d (mL/g)	Receptor Well Concentration (adult) (mg/L)	High-End DAF	Estimated Leachate Concentration (mg/L)	Waste Concentration (mg/kg)
Lead	7439-92-1	900	NA	1.E+30	NA	NA
Nickel	7440-02-0	150	1	3.7	3.7	103,556
Arsenic	7440-38-2	200	0.001	3.8	0.0038	141
Barium	7440-39-3	60	3.5	3.7	12.95	147,098
Chromium VI	7440-47-3	850	0.25	3.9	0.975	153,403
Copper	7440-50-8	35	NA	1.E+30	NA	NA
Vanadium	7440-62-2	1000	0.35	1.E+30	NA	NA
Zinc	7440-66-6	40	15	57.2	858	>1,000,000

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NA = Not applicable.

Note: Arsenic is treated as a carcinogen and two high ends are X-well distance and exposure duration. All other constituents are noncarcinogens and two high ends are X-well distance and Y-well in center of plume.

Table I-10. Filter Aid Results

Constituent	CAS No.	K^d (mL/g)	Receptor Well Concentration (adult) (mg/L)	High-End DAF	Estimated Leachate Concentration (mg/L)	Waste Concentration (mg/kg)

Relevant data are not included at present because of business confidentiality concerns.

I.5 References

Allison, J.D., D.S. Brown, and K.H. Novo-Gradic. 1991. *MINTEQA2/PRODEFA2, A Chemical Assessment Model for Environmental Systems: Version 4.0 User's Manual*. EPA/600/3-91/021. U.S. Environmental Protection Agency, Athens, GA.

Carsel, Robert and Rudolph Parrish. 1988. Developing joint probability distributions of soil water retention characteristics. *Water Resources Research* 25(5):755-769.

Carsel, Robert, et al. 1988. Characterizing the uncertainty of pesticide leaching in agricultural soils. *Journal of Contaminant Hydrology* 2:111-124.

Kollig, Heinz, editor. 1993. *Environmental Fate Constants for Organic Chemicals under Consideration for EPA's Hazardous Waste Identification Projects*. U.S. Environmental Protection Agency, Environmental Research Laboratory, Office of Research and Development, Athens, GA.

Loux, N. T., C. R. Chafin, and S. M. Hassan. 1990. *Statistics of Aquifer Material Properties and Empirical pH-dependent Partitioning Relationships for As (III), As (V), Ba(II), Cd(II), Cr(VI), Cu(II), Hg(II), Ni(II), Pb(II), Sb(V), Se(IV), Tl(I), and Zn(II)*. Office of Research and Development, U.S. Environmental Protection Agency, Athens GA.

US EPA ARCHIVE DOCUMENT

U.S. EPA (Environmental Protection Agency). 1988. *Draft National Survey of Solid Waste (Municipal) Landfill Facilities*. EPA/530-SW-88-034. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1993. *Parameter Values for EPA's Composite Model for Landfills (EPACML) Used in Developing Nationwide Regulations: Toxicity Characteristic Rule*. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1996a. *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) Background Document*. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1996b. *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) Background Document for the Finite Source Methodology*, Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1996c. *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) Background Document for Metals*. Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1997a. *EPA's Composite Model for Leachate Migration with Transformation Products (EPACMTP) User's Guide*, Office of Solid Waste, U.S. EPA, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1997b. *Analysis of Subtitle D Waste Management Units Databases Used in the Groundwater Pathway Analysis for HWIR*. Office of Solid Waste, U.S. EPA, Washington, DC.

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