Appendix A

Cement Kiln Dust Peer Review

Draft Risk Assessment for Cement Kiln Dust Used as an Agricultural Soil Amendment
Draft Report
EPA Reference DW 12938494-01-0

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Summary

The Peer Review Committee **(PRC)** was given five objectives for their review of the EPA Risk Assessment for the Use of Cement Kiln Dust as an Agricultural Liming Agent:

1) Review and comment on the assumptions used for application practices including application rate and frequency, duration of application and depth of incorporation. Provide advice on alternate, more appropriate parameters.

2) Plant soil bioaccumulation factors (Br) for metals were obtained from the Technical Support Document for Land Application of Sewage Sludge. Evaluate the use of these Br values for assessing risks from agricultural use of CKD. Discuss any alternative, more appropriate Br factors.

3) Evaluate and comment on the use of: a) MINTEQ modeling to determine metals speciation; b) Jury equations to determine dioxin and metal partitioning in soil; and c) the ISCST3 model for air dispersion and deposition.

4) Comment on how phytotoxicity and ecological risk are addressed in the analysis. Provide recommendations on appropriate alternative method(s).

5) Evaluate and comment on the uncertainty/variability analysis conducted in support of the point risk estimates.

In the review process, a thorough editing of all aspects of the document was completed and is provided for the benefit of the EPA.

The PRC commends the EPA for producing the risk assessment as there is a strong need for the information that is presented. The procedures that were followed were sufficiently rigorous for the task at hand. The use of the deterministic approach supplemented by the probabilistic approach is the appropriate methodology for this situation. In general, the probabilistic approach was supportive of the deterministic approach, which lends credibility to the overall risk assessment.

The PRC concluded that the intent of the document was not explicitly stated nor was it inherently obvious after the review was completed. Analogies are drawn to the *Technical Support Document for the Land Application of Sewage Sludge,* but that document had a clear purpose in setting regulatory limits on application rates for sewage sludge and contaminants. No such conclusions are made in the CKD risk assessment. Similarly, the CKD risk assessment is not a risk assessment methodology or guidance document.

Four receptor scenarios were considered for a number of inorganic contaminants and dioxins. A serious deficiency is the lack of presentation of a screening procedure that was used to select the chemicals of concern and the receptor scenarios. Several potentially important omissions include B, Co, Cu, Mo, and Zn. If these or other contaminants were considered, the identity of those substances should be presented along with the rationale for their elimination from further consideration. Likewise, all receptor scenarios that were considered should be presented along with the rationale for their elimination from further consideration. For example, the risk assessment indicates that Pb may be a problem, which suggests that a pathway considering the conversion of CKD-amended land to residential use should be considered.

Objective 1:

The assumptions used for application practices including application rate and frequency, duration of application, and depth of incorporation for acidic soils are generally correct. The risk assessment needs to take into account the real possibility that the CKD application rate may be high enough to raise the soil pH above 7.0. Assumptions on the distribution of soils that would be candidates for CKD applications were not correct. There is a large area of soils that would be candidates for CKD applications that were not considered in the risk assessment. This problem is a result of using out-dated soils information at too large of a scale. More recent soil classification information applied on a smaller scale would help correct this deficiency. Similarly, the assumption limiting the use of CKD to within 20 miles of the point of application seems arbitrary and excludes many areas that are reasonable sites for CKD application.

Objective 2:

The use of plant soil bioconcentration factors (Br) for assessing the risk from agricultural liming use of CKD is acceptable. The only realistic alternative would be the use of uptake slopes, but it is recognized that there is not sufficient data for this type of analysis.

The PRC felt that the use of Br factors from the *Technical Support Document for Land Application of Sewage Sludge* was not appropriate, but admits that there are few alternatives. The matrix for sewage sludge would be completely different than CKD due to the presence of organic materials and other constituents that may act as metal adsorbents. The EPA is encouraged to take the required steps to gather the data that is needed to calculate Br values from CKD amended soils, The EPA is also encouraged to investigate the use of data for materials that are more similar to CKD than sewage sludges, such as coal fly ashes, wood ash, or flue-gas desulfurization by-products.

Objective 3:

It is difficult to evaluate the use of MINTEQ modeling to determine metals speciation. Some of the Kd values for metals were estimated with MINTEQ (Ag, Ba, Be, Cd, Hg, Ni) some were based on empirical relationships (As, Cr, Se, TI), and for others (Pb, Sb) it is not clear how **Kd** values were obtained. It is clear that some of the assumptions that were used in the modeling are questionable. In particular, the emphasis on iron oxides as adsorbents is unrealistic for the

elements considered with MINTEQ, but would seem more realistic for elements that exist as oxyanions (As, Cr, Se) for which empirical relationships were used. The net effect is difficult to ascertain but it would seem likely that the approach used would under predict **Kd** values, and therefore over predict risk, if the appropriate input data were used. It is also concluded that site-specific soil parameters were not risk drivers, although the rationale for this statement is not clearly presented.

The use of the Jury equations to determine dioxin and metal partitioning in soil is justifiable. Some errors were found, as noted in the specific comments.

The use of the ISCST3 Gaussian-plume model for air dispersion and deposition seems appropriate. The simulations are conducted with standard software that was not available to the PRC members. While the outcome cannot be verified by actual measurements, in this case, model simulation is appropriate because there is no other reliable way of estimating. The assumptions used in developing the exposure scenarios and selecting input data to calculate fluxes and concentrations were in general cautious. The end result of parameter estimation would therefore be conservative. If there is fault with this estimation, it would have to be on the potential of overestimating concentrations of airborne substances due to volatilization, wind erosion, and tillage operations. As a result, the subsequent calculations on vapor adsorption and foliar deposition of dioxin and metals could be overestimated. The authors report that many parameters such as soil texture and size of the application field had no significant effect on the outcome, which indicated that concentration estimates of airborne pollutants would remain essentially a function of the CKD application rates.

Objective 4:

The PRC concluded that the methods for assessing phytotoxicity and ecological risk are inadequate. The use of benchmarks from the *Technical Support Document for Land Application of Sewage Sludge* is not appropriate. The PRC recommends a literature review for ecological benchmarks of ecological risk assessments for metals from various sources and dioxins. The information presented should be summarized in a table to facilitate the comparison with soil contaminant concentrations from this risk assessment. There have been a number of ecological risk assessments performed for metal contaminated sites that can be used as a guide for ecological benchmarks for soil and phytotoxicity.

Objective *5:*

Descriptions and discussions of the Monte Carlo simulations were scattered throughout the document, making it difficult to get a comprehensive picture on how the simulations were run. As the computational algorithms for Monte Carlo simulations are relatively straightforward, the usefulness of the results are entirely dependent on the appropriate selection of parameters and the range and distribution of the data. With few exceptions, the simulations seemed reasonable. The presentation of the results could be improved in places, as noted in the specific comments.

Recommendations

1) Clarify the intent of the document.

2) Present a complete list of receptor scenarios and rationale for selecting the four scenarios for further development.

3) Present rationale for selecting chemicals of concern.

4) Include list of abbreviations and glossary.

5) Correct deficiencies with Jury equations and any associated problems.

6) Update soils information.

7) Provide suitable limits for metals and organic chemicals in CKD and for the lifetime of applications.

8) Use suitable approach for ecological risk assessment and repeat ecological risk assessment.

7) Review editorial comments and make changes as necessary.

Table of Contents

Detailed Review

Although an analysis of uses of CI(D is important, it should be stated up front that the risk assessments conducted for this document are specific to application of CKD as a liming material and not for any other purpose. The title may need to be changed to read “Draft Risk Assessment for Cement Kiln Dust Used as a Soil Liming Amendment.”

This is one of many risk assessment documents produced by EPA. The PRC hopes that the authors will participate in recent efforts by EPA to standardize the presentation.

Several formatting changes and additions will help the presentation of material. A list of abbreviations is a critical need. A glossary would be helpful to some readers. Please identify the subsections in the table of contents and check page numbers for accuracy. Provide a list of figures and improve the table captions so that they are self-explanatory.

There are several potentially important omissions in the risk assessment. One is handling, processing, storage and transport of CKD and the assumption that there is negligible risk from these activities. The handling issues are indirectly related to agricultural operations, but are important and potentially a substantial risk. The dusts can be quite caustic and difficult to handle. Salinity/sodicity issues can also be a problem, particularly for germination. Timing of CKD applications, management practices, and weather can be important variables. Preventing negative outcomes from the use of CKD is in everyone’s best interest.

In the summary section there was a brief description of the Monte Carlo simulation method and its limitations. In the main text of the document, the discussions of Monte Carlo simulations were scattered in various sections and were integrated into the general discussions on selection of data, exposure scenarios, and pathways. As the computational algorithms for Monte Carlo simulation are relatively straightforward, the usefulness of the results is entirely dependent on a reasonable selection of parameters and data range and distribution, With the way the document is organized, it was difficult to get a comprehensive picture on exactly how the simulations were run. For example, how many parameters were involved and what ranges and distributions were used for a given simulation. It was also not clearly explained why a triangular distribution was used instead of another type of distribution.

Chapter 1 Summary

General:

The PRC felt the summary was not very informative. The overall purpose of the document is not clear. At this point the reader cannot discern whether this is a risk assessment methodology document (descriptive), a risk assessment guidance document (prescriptive), a basis for regulations, or simply a risk assessment to determine if unacceptable risk results from the land application of CKD. It is clear that some risk assessment results have been generated, and as a summary it would seem that some measure of the risk associated with the use of CKD in terms of human health, phytotoxicity, and ecology should be presented in terms understandable to the lay person. In particular, the establishment of regulatory cutoff levels is mentioned yet these values are not present in the document (this mention of regulatory cutoff levels further confuses the reader as to the purpose of the document). The risk assessment really only covers the use of CKD as a liming material and this should also be clarified in this section. The addition of the word liming in the first sentence (... an agricultural soil liming amendment.) would help considerably.

Four receptor scenarios are presented, but it is never clear how these were selected for the detailed risk assessment that follows. What other scenarios were considered and why were the four presented here developed further?

Specific:

The references need some work. The reference for EPA 1988 should be either 1988a, 1988b, or 1988c. There is no EPA 1989 in the list of references.

Chapter 2 - Characterization of CKD

General:

The description of the samples used for the characterization data is lacking. The reference used (1996d) is incomplete so it would not be possible for someone to verify the data. Samples were collected from some 20 facilities, 10 that burned hazardous waste and 10 that did not, but there is no way to tell what proportion of the analyzed samples were from facilities that burned hazardous waste. Of the 11 samples analyzed for dioxin, for example, one could not be sure that only a single sample was analyzed from a hazardous waste burning facility. It is also not sufficient to say that metals were analyzed for 15 facilities (or dioxin for 11) because that does not indicate how many samples were analyzed in total for metals or dioxins. Were multiple samples run from one facility? There is a discrepancy between a description provided in Appendix C and the sample description in this section. On page 6 in Appendix C, reference is made to data for dioxins from 14 facilities and 63 facilities for metals. The data in Table 2, Appendix C, and Table 2-1 are nearly identical, suggesting the same data, but the descriptions do not match. The characterization of CKD is critical to this document, and the authors should carefully describe the samples that were used to ensure credibility.

There is no rational presented for the selection of the metals that are covered in the risk assessment. Several potentially important omissions include B, Co, Cu, Mo, and Zn. Were concentrations of these elements not determined in the samples that were analyzed? Were the concentrations below the detection limits of the elements listed above? Was there some other specific reason for the absence of these elements?

Specific:

Table 2-1 has a zero for the median Hg concentration. If this table is supposed to agree with Table 2 in Appendix C then this value should be 0.1. Define the meaning of” --“ for the background soil concentration for Cd. The background soil concentration for Ag and Tl can not be zero. Select another reference if Dragun and Chiasson does not have values for these elements.

The reference to USEPA 1996b does not agree with the USEPA 1996d given on page 3.

The reviewers question the use of significant digits in Table 2-2. To state a concentration of 0.00188 ppb implies that you can distinguish between 0.00188 and 0.00189 ppb, which generally cannot be done.

Chapter 3.0 - Agricultural Liming Practices

General:

There are some deficiencies in the methods used to select sites and soils that would be suitable candidates for CKD applications. The authors are incorrect in assuming that liming materials would only be required on soils that were classified as generally acid by the 1968 data from the USDA (Figure 3-2). Cultural practices can produce acidic soils in areas noted as neutral or transitional or even generally alkaline according to the classification scheme used here. For example, the use of ammoniacal nitrogen fertilizers has produced large areas with acidic soils in the Central Plains that would not be considered in this risk assessment. For example, Kansas and Oklahoma are not included in Table 4, Appendix C, because they do not have soils classified as generally acid, yet there is a strong demand for liming materials in these two states. These improper assumptions are made worse by the use of outdated soil classification information. The data used to generate Figure 3-2 are over 30 years old and the terminology that is presented is not used anymore. The NRCS has soil classification data readily available at http://www.ftw.nrcs.usda.gov/ssur_data.html that includes the SSURGO database that would probably be the most appropriate for this application. Given the expanded region having soils that could receive CKD, some consideration needs to be given to climatic data used in the risk assessment. The rainfall and temperature distributions in the central plains are quite different than in the locations that were considered. There is no sensitivity analysis to indicate the effects of climatic data inputs on outcomes of estimation.

Specific:

Page 7. The assumption regarding the use of CKD on low p1-I soils should be stated in the summary.

Table 3-1. This table lists the high end deterministic values for tillage depth as lower than the central tendency value whereas Table 5, Appendix C, has the high end tillage depth as higher than the central tendency. Please clarify.

Page 8. What is meant by “tilling is assumed for 15 days per year?” Fifteen tillage operations? This might be appropriate for CKD used on a home garden, but would not be correct for typical crop production practices. What about the use of CKD with reduced or no-till practices where the material may not be incorporated or may only be incorporated a few inches?

Page 9. Please include a figure caption and label the axes. The 100 year lifetime is different than used in the sensitivity analysis (Appendix C). Please explain.

Table 3-3. Soil texture information should be supplied. The worst case scenario for land application of CKD would be a coarse-textured soil with the saturated zone near the surface. Why was Indianapolis, IN eliminated from consideration?

Page 10. To limit the use of CKD to within 20 miles of the place of production seems arbitrary. What is the basis for this limitation? A larger radius should be considered.

Chapter 4.0 - Fate and Transport in the Environment

General:

This section covers the basics of fate and transport for organic and inorganic contaminants in CKD. It is not clear how Kd values were obtained for Pb and Sb since it is specifically mentioned that MINTEQ was used for Ag, Ba, Be, Cd, Hg, and Ni and empirical relationships were used for As, Cr, Se and TI. No references are cited for the empirical relationships for Kd values for As, Cr, Se, and Tl and they should be provided. In particular, the relationships indicate As adsorption increases as pH increases and this runs contrary to what chemistry would suggest for anionic compounds that do not form insoluble precipitates at a high pH. The most likely oxidation state for As in surface soils would be V as arsenate and not III as arsenite. The reviewers disagree with the statement that the geochemistry for As, Cr, and Se is poorly understood as considerably research has been done with each of these elements. Some assumptions used in the MINTEQ modeling are questionable, but the net effect would seem to be to overestimate risk. Given the assumptions that were used and the conclusion that site-specific soil parameters were determined not to be risk drivers, it seems unlikely that correcting the assumptions will change the overall outcome of the risk assessment.

The approach used for dioxin and metal partitioning in soil using the Jury equations appears reasonable with the exception of the errors noted on pages 8 and 9.

A standard approach was used to determine risk from PM_{10}. The authors might want to consider recent emphasis on PM_{25} in addition to PM_{10}. It is not clear whether the inhalation pathway risk was due to contaminants in the PM_{10} or from the PM_{10} itself If the risk was for contaminants associated with PM_{10} then the assumptions regarding enrichment factors (PM_{I0} versus whole soil contaminant concentrations) need to be stated.

The use of Br factors from the *Technical Support Document for Land Application of Sewage Sludge* is inappropriate, although the reviewers are not aware of data dealing specifically with CKD. The matrix for biosolids would be completely different than CKD due to the presence of the organic materials and other constituents that may act as metal absorbents. The Br values used in California Department of Food and Agriculture (1998), a risk assessment for As, Cd and Pb in inorganic fertilizers, are generally higher than those presented here. Many of the Br values presented in the California report are derived from studies using inorganic salts, illustrating the influence of the source of the element. It is not likely that plant uptake studies using inorganic metal salts would be more appropriate for CKD than those from biosolids. Alternatively, metal uptake studies using coal fly ash, wood ash, or flue-gas desulfurization by-products would also seem more appropriate than studies utilizing biosolids. There is also a problem with the terms and abbreviations used for the plant-soil bioconcentration factor. In other places it is called the plant biotransfer factor and either Br or BCF are used as the abbreviation. These should be uniform throughout the document.

The atmospheric concentrations of CKD constituents were used to estimate the exposure risk to airborne metals and dioxins at the application site. The estimations were entirely based on hypothetical situations and model calculations and therefore it would be difficult to reviewers of this document to comment on the accuracy of the results without repeating all of the model simulations. We chose to comment on the appropriateness of the simulation models, exposure scenarios, and input data. The general considerations were:

1) Exposure to airborne CKD constituents: direct inhalation by farmers, vapor uptake by plants, and dry deposition of particulates to plants. Exposure due to dispersion to offsite locations is not significant.

2) Pathways: volatilization, emissions due to wind erosion, and emissions due to agricultural tilling.

3) Emission estimation methods: volatilization was based on the Jury partition model while particulate emissions were based on two empirical equations for estimating PM_{10} and PM_{30} from wind erosion and tilled fields.

4) Air dispersion and deposition: Gaussian plume model ISCST3 was used to estimate vapor concentration and dry deposition rates (default option was used).

The assumptions were:

1) Fields are not covered by continuous vegetation or snow and surface soil has an unlimited reservoir of erodible surface particles.

2) Silt contents ranging from 3 to 87% has no significant influence on the risk estimation.

3) Fields tilled for 730 hours.

4) No dry deposition on rainy days and wet deposition is negligible.

5) Three field sizes: 800 m x 800 m, 950 m x 950 m, 1150 m x 1150 m.

6) Climatic data from Alpena, MI; Indianapolis, IN; and Miami, FL.

In this estimation, outputs from Jury's model (dioxin vapor fluxes) and results from calculations by two empirical equations (for airborne particulate fluxes due to wind erosion and agricultural tillage) were linked with ISCST3 to obtain the actual air concentration estimates. The models used in the simulation were all standard models (except Jury's transport model) used by federal agencies. While the outcome cannot be verified by actual measurements, in this case, model simulation is appropriate because there is no other reliable way of estimating. As the assumptions used in developing the exposure scenarios and selecting input data to calculate fluxes and concentrations were in general cautious (such as 730 hours of tillage time), the end results of parameter estimation would therefore be conservative. If there is a fault with this estimation (if geographical location of the application site is not an issue), it would have to be on the potential of over estimating concentrations of airborne substances due to volatilization, wind erosion, and tillage operations. As a result, subsequent calculation on vapor adsorption and foliar deposition of dioxin and metals (or concentration in plants) could be over estimated. Generally, an overestimation may be compensated by conducting a Monte Carlo simulation which takes into consideration the distribution of parameter values. In this case, the authors of the document reported that many parameters such as soil texture and the size of the application field had no significant effect on the outcome. The concentration estimations of airborne pollutants would remain essentially a function of the CKD application rates.

Specific:

Page 20. Target pH values for corn would be between *6.5* and 7.0, not 6.0 as stated here. An upper-end pH as high as 8.3 would be more reasonable given the reaction that occurs when CKD is added to soil. The pH will increase considerably at first, to values in excess of 9.0, and then conversion of Ca(OH)2 to CaCO3 will reduce the pH to approximately 8.3 while equilibrium with CaCO3 is maintained. Some farmers do apply liming materials in excess of their needs, which suggests that soil pH levels may be maintained at values greater than 7.0 for significant periods of time.

Page 20-21. The emphasis on iron-oxide content seems to be driven by the fact that MJNTEQ can handle this adsorbent rather than by reality. The lack of consideration of clays as absorbents is a significant omission, but this is one of the assumptions that will over estimate risk (predict lower Kd values). Some speciation models (GEOCI-IEM, SOILCHEM) will handle clays and efforts could be made to utilize these models instead of MINTEQ. The cation exchange capacity of most of the soils being considered for CKD applications will be predominantly from the permanent charge in 2:1 clays and not the variable charge associated with Al and Fe oxides. Further compounding this problem is the use of a single value for the iron-oxide content (Table 3-3) for all soils. The NRCS soil characterization laboratory in Lincoln NE should have better data than what is used here.

Page 21. It is not reasonable to assume that soil pore water has a composition similar to that of rain. Similarly, the carbon dioxide concentration in the soil air is several hundred times that in the atmosphere. The considerable difference in carbon dioxide enrichment between rainwater and the soil solution results in a marked difference in the solubility of a number of elements and influences their speciation. For instance, the Ca concentration in the soil solution can be in the range of 0.005 to 0.01 M, which is many times higher than the value given in Table 4-2. If the actual soil solution composition is not known, average values from other locations should be used instead of rainwater,

Page 22. Be consistent with the use of units. You have used English (tons/acre) and metric (cm) units simultaneously.

Page 23. In some locations, a soil Pb concentration of 842 mg/kg would indicate soil remediation is necessary. This and other values in Table 4-3 seem too high. If one calculates the application of Pb in kg/ha from 14 applications at 2 tons/acre and a Pb concentration of 1346 mg/kg (95 th percentile) you get 85 kg/ha. In a 20 cm soil layer this translates into an increase in soil Pb concentration of approximately 57 mg/kg. What is the reason for using 14 applications at 2 tons/acre? The application rate is less than the central tendency shown in Table 3-1 and 14 applications doesn't agree with the application frequency and 100 year lifetime values that are used. Please explain.

Page 24. It is stated that the background soils for the three sites are characterized by large quantities of clays, yet Table 4-5 shows very high silt contents. Please clarify.

Page 24. The reviewers agree that it is reasonable to not consider competition between trace metals, but feel that competition between Ca and metals should be considered, Calcium would be high in these systems and the presence of high Ca levels would tend to decrease K_d values for the metals of concern.

Page 24. The use of an intermediate value for pH throughout the lifetime of the agricultural field does not simulate reasonable worst case scenarios. If one wants to conservatively estimate risk from cationic metals, the soil pH should be acidic, for example, which might occur when CKD is used for a period of time with no additional applications, followed by soil acidification. A soil pH of *5.0-5.5* would be better for assessing the risk from cationic metals.

Page 26. It would seem that equation 4-6 should multiply the concentration of contaminant in the CKD times the application rate rather than the soil concentration by the application rate. This has implications for equation 4-1 1 as well.

Page 27. Equation 4-8 should have exp(-kt). The minus sign on k was left out.

Page 27. This is a rather arbitrary way of calculating degradation. It assumes that we have no information on degradation rates, but have an experimental data base of environmental persistence values, which embody all of the effects that lead to dissipation of contaminant from soil. Degradation is estimated as the amount determined from this loss coefficient minus the calculated material losses from all other mechanisms. Why not calculate degradation directly from a degradation half-life? Although laboratory derived values of this parameter are crude, they will probably be at least as accurate as they are calculated in this document, and quite possibly more so. With the present approach, the validity of the expected loss of contaminant mass depends on whether or not the chosen $k\text{-}_{half}$ is correct. The data source for the $k\text{-}_{half}$ values should also be stated.

Page 28. The section at the top of the page is very confusing. All that is required is to state that the height of the soil does not increase with the added material. The reference to a subsurface layer that is not used is superfluous to the modeling discussion and very confusing.

Page 28. Provide the units for tillage depth in Equation 4-11.

Page 28. Equation 4-13 is only valid when $V_E = 0$ and cannot be added to a convective term to produce convective-dispersive volatilization.

Page 29. Equation 4-15 is wrong. To derive the equation you need, you must let $H_e \rightarrow \infty$, in equation 25 of Jury et al. (1983) which produces (in Jury's units):

$$J_s 9(0,t) = \tfrac{1}{2} C_o V_E \{ \mathrm{erft}\,[V_{ET}/(4D_{ET})^{1/2}] - \mathrm{erfc}\,[L+V_E t/(4D_{ET})^{1/2}] \} + C_o\,(D_E/\pi t)^{1/2}\,[\exp(-V_E^2 t/4D_E) - \exp(-(L+V_E t)^2/4D_e t)]$$

This reduces to Equation 4-13 when $V_E = 0$ and is correct when $VE \neq 0$. It is also not clear what the relationship is between the volatilization equations derived in this section and the volatilization transfer coefficient given in Appendix A on page Al .13. The latter is an empirical engineering correlation. There is also some question about assuming that $H_e \rightarrow \infty$ since some of the dioxins have low enough Henry's Law constants that they would accumulate in the boundary layer**.**

Page 31. Provide information on how these values were obtained from the Jury equations. What was the CKD application rate and frequency and what values were used for contaminant concentrations? What about metals?

Page 34. There is no soil classification for silty till shown in Table 4-5. Provide the source of data for that used in Table 4-6.

Page 35. We question the assumption that exposures from transporting, loading, and unloading CKD will be minimal compared to continuous releases from the agricultural field due to wind erosion and tilling. The CKD materials can be fine powders that can produce considerable dust during handling.

Page 35. There is some confusion regarding the site selection. Earlier the three sites were in MI, NY, and SC and now we have MI, IN, and FL. What soil data was used for this study?

Page 37. What does M-O represent in Table 4-7.

Page 40. Define Rp for Equation 4-21.

Page 41 and 42. References to Table 4-9 are not correct.

Page 42. Define Rp for Equation 4-23. Change the first minus sign to an equal sign.

Page 47. What is the source of the 0.01 empirical correction factor used to adjust the RcF values for barley roots? Is there a model available for bulky roots rather than trying to adapt a model for barley?

Page 50. The assumption that all soils in the watershed are the same is a poor one.

Page 51. The units do not work out for Equation 4-27. In the second term on the right side, area and concentration variables are missing and from the fourth term the conversion factor of 0.001 is missing.

Page 52. The enrichment ratios for metals are often >1.

Page 52.$S_{c,erode}$ is not defined for Equation 4-28. It must have units of mg/kg for the units in the equation to work out.

Page *53*. The units do not work out in Equation 4-30. The problem is with ($X_{e,SB}$ x SD_{SB}) in the numerator of the first term,

Page 56. Provide units for the Henry’s law constant, molecular weight, solubility and RfD in Table 4-16. Define all abbreviations used in this table.

Page *57*. Soil microorganisms are capable of methylating Hg, which is contrary to the statement made in the second paragraph. The reference to Table 4-14 in the third paragraph is not correct.

Page 58. Put (HQ) in the table heading.

Page 59, Provide references for the data in Tables 4-18 and 4-19.

Page *59.* The reference to Table 4-18 in the last paragraph should be to Table 4-20.

Page 61, There is no reason to have Pb vegetable concentrations in this table if they are all zero. There are too many significant digits for soil Pb concentration. How were the soil Pb concentrations obtained? Were there assumptions about CKD application rate and CKD Pb concentrations that were used to generate the range of soil Pb concentrations used in the IEUBK modeling? What assumptions were used in the IEUBK for soil Pb bioavailability and other parameters? The simulation clearly shows potential problems between the 95th and 100th percentiles.

Chapter 5 Scenarios and Exposure Routes

General:

The scenarios and exposure routes considered for the receptor scenarios seem reasonable and justifiable.

Specific:

Page 63. The use of a 60 kg average body weight will overestimate risk for most adults,

Page 64. Why was a triangular distribution selected, especially since the authors recognized this distribution may overestimate the frequency of high-end ingestion which would be the most critical scenario.

Page 65. Throughout this chapter it would be helpful if the figures had captions, the axes on the figures were labeled, and the source of data in the table/figure combinations was cited, if appropriate.

Page 65. It appears that a single value was used to represent the fraction of vegetable consumption that was home-grown on contaminated soil. Judging from the values in Table 5-3, this would be a worst possible scenario. Again, it was a conservative bias in selection of input data. In deterministic calculations it is acceptable to use the worst case scenario. The homegrown fraction of vegetables would be such a variable and a distribution of values should be assigned if one does Monte Carlo simulation. At least a sensitivity analysis should be conducted to show that the fraction of vegetable consumption that was home grown is not a risk driver.

Page 66. It seems odd that the fraction of dietary item listed as home-produced is higher for households on farms compared to households with gardens. Are we assuming that farm households also have gardens?

Page 69-86. This section contains probabilistic distributions of consumption rates for home grown fruit and vegetables and the probabilistic distribution of home grown beef and dairy intake. For each data set, there was a table listing consumption rates and their corresponding probability figure that presumably depicted the probabilistic distribution in graphical form. The scales of the figures were not easy to understand. The horizontal scale (consumption rate) was confusing because the marked intervals on each graph did not always have the same range. The vertical scale (presumably probability) was not labeled. Tables *5-8* and 5-9 had identical tabulated distribution patterns but the distribution patterns were not the same graphically. This was in contrast to Table 5-12 vs. Table 5-13 and Table 5-14 vs. Table *5-15* where tabulated and graphical distributions agreed. Tables 5-28 and 5-29 had very similar tabulated distribution values but the graphical distribution patterns were quite different. Perhaps the uneven horizontal scale had something to do with it.

Page 71. For many of these probability tables the continuous range does not steadily increase, as is the case for Table 5-1 1. The first range is 0.0000 to 0.0000 and the second range is 0.0000 to 0.0004. There are also different font sizes used within tables. Is there a reason for this?

Chapter 6. Ecological Screening Analysis

The reviewers concluded that this section is inadequate. The use of ecological benchmarks for soil and phytotoxicity from the *Technical Support Document for the Land Application of Sewage Sludge* is again inappropriate. This direct comparison can lead to arguments that rules for biosolids should be applied to CKD, as commented earlier, and that the CKD soil numbers are acceptable even though no studies have been done to directly compare their results. The reviewers suggest a literature review of ecological benchmarks for metals from various sources with a presentation of a range of values so it can be determined where the range of soil concentrations shown in Table 6-1 are in comparison to other benchmarks. There have been a number of ecological risk assessments performed for metal contaminated sites that can be used as a guide for ecological benchmarks for soil and phytotoxicity. The authors are also referred to Will and Stuer (1995).

Chapter 7. Risk Assessment Results

General:

The reviewers generally felt this section was inadequate. This section represents the culmination of all of the efforts to this point and yet it is summarized in less than one page. The reader is forced to scan all of the tables themselves to determine when Tl and As present unacceptable risk for the child of farmer scenario or which dioxin congeners present unacceptable risk for the farmer and child of farmer scenarios. Summary tables are drastically needed here as well as considerably more interpretation and summarization. The issue of Pb is not addressed in this section at all, and wasn't summarized in Chapter 4 either.

After studying the entire document, the purpose of the effort is still not clear, although the accomplishments are more obvious. If the risk assessment results are to agree with what is presented in the summary (Chapter 1), the reader was expecting to find regulatory cutoff levels here, but there are none. It is clear that the report is not a risk assessment methodology or guidance document.

It is encouraging to see the results of the deterministic and probabilistic analyses agree fairly well.

Specific:

Page 90. These tables could be a little more user friendly if it was clear which columns were hazard quotients and which were risk factors. If one does not know this information (it can be ascertained from Appendix B) there should be a reference to it in this section. Similarly, it would be useful to state the critical values used to determine when there is increased risk (HQ 1, Risk > I 0-5). Not all such values are written in bold type.

Page 104 and 107. The table headings should indicate dioxins and not metals.

Appendix A

In many of the tables there are separate columns for central tendency and high end values yet only a single value is provided. These columns should be combined when there is no need for the separate columns.

Table A-1.1. ER is not defined.

Table A-1.2 A_B is not defined.

Table A-1.6. What is the background document that is referred to in this table and others?

Table A-1.8. There should be a different value of b for each location if this variable is soil-specific.

Table A-1.10. Give units on 0.1 conversion factor (g m2/kg cm^2).

Table A-2.3. Is $X_{e, WF}$ the same as $X_{e,F}$?

Table A-2.4. Unclosed parenthesis on the units for

Table *A-2.5.* The units for Kd_{bs} should be cm3/g and not g/cm3.

Table A-2.7. Why is TSS set to be a constant 80 mg/L?

Table A-2. 11. Why is the bed sediments concentration set to 1?

Table A-2.20. The values of OC_{bs} seem extremely low. Are they correct?

Table A-3.1. A conversion from g/kg to mg/kg is needed. The same holds for Tables A-3.4 and A-4.3.

Table A-3.2. A conversion from cm3 to m3 is needed. The same holds for Tables *A-3.5* and A-4.4.

Table A-5.1 to *5.6.* The calculated values listed in these tables suggest that Sc can be found in Appendix A, but where? Where in Appendix B and D can you find the other values?

Table A-5.2. Is I_{ev} the same as I_{ag}? The units work out to be mgld while the units listed for lag are given as mg/kg FW. The unit problem is also found in Tables *A-5.3* and *A-5.4.*

Table *A-5.3.* The value of Pd is calculated, but how?

Table *A-5.4.* Is I_{ev} the same as I_{rv} and is Pr_{bg} the same as Pr_{rv}?

Table *A-5,5.* The values for some of the parameters vary, but the location of the calculations are unknown.

Table A-5,6. Where in Appendix A and D can these values be determined?

Table *A-5.7.* There are no units given for I_{ev} and I_{rv}

Table *A-5.8* and *5.9.* Where in Appendix B and D can these values be determined?

Table A-5.1 1. Table A-5.7 calculates daily intake, not cancer risk as suggested in the equation given.

Table A-6. 1. Where in Appendix A and B can these calculations be found?

Table A-6,2. C_a and ED are not defined.

Table A-6.4. References to Tables A-61 and A-62 should probably be A-6.1 and A-6.2.

Appendix B

There is no numbered list of references corresponding to the last column in each table.

Change Ba_{beef}/Ba_{pork} to Ba_{beef},Ba_{port} as the current usage implies a ratio. Change the definition to read “Biotransfer factor for beef or pork”.

Appendix C

This is clearly a document produced by another group of individuals other than the ones preparing the main body of this draft document. It was completed almost one year in advance of the draft document, yet it appears that it was not integrated into the report and was tacked on at the end. Because this starts out as a PRELIMINARY DRAFT, should additional work have been conducted?

Page 2. How were the risk drivers determined? References are not properly formatted, i.e., is it USEPA a, b, or c?

Page 3, How were the potential risk drivers determined? The risk ratio is used in this table and the description of the risk ratio is not presented until page 16. The risk ratio should be defined the first time it is used. The values for the risk ratios in the table are actually the range of risk ratios and this should be clarified. The range of risk ratios do not agree with those shown in Tables 10 to 13.

Page 4. This is a poorly referenced table. References are not listed in the reference section. There should be a value listcd for the background soil concentration for Cd. The reference column only refers to the background soil concentration and should be indicated as such.

Page 5. What are the units for the background soil concentrations?

Page 6. What 14 facilities supplied the samples for dioxin analysis and what 63 facilities suppliedsamples for metals? On page 3 in the Characterization of CKD section of the main document there were only 20 facilities sampled. Why the difference? References are incorrectly written. There is an incomplete sentence on the second from the last line.

Page 7. Note that almost all of the sites are east of the Mississippi River. The sixth line from the bottom should read 2, 3, and 5 years according to Table 5. Where is the reference for RTI (1996)? Reword the sentence starting with “The bulk density ..“

Page 8. In the main body of the document the lifetime of an agricultural field or home garden was assumed to be 100 years. Why were the lifetimes for the field and garden assumed to be 40 years in this analysis? References are needed for Table 5. Why would a steady state be reached if applications are to be continued?

Page 9. There are contradictory statements made on this page. First it is stated that particles greater than PM_{10}s are not important, yet in the equation PM_{30}'s are used. Why? What is the extra “I” in the definition of K_{at}? Separate N_{op}, which is on the same line as S. What does the “total waste stream” in the second paragraph from the bottom refer to with respect to this analysis?

Page 10. Why was silt used as a parameter in the sensitivity analysis? References are needed on this page. Is it USEPA 1993 a, b, or c? Change the word theat to that. Change form to from on the 11th line from the bottom.

Page 11. Old information is used for the soil taxonomic information. Change n to in. Soil Foc are extremely low. Because the CKD was only supposed to be used on acid soils, why is the 95th percentile value equal to 7.2?

Page 12. Rewrite first sentence. References are needed for the Metal Speciation and Partitioning section. Other references are reported incorrectly.

Page 13. References are needed for footnotes of Table 8. USEPA 1992 and 1996 a, b, or c?

Page 14. Why are the units different from the equation given? References are needed for section 7.0.

Page 15. Why are there no data for ingestion by children other than soil?

Page 16. Watch the extra periods. Rewrite the last few sentences in the second from the last paragraph.

Appendix D

What facilities are the values associated with?

Why do the relative probabilities vary sometimes? For example, in the sampling data for Pb most values are 0.015873 with an occasional value of 0,031746, It is difficult to understand why single point distributions instead of continuous distributions were used to represent the pollutant concentrations in CKD treated soils. For Pb, TI, Sb, As, Be, and Cd the concentration ranges were considerably higher than concentrations of the same elements listed in Table 4-3 (page 23).

References

California Department of Food and Agriculture, 1998. Development of risk-based concentrations for arsenic, cadmium, and lead in inorganic commercial fertilizers. California Department of Food and Agriculture, Sacramento, CA.

Will, M.E., and G.W. Suter. 1995. Toxicological benchmarks for screening potential contaminants of concern on terrestrial plants. 1995 Revision. Oak Ridge National Laboratory, TN,

Appendix B

Evaluation of Peer Review Issues

November 6, 1998

Assessment of Risk from Fertilizer Use

Work Assignment Number B-17
Amendment 1

Evaluation of Peer Review Issues

Prepared for

U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street, SW (5307W)
Washington, DC 20460

EPA Contract Number 68-W-98-085

RTI Project Number 92U-7200-017

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1.0 Introduction

1.1 Background

In 1997, in response to concerns raised by the public regarding potential risks associated with the use of certain wastes in the manufacture of agricultural fertilizers and soil amendments, the U.S. Environmental Protection Agency (EPA) initiated an effort to examine whether contaminants in fertilizers may be causing harmful effects and whether additional government actions to safeguard public health and the environment may be warranted. As part of this effort, the Office of Solid Waste (OSW) is planning to conduct an analysis of potential risks associated with the use of a wide range of fertilizers and soil amendments. Materials to be assessed include the most commonly used macronutrient fertilizers, which contain nitrogen, phosphorus, and potassium (NPK fertilizers); micronutrient (e.g., zink) fertilizers; and soil amendments (i.e., materials applied to the land primarily to enhance soil characteristics rather than as plant food).

The preliminary assessment will be conducted using the risk assessment methodology originally developed to assess risks from use of cement kiln dust (CKD) as a liming agent. Liming agents are used to elevate the pH of acidic soils to a level appropriate for crops. The CKD risk assessment was submitted for peer review to the Cooperative State Research Education and Extension Service Technical Committee W-170 of the U.S. Department of Agriculture (USDA). A number of the substantive recommendations made by the peer reviewers regarding the CKD assessment are pertinent to the fertilizer assessment currently being planned. This issue paper addresses the concerns raised by the CKD risk assessment peer review panel and presents options and recommendations for how the CKD methodology can be adapted or altered to assess the risks associated with hazardous constituents in fertilizer products.

1.2 Summary of Primary Risk Assessment Issues

The basic concerns expressed by the peer reviewers about the methodology are outlined below, and options for addressing these concerns are presented in the remaining sections of this document.

Soil classifications were thought to be outdated, and use of other, more recent data sources was recommended. The reviewers recommended using the Soil Survey Geographic (SSURGO) database.

The geographic area of concern (which for the CKD analysis was based on the location of cement plants) was considered to be too narrow. The reviewers recommended an expanded nationwide analysis covering a broader range of climatic conditions.

- K_d values (surface media/water distribution coefficients) used in the fate and transport modeling were questioned as was the use of the MINTEQ model for estimating K_d values in agricultural soils. The reviewers were critical of some of the soil and solution parameter assumptions used in the MINTEQ model.

- The model used to determine contaminant loss to various media (i.e., the Jury equations) was judged to be appropriate with some technical corrections. These corrections have been incorporated and, thus, are not addressed as options in this document.

- The plant uptake (Br) factors were taken from the risk assessment for the agricultural application of sewage sludge. These factors were empirically derived specifically for sewage sludge applications. Commenters noted that these factors are inappropriate for inorganic fertilizer and soil amendment applications. The reviewers also noted, however, that more appropriate data for use in the CKD analysis are not readily available.

- The air dispersion and deposition portion of the analysis was judged to be appropriate for the purpose for which it was used. (Emissions were estimated using EPA's AP-42 model; the Industrial Source Complex Short Term, Version 3 [ISCST3] model was used to model dispersion.)

Three basic concerns of the peer reviewers are addressed in this report: (1) the limitations of the soil and climate conditions considered in the CKD risk analysis due to its narrow geographic focus, (2) the estimation methods and parameters used for developing point values for K_ds for metals, and (3) the use of Br factors developed for the application of sewage sludge to agricultural fields for analysis of application of the inorganic fertilizers and soil amendments to crops. The report also discusses potential use of geographic information system (GIS) data to obtain data on crop and soil types.

Soil and Climate Parameters

The peer review panel was concerned that the geographic focus of the CKD risk assessment was too narrow, even for the use of CKD as a liming agent. Because the geographical distribution is assumed nationwide for fertilizer use, additional soil and climatic conditions will be examined. Options for nationwide agricultural soil parameter databases and those databases' associated contents are described. The source of climatic data will be the *International Station Meteorological Climate Summary, Version 2.0* (NOAA, 1992); however, options for refining the data for this risk assessment are also discussed. The issues, options, and recommendations for appropriate soil and climate data are presented in Section 2.0.

Distribution Coefficients

For the CKD risk analysis, soil-water partitioning coefficients (K_ds) for most constituents were estimated using the MINTEQ model, with adaptations for agricultural soils. K_ds for arsenic, chromium, selenium, and thallium were determined using empirical pH-dependent adsorption relationships. Peer reviewers questioned whether MINTEQ is an appropriate model for deriving K_ds for surface soils. The collection of measured values from the literature may be a viable alternative to generating modeled values. Options for estimating K_d values are examined, and a recommendation is presented in Section 3.0.

Plant Uptake Factors

The development of revised plant uptake (Br) values based on data reported for plants grown in inorganic soil matrices is examined. A review of selected readily available literature has been conducted to examine the feasibility of developing more appropriate Br values for use in the risk assessments for fertilizers. This initial literature review and the data analysis are presented in Section 4.0.

GIS Data Options

Fertilizer use is nationwide and not restricted to any particular soil, climate, or crop type, or any single combination of the three. Agricultural soil types, climatic conditions, crop types, and fertilizer use patterns are interrelated, not independent, variables. Therefore, in an attempt to include all potential sources of risk but to limit the assessment to realistic combinations, the appropriate combination of soil, crop, climate, and fertilizer use practices may be linked using a GIS. The possible use of this readily available tool is addressed in detail in Section 5.0.

1.3 Recommendations for Risk Assessment for Fertilizer Use

1.3.1 Soil and Climate Data and Data Sources

The distribution of soil types in the CKD risk assessment were assumed to be relatively uniform because of the assumptions made concerning the use patterns of CKD as an agricultural liming agent. CKD was assumed to be used only in geographic areas with initially acidic soils and within a 20-mi radius of a cement kiln generating significant quantities of CKD. Thus, the limited variation of soil parameters was not examined in detail after an initial sensitivity analysis conducted to examine the range of soil conditions. The peer review panel stated that the range of soils considered in the CKD risk assessment was too narrowly defined. The scope of the fertilizer risk assessment includes all agricultural soils in the United States. Therefore, a nationwide distribution of soil parameter data needs to be considered for this risk assessment. The database with the most complete and detailed soil parameter data available is the State Soil Geographic (STATSGO) database. The SSURGO database recommended by the peer reviewers provides very detailed soil descriptions; however, SSURGO data are not available at this time for all sections of the country as required for this analysis. The STATSGO database is, therefore, recommended.

The peer reviewers also suggested that when the scope of the risk assessment was expanded to include greater variation in geographic regions, the variation in climate data should also be re-examined. For meteorologic data, the 29 climate sites should be sufficient to characterize the nationwide distribution of meteorologic conditions throughout the country. Its use of the more than 200 available sites does not seem necessary for this purpose.

1.3.2 Recommendations for Estimating K_d in Agricultural Soils

The estimations of K_d used for most metals in the CKD risk analysis were obtained from MINTEQA modeling at a pH of 6.8. These values were questioned by the peer review panel. The use of MINTEQA modeling for surface soils and sediments has since been abandoned for other OSW risk assessments because of the lack of data. Therefore, the only alternative for estimating K_d is the use of measured values from the literature. A range of measured values is being determined for other OSW projects under another contract. This work may be completed in a time frame that will be useful for this risk assessment. If so, these distributions can be used for the fertilizer risk assessment. If not, continuing to pursue the literature search and data extraction effort is recommended in order to estimate a range of K_d values that could be used in this risk assessment.

1.3.3 Recommendations for Plant-Soil Uptake (Br) Factors

The values in the CKD risk analysis were based on the estimations developed for the risk assessment in support of the land application of sewage sludge. The peer reviewers considered these values inappropriate for the inorganic soil matrix evaluated for the CKD risk assessment. The reviewers also stated that there are no readily available Br values for metals in inorganic soils. A preliminary literature survey has been conducted to identify appropriate data for developing Br values for metals that can be used in inorganic agricultural soil matrixes. The results of this preliminary analysis indicate that data are available from appropriate studies that can be used to develop Brs. The data that have been collected, however, indicate that significant data gaps remain. A comprehensive literature search should be conducted for articles published within the last 3 years to identify additional data to fill these gaps in the plant-soil database and to allow for the development of Brs for inorganic soil matrixes based only on field studies as recommended by the peer reviewers.

1.3.4 Input Expected from the Expert Consultants

Research Triangle Institute (RTI) has retained two independent consultants as reviewers for the waste-derived fertilizer risk assessment. Dr. Sparks is Distinguished Professor and Chairperson of the Department of Plant and Soil Science at the University of Delaware. Dr. Mikkelsen is an Associate Professor of Soil Science at North Carolina State University, an agronomist, and a licensed soil scientist. The role of these experts will include reviewing and making recommendations on pertinent soil parameters and reviewing plant-soil relationships. They should be able to provide insight into the data analysis of the plant-soil database and the development of appropriate Br values as well as the analysis of literature values that may be used in developing a distribution of values for K_d. Dr. Sparks recently published an article on the kinetics and mechanisms of sorption and desorption of lead (Strawn, Scheidegger, and Sparks, 1998).

1.4 References

Francis, M., and M. Nishioka. 1997. *Fertilizers: A Background and Characterization of Use, Contaminants and Regulations.* Prepared by Battelle, Columbus, OH, for Office of Pollution Prevention and Toxics, U.S. Environmental Protection Agency, Washington, DC. December.

NOAA (National Oceanic and Atmospheric Administration). 1992. *International Station Meteorological Climate Summary, Version 2.0.* CD-ROM. National Climatic Data Center, Asheville, NC. June.

RTI (Research Triangle Institute). 1998. Draft Risk Assessment for Cement Kiln Dust Used as an Agricultural Soil Amendment. Prepared under EPA Contract No. 68-W6-0053, WA 4 for Office of Solid Waste, U.S. Environmental Protection Agency, Washington, DC. June.

U.S. EPA (Environmental Protection Agency). 1996. *Technical Support Document for the Round Two Sewage Sludge Pollutants*. EPA-822-R-96-003. Office of Water, Washington, DC.

2.0 Soil and Climate Parameters

The peer reviewers for cement kiln dust (CKD) asserted that the assumptions concerning the distribution of soils that would be candidates for CKD application were incorrect because they were constrained by outdated soil data and because many more soil types should have been included in the analysis. The reviewers suggested that applying more recent soil classification information on a smaller scale would help identify regions where liming would be indicated to adjust the soil pH. They specifically suggested using the SSURGO database currently under development. The application of fertilizers is not limited to soils within a specific range of soil pH and, thus, all agricultural soils nationwide should be included in the analysis. This section presents options for identifying applicable soil parameters for locations nationwide. The commenters also indicated that by expanding the geographical area of the analysis, consideration of climatic conditions should be expanded as well. Both these issues are addressed in this section.

2.1 Soil and Climate Parameters that Affect Metals Behavior and Availability

Soil data in this effort supports the fate and transport of metals in agricultural soils according to soil type and climatic regime. The descriptive data parameters necessary for this analysis are soil texture/type, hydrologic group, clay content, and climatic trends. Soil chemical and physical factors are also discussed in this section and include cation exchange capacity, pH, organic matter content, and oxidation-reduction potential.

Soil texture/type — Soil texture affects the movement of metals through the soil column. Leaching or translocation of metals is favored by water movement (for example, in permeable sandy soils that are low in clay and organic matter).

Hydrologic group — The various hydrologic soil groups describe soils having similar runoff and leaching characteristics. The chief consideration is the inherent capacity of the soil to permit infiltration. Native soil permeability and prior wetness are considered in assigning soils to hydrologic groups.

Clay content of soils — Trace metals and micronutrient cations interact with clays in two ways. First, they may be involved in cation exchange reactions. Second, they may be more tightly bound or fixed to certain clays (e.g., 2:1 clays). For example, zinc is often found as an element in the crystal structure of clays. The fixation is possible because zinc is present in soil in a small quantity; however, when zinc is added to the soil, the concentration may overwhelm the fixation mechanisms of the system and result in increased unbound zinc in both surface and ground waters.

Climatic trends — Precipitation and temperature are the most important attributes of climatic conditions that influence the behavior of metals in soils. Increased precipitation increases the volume of leachate and runoff. In addition, an increase in precipitation most likely will increase the biomass of vegetation, with varying effect on soil depending on temperature.

Fraction organic carbon — Many metals are bound to the net negatively charged organic matter. Some organically bound elements are not readily available to plants but can be released over time. Determination of fractional organic carbon is used in estimating the sorption characteristics of a soil.

Cation exchange capacity (CEC) — CEC and organic matter are closely related. Organic matter possesses functional groups that are or act as weak acids. CEC is generally pH-dependent, with greater values at higher pHs. Hydrogen ions and micro-organisms replace cations from the exchange complex by cation exchange. The displaced cations are forced into the soil solution where they can be assimilated by plant roots or transported by drainage water.

Soil pH — Metals are most soluble under acid conditions ($pH<6$). As the pH increases, the ionic forms of the micronutrient cations change first to the hydroxyl ions of the elements and, finally, to the insoluble hydroxides or oxides. All of the hydroxides of the metals of concern in this risk assessment are insoluble, some more so than others. The exact pH at which precipitation occurs varies from element to element and even between oxidation states of a given element. For example, the higher valent states of iron and manganese form hydroxides that are much more insoluble than their lower valent counterparts. At low pH values, the solubility of micronutrient cations is at a maximum; as the pH is raised, their solubility and availability to the plant decrease.

Oxidation state — At pH values common in soils, the oxidized state of metals (for example, copper) is much less soluble than the reduced state. The hydroxide (or hydrous oxide) of high valence forms precipitates even at low pH values and is extremely insoluble. Most inorganic elements are rendered less mobile and less available if the soil pH is kept near the neutral level or above.

2.2 Soil Databases

The Natural Resources Conservation Service (NRCS) established two soil geographic databases applicable to this effort: the STATSGO database and the SSURGO database. The map units in each database generally depend on the level of detail of soil characteristics provided in the database. Map units are displayed differently for each geographic database to be consistent with differing levels of detail.

Comparison of STATSGO and SSURGO Databases

The STATSGO database was designed primarily for regional, multicounty, river basin, state, and multistate resource planning, management, and monitoring. These data are collected as part of the National Cooperative Soil Survey (NCSS). Soil maps for STATSGO provide coverage of the conterminous United States, Alaska, Hawaii, and Puerto Rico and are made by generalizing the detailed soil survey data. The mapping scale for the STATSGO maps is 1:250,000 (with the exception of Alaska, which is 1:1,000,000).

The SSURGO database level of mapping is designed for use by landowners, townships, and county natural resource planners and managers. Field mapping methods using national standards are used to construct the soil maps in the SSURGO database. Mapping scales generally range from 1:12,000 to 1:63,360. SSURGO is the most detailed level of soil mapping done by the NRCS. SSURGO digitizing duplicates the original soil survey maps. SSURGO data are available for only selected counties and areas throughout the United States and its territories. For both databases, digitizing is done by line segment (vector) format in accordance with NRCS digitizing standards.

The base map used for STATSGO is the U.S. Geological Survey's (USGS') 1:250,000 topographic quadrangles. The number of soil polygons per quadrangle map is between 100 and 400. The minimum area mapped is about 1,544 acres. STATSGO data are collected in 1:250,000 quadrangle units. Map unit delineations match at state boundaries. States have been joined as one complete seamless database to form statewide coverage. Composition of soil map units was coordinated across state boundaries, so that component identities and relative extents would match.

The mapping bases for the SSURGO database meet national map accuracy standards and are either orthophotoquads or 7.5-min. topographic quadrangles. SSURGO data are collected and archived in 7.5-min. quadrangle units and distributed as complete coverage for a soil survey area. Soil boundaries ending at quad neatlines are joined by computer to adjoining maps to achieve an exact match.

Each STATSGO map is linked to the Soil Interpretations Record (SIR) attribute database. The attribute database gives the proportionate extent of the component soils and their properties for each map unit. The STATSGO map units consist of 1 to 21 components each. The SIR database includes more than 25 physical and chemical soil properties, interpretations, and productivity. SIR data are available for all recognized soils and miscellaneous areas in the United States Both have a common link to an attribute data file for each map unit component provided by the SIR database. SIR is a database of the national values and ranges of soil and nonsoil properties, interpretations, and performance data for approximately 18,000 soil series and their phases. Its primary use currently is two-fold. SIR, in concert with the Official Soil Series Database (OSSD), sets the standards or limits and definitions for soil series and their phases. SIR is also used to generate the initial unedited version of the Map Unit Interpretation Record (MUIR) database.

SSURGO is linked to a MUIR attribute database. The attribute database gives the proportionate extent of the component soils and their properties for each map unit. The SSURGO map units consist of 1 to 3 components each. MUIR data are a collection of soil and soil-related properties, interpretations, and performance data for a soil survey area and its map units, map unit components, and component layers. MUIR data contain about 88 estimated soil physical and chemical properties, interpretations, and performance data. These include available water capacity; soil reaction; soil erodibility factors (K, Kf, and T); hydric soil ratings; ponding, flooding, and water table depth and duration; bedrock; interpretations for sanitary facilities, building site development, engineering, cropland, woodland, and recreational development; and yields for common crops, site indices of common trees, and potential production of rangeland plants.

Examples of information that can be queried from the STATSGO database are the map unit identifier, a two-character state abbreviation; available water capacity of the soil; percent clay in the soil; actual k-factor used in the water erosion component of the universal soil loss equation; organic material in soil; soil permeability; cumulative thickness of all soil layers; hydrologic characteristics of the soil; quality of drainage; surface slope; liquid limit of the soil; share of a map unit having hydric soils; and annual frequency of flooding. (Source: http://water. usgs.gov/nsdi/usgswrd/ussoils.html#Identification_Information and http://nssc.nrcs.usda. gov/sww/ nsdafmap.html).

Examples of information that can be queried from the SSURGO database are available water capacity; soil reaction; salinity; flooding; water table; bedrock; building site development and engineering uses; cropland, woodland, rangeland, pastureland, and wildlife; and recreational development (available online at http://nssc.nrcs.usda.gov/sww/nsdafmap.html).

Additional Databases to be Used

The U.S. Soils (USSOILS) database contains selected erosion and hydrologic variables from the STATSGO data set, including

- # available water capacity of the soil,
- # percent clay in the soil,
- # actual k-factor used in the water erosion component of the universal soil loss equation,
- # organic material in soil,
- # soil permeability,
- # cumulative thickness of all soil layers,
- # hydrologic characteristics of the soil,
- # quality of drainage,
- # surface slope,
- # liquid limit of the soil,
- # share of a map unit having hydric soils, and

- annual frequency of flooding.

The USSOILS coverage was originally compiled to support a national model of water quality. USSOILS aggregates the STATSGO layer and component information up to the level of a map unit by depth-averaging, over the entire soil column, median properties within a component and then area-averaging component values across a map unit.

The Continental United States (CONUS) database also contains selected erosion and hydrologic variables from the STATSGO data set, including

- soil texture class,
- depth to bedrock,
- sand,
- silt,
- clay fractions,
- rock fragment class,
- rock volume class,
- bulk density,
- porosity,
- hydrologic soil groups, and
- available water capacity.

The CONUS soils data set was compiled by the Earth System Science Center in the College of Earth and Mineral Sciences at Pennsylvania State University for application to a wide range of climate, hydrology, and other environmental models (Miller and White, 1998). CONUS contains STATSGO soil properties averaged to 11 standard layer depths, from the STATSGO layers to a depth of 2.5 m. Within each STATSGO map unit and CONUS standard layer, soil properties represent either the predominant property (as with soil texture) or area-weighted averages of STATSGO component values.

Metadata providing greater detail on STATSGO and USSOILS may be found on the Internet at http://www.ftw.nrcs.usda.gov/stat_data.html.

Additional information on CONUS can be found on the Internet at http://www.essc.psu.edu/soil_info/index.cgi?soil_data&conus.

As described above, data needs for the waste-derived fertilizer risk assessment include national coverage of soil parameters as they relate to the location of soil types, soil texture, and other physical properties of the soil. The primary reason for using STATSGO in conjunction with USSOILS and CONUS as the preferred source for soil data is the ability to draw from national soil coverage and the additional extent of soil component layers in the data set. This risk analysis requires that national evaluation of fertilizer effects be accounted for. SSURGO cannot, at this time, provide the national coverage nor the level of detail necessary.

2.3 Climate Databases

Climatological data for this risk assessment can be obtained from the National Climatic Data Center (NCDC) World Data Center-A. NCDC is maintained by the National Oceanic and Atmospheric Administration (NOAA) and supports a three-tiered national climate services support program in partnership with regional and state climatologists. Meteorological data are available for more than 200 meteorological stations in the contiguous United States. Environmental Quality Management performed a statistical analysis of air modeling data for all 200 locations in support of the *Evaluation of Dispersion Equations in Risk Assessment Guidance for Superfund (RAGS): Volume I - Human Health Evaluation Manual* (Environmental Quality Management, Inc., and E.H. Pechan & Associates, 1993) and determined that 29 stations would be a sufficient sample to represent the population of 200 stations and predict mean air dispersion values with a high (95 percent) degree of confidence. The 29 meteorological stations are distributed among 9 climate regions based on meteorological representativeness and variability across each region. This sample of 29 meteorologic stations has been used in other OSW risk assessments (air characteristics and the Hazardous Waste Identification Rule [HWIR]) to represent a nationwide distribution of climatic conditions.

Because the objective of the fertilizer risk analysis is to obtain a set of annual average concentrations for a nationwide distribution of sites, the set of 29 sites provides the range of meteorological data appropriate for this analysis. This meteorologic data selection process has been peer reviewed, and the 29 sites have been judged adequate for use in risk assessments with a nationwide distribution.

2.4 Issues

A comprehensive, detailed assessment of potential risks associated with use of fertilizers and soil amendments would require further research on the following factors:

- Effect of pH on trace metals bioavailability,
- Bioavailability as it relates to soil-specific liming requirements,
- Agronomic practices (fertilization method/rate) by crop,
- Combination effects of fertilizers in the soil, and
- Additional literature reviews for micronutrient and trace metal soil kinetics data.

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3.0 Distribution Coefficients

One of the peer review committee's objectives focused on the derivation of distribution coefficients (K_ds) to determine metal partitioning between the sorbed and dissolved phases within the specified system. The following points were raised by the committee:

- Methodologies used to derive the distribution coefficients are inconsistent;
- Iron oxide adsorbents are unrealistically emphasized in MINTEQ model simulations, especially with regard to cationic species;
- Clay adsorbents are not considered in MINTEQ model simulations;
- Soil pore-water concentrations used in MINTEQ model simulations should reflect measured soil solution compositions as opposed to those of precipitation;
- Competition between calcium and metals should be considered in MINTEQ model simulations;
- The pH distribution of the modeled system may not be sufficiently broad to encompass all possible scenarios; and
- Conclusions about the behavior of arsenic in the environment are contrary to what would be expected based on thermodynamic considerations.

This section addresses comments made by the committee on the derivation of distribution coefficients. The majority of the committee's comments focus on the appropriateness of using the MINTEQA2 aqueous speciation model to estimate distribution coefficients for agricultural soil environments. Committee comments related to very specific topics (ionic competition, pH distribution, and arsenic) are not addressed directly.

3.1 MINTEQA2 Model Simulations

Metal speciation is an important factor in assessing the fate and mobility of metals in the environment. Because metal speciation is affected by such a large number of simultaneously occurring processes, determining speciation is a complex problem. One method that has been applied to this problem is the use of aqueous equilibrium speciation models such as MINTEQA2.

In order for a computer model such as MINTEQA2 to yield meaningful speciation results, the system of interest must be represented as accurately as possible. This requires a good working knowledge of the environmental setting. Factors that must be considered include the chemistry of the substrate (e.g., the availability of potential sorption sites in aquifer material, soil, or sediment) and the associated background pore-water chemistry (e.g., the available concentrations of reacting and nonreacting components in groundwater, surface waterbodies, or the marine environment). All important chemical reactions for the metal of interest should be considered in the model application. For each of these chemical reactions, accurate and reliable thermodynamic data also must be available.

3.1.1 Substrate Definition

MINTEQA2 has been successfully used by the U.S. Environmental Protection Agency (EPA) to simulate metal behavior for a variety of metals. The defined data sets characterizing the substrate and the background pore-water chemistry, however, are representative of groundwater systems and not appropriate for agricultural soil systems. One weakness is the emphasis on iron oxide sorbents over organic matter and clay sorbents. In agricultural soil environments, organic matter and clay increase in importance and should be considered in model simulations.

MINTEQA2 incorporates a specialized model that treats organic matter as a complex mixture of carboxylic functional groups. This specialized model, referred to as the Gaussian model, provides for a continuous distribution of binding affinities over a defined range for a particular metal. The Gaussian model is implemented in MINTEQA2 for a database that includes hydrogen, aluminum, barium, beryllium, calcium, cadmium, chromium, copper, iron, magnesium, nickel, lead, and zinc. The database does not include data for all metals of interest (e.g., oxyanions).

Site density factors and binding constants for the Gaussian model are needed in order for MINTEQA2 to predict sorption to organic matter for the oxyanions. These data are derived from laboratory measurements. At this point, there are no plans to parameterize MINTEQA2 for the oxyanions. This data deficiency makes MINTEQA2 a poor choice for estimating distribution coefficients for the full range of metals that may be present in fertilizers used in agricultural soil environments. Other environmental settings in which organic matter is an important component (e.g., surface water and sediment environments) are also affected by this data deficiency.

A subtler consideration is the metallic partitioning between dissolved and particulate organic matter. Because particulate organic matter is assumed to be part of the substrate, sorption to particulate organic matter immobilizes the metals (i.e., the metal is less available for transport through the system). In contrast, dissolved organic matter is assumed to be mobile in the environment, and metals complexed to dissolved organic matter are considered to be mobile in the environment. Sorption to particulate organic matter underpredicts metal mobility, resulting in conservative results. Sorption to dissolved organic matter is also underpredicted; however, because dissolved organic matter may be transported through the system of interest, this prediction is nonconservative. Thus, as the concentration of organic matter increases in the environmental system, it becomes even more important that reactions for all metals of interest be considered in the model simulations.

Metal sorption to clays is not represented in MINTEQA2. Preliminary research shows that a minimum of three different binding sites are required to adequately simulate metal sorption to clays. Currently, no such database exists. EPA gauged the magnitude of omitting clays in its groundwater assessments and concluded that the properties are not so dissimilar among the different adsorbents (e.g., iron oxide, clay, carbonate, silicate) as to yield poor results; however, clays increase in importance in soil and sediment environments. The absence of sorption reactions to clay surfaces makes MINTEQA2 a poor choice to estimate distribution coefficients for metals that may be applied to agricultural soil environments.

Finally, a source of data characterizing the central tendency and high-end concentrations of organic matter and clays in agricultural soil environments has not been identified. These data exist and could be obtained. In the absence of the required thermodynamic reactions and supporting databases, however, these data would be of little use in MINTEQA2 simulations.

In conclusion, MINTEQA2 is a poor choice for estimating distribution coefficients for metals in agricultural soils due to the following:

- # The Gaussian model, describing metal sorption to organic matter, has only been parameterized for a limited suite of metals;
- # Reactions describing sorption to clay surfaces are lacking for all metals of interest; and
- # Central tendency and high-end concentration values for organic matter and clays in agricultural soils are lacking.

3.1.2 Background Pore-Water Chemistry Definition

EPA has characterized the background pore-water chemistry for use in MINTEQA2 model simulations for groundwater systems. A similar data set characterizing background pore-water chemistry in agricultural soils has not been developed, and no efforts are currently under way to do so. The CKD peer review committee indicated that the use of precipitation data is not an appropriate surrogate for soil solution composition.

Sufficient characterization of agricultural soil systems has likely been conducted to determine central tendency and high-end concentration values for the major and minor constituents comprising background pore-water chemistry in agricultural soils. A data source has not been identified, however, and the level of effort needed to assess and compile the data is unknown. MINTEQA2 model simulations are not appropriate without adequate characterization of the background pore-water chemistry.

3.1.3 Consistency in Estimation Methods

Although MINTEQA2 has been used successfully to simulate the behavior of a variety of metals, it does not contain the thermodynamic reactions and supporting databases to simulate reactions for all possible metals of interest. Specifically, MINTEQA2 is more adapted for predictions involving cations than anions. MINTEQA2 supported model simulations for barium, beryllium, cadmium, lead, mercury, nickel, and silver for the CKD risk assessment. The necessary reactions and supporting databases for antimony, arsenic, chromium, selenium, and thallium were lacking, however, and alternative methodologies were needed for estimating the distribution coefficients for these metals.

The necessity of having to use different methodologies to estimate distribution coefficients highlights a major weakness. Inconsistency is introduced, which, in turn, introduces uncertainty and makes defense of the final risk assessment results difficult.

EPA acknowledges this problem. MINTEQA2, however, represented one of the best methodologies available to estimate distribution coefficients for a host of projects (the Hazardous Waste Identification Rule [HWIR], the soil screening levels [SSLs], and the Superfund Chemical Data Matrix [SCDM]). To ensure that the model reflects current research, EPA performed a comprehensive recompilation of the thermodynamic databases to incorporate the latest and most defensible data. EPA also developed data sets for the Diffuse Layer Model (DLM) for metals not originally covered in earlier versions of the model. By updating the DLM to include the oxyanions, inconsistencies originating from the need to use multiple methodologies to define distribution coefficients were eliminated.

The revised MINTEQA2 model is available and will be used to estimate distribution coefficients for groundwater systems. This model is appropriate because the necessary system parameters (e.g., substrate and background pore-water chemistry) have been satisfactorily defined. As noted earlier, however, system parameters are specific to groundwater systems and not appropriate for soil, sediment, or surface water environments, which require a greater emphasis on organic matter and clay sorbents and a different background pore-water chemistry. Parameterizing MINTEQA2 for these additional environmental systems (soil, sediment, and surface water environments) would require a substantial effort. No such effort is currently under way. Consequently, EPA does not recommend use of MINTEQA2 to estimate distribution coefficients for soil, sediment, or surface water environments in other Office of Solid Waste (OSW) risk assessments. Similarly, it would be inappropriate to apply MINTEQA2 to agricultural soils.

3.2 Data Reviews and Compilations

In order to develop a consistent approach in the determination of distribution coefficients, EPA is undertaking an extensive and thorough literature review. This review will collect distribution coefficients measured in soils, surface waters, and sediments. Values reported in the literature will be compiled along with reported environmental conditions. Best professional judgment will be used to define a reasonable range and central tendency for distribution coefficients in each medium of interest for each metal. This effort is currently under way. A preliminary report is expected to be completed by the end of November 1998.
Assuming that the time frames for this project and the fertilizer risk assessment are congruent, data collected for this effort can reasonably be used to support the fertilizer risk assessment. If the two time frames are discordant, a similar (but less comprehensive) effort can be undertaken to support the fertilizer risk assessment.

3.3 Literature Search

The most basic data needs for assessing the fate and transport of metals in the environment are system-specific distribution coefficients. A preliminary search of online databases was conducted to identify potential data sources. The following online databases were searched:

- GeoRef
- Inside Conferences
- Biol. & Agric. Index
- Enviroline
- Env.Bib
- GeoArchive
- Water Resour.Abs.
- AGRICOLA
- AGRIS
- CAB Abstracts
- BIOSIS PREVIEWS
- Pollution Abs
- GEOBASE
- NTIS
- Ei Compendex.

The following search string was used:

"distribution coefficient(s) OR Kd OR partition coefficient(s) OR Kp"
AND "metal(s) OR barium" AND "soil(s)"

Search fields included title, keywords, and abstracts (if available). Emphasis was placed on locating distribution coefficients for barium for soil environments. Although “agricultural soil” was used as a potential search string, only two records were returned. Thus, “agricultural soil” was deemed too limiting and replaced with “soils” in the search string. The broad grouping of “metal(s)” was also included in the search string. An individual search for each of the metals of interest (e.g., barium) will likely be required, however, to ensure that all applicable data are located.

To ensure that articles from the most relevant journals are included in the search, each of the following journals was indexed in one or more of the databases searched:

- *Environmental Science and Technology*
- *Geochimica et Cosmochimica Acta*
- *Water Research*
- *Soil Science Society of America Journal*
- *Water, Air and Soil Pollution*
- *Journal of Environmental Quality*
- *The Science of the Total Environment*

- # *Environmental Toxicology and Chemistry*
- # *Applied Geochemistry*
- # *Organic Geochemistry*
- # *Geoderma.*

A total of 159 records were returned (Appendix A). Abstracts are available for the majority of the records and can be used to assess each potential data source. Reports with the greatest potential use can be ordered through interlibrary services. Upon receipt, these reports can be reviewed and data extracted and compiled in an Excel spreadsheet. Important fields that should be included in the spreadsheet are

- # Report title
- # Authors
- # Date
- # Metal
- # Experimental methodology (e.g., column versus batch)
- # Metal concentration
- # pH
- # Soil characteristics (soil type as well as clay and organic matter content, if reported)
- # Solution composition
- # Distribution coefficient value
- # Range in distribution coefficient values (if reported)
- # Number of observations
- # Comments.

Because this project is specific to fertilizer applications, data compilation should be limited to agricultural soil/water environments in the pH range of 4.5 to 9.0. Although every attempt should be made to avoid biasing the data in terms of any one researcher or set of researchers, all reported values that fit the application should be recorded.

3.4 Options and Recommendations

Although significant effort has been devoted to revising and updating the MINTEQA2 aqueous speciation model, revisions have not included incorporation of adsorbent surfaces that would be more representative of an agricultural soil environment (i.e., organic matter and clays). Furthermore, concentration values for important constituents in the system of interest have not been determined. Both of these factors make the use of MINTEQA2 a poor choice for estimating distribution coefficients for the fertilizer risk assessment.

Given the inappropriateness of using MINTEQA2 to estimate distribution coefficients for agricultural soil environments, a literature review should be conducted to collect distribution coefficients measured in agricultural soils. The conditions under which the distribution coefficient was derived must approximate the environmental system of interest as closely as possible. Best professional judgment can be used to define a reasonable range and central tendency for distribution coefficients for each metal. Appendix A is an example of the literature search results that may be anticipated. The literature search and retrieval process will take approximately 2 weeks to complete, and review of the articles, data entry, and quality assurance will require an additional 4 to 6 weeks. Data analysis will take additional time. The literature search and retrieval can begin immediately, and the database can be completed by the end of December. The services of a statistician probably will be required to develop appropriate central tendency and high-end values and distributions of K_ds appropriate for use in nationwide risk assessments. The data analysis resources required for the data analysis depend on the results of the data collection. It is, therefore, impossible at this time to accurately predict the time requirements of this portion of the analysis. No appropriate K_d values are readily available for use in this risk assessment, so some aspects of this approach are required before the risk assessment can be performed.

4.0 Plant Uptake Factors

The cement kiln dust (CKD) peer reviewers noted that the use of plant-soil bioconcentration factors (Br) for assessing risk from agricultural liming using CKD was appropriate. The committee observed that the use of Br factors developed for the land application of sewage sludge, however, was not appropriate but acknowledged that there were few alternatives. They noted that the organic materials and other constituents in sewage sludge may act as metal adsorbants and, thus, reduce the bioavailability of metals to plants. The committee encouraged U.S. Environmental Protection Agency (EPA) to identify and use data for materials that are more similar to CKD than sewage sludge.

Plant uptake of metals from soil occurs either passively with the mass flow of water into the roots or through active transport across the plasma membrane of the root epidermal cells. Under normal growing conditions, plants can potentially accumulate concentrations of some metal ions on orders of magnitude greater than concentrations in the surrounding medium (Raven et al., 1982). On the other hand, uptake of some metals appears to be saturation-limited. Still other metals that are also plant nutrients are taken up only as needed; therefore, concentrations do not vary relative to the soil concentration (Sample et al., 1997). The availability of metals for uptake into plant roots is a function of (1) characteristics of the metal itself; (2) soil characteristics, such as pH, clay and/or organic matter content, and cation exchange capacity (CEC); and (3) the particular plant species' morphology and physiology. In addition, the presence of certain nutrients and minerals in the soil can affect the bioavailability of contaminant metals. For example, Miller and colleagues (1976) report that cadmium uptake increases with increases in available soil phosphorous.

Metals taken up from soils into roots can either remain in the root tissue or be translocated to aerial parts of the plant. From the roots, minerals are secreted into the xylem (vascular tissue) and transported upward through the transpiration stream. Within the aerial parts, metals may move from cell to cell or through the apoplast (system of cell walls). Certain inorganic ions are transferred in leaf tissue to the phloem and translocated to flower and fruit structures. Translocation of metals from the roots throughout the plant tissue differs among metals and plant species. For example, lead and arsenic tend to accumulate in root tissue and are not translocated to aerial parts (Chaney and Ryan, 1994).

For risk assessment, estimation of metal concentrations in plants is generally based on the application of uptake factors to known or modeled metal concentrations in the soil. No established or generally accepted plant uptake factors are available for metals in inorganic matrices. Based on a review of the literature, the development of plant uptake factors for metals must include consideration of specific soil types and their respective chemistry, plant species, and plant parts of concern (e.g., roots, aerial parts, fruits). Plant uptake is linearly correlated with exposure through human ingestion of plant material (e.g., fruits and vegetables). Metal contaminants can also bioaccumulate in food animals and result in exposure to humans through secondary ingestion of meat and dairy products.

4.1 Data Collection Methods for Development of Uptake Factors

Three primary sources of plant uptake data have been identified as follows:

California Department of Food and Agriculture (CDFA) report on risk-based concentrations for certain metals in fertilizers (CDFA, 1998);

Oak Ridge National Laboratory report, *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants* (Sample et al., 1997); and

Chaney and Ryan's *Risk Based Standards for Arsenic, Lead, and Cadmium in Urban Soils* (Chaney and Ryan, 1994).

The first two sources include compilations of data from the literature and plant uptake factors derived from those data. However, the data used to develop these uptake factors are in some ways problematic and pose questions about the appropriate methods for uptake factor development. These issues are discussed in detail in Chaney and Ryan's (1994) report. Studies cited in the Chaney and Ryan (1994) report were screened to eliminate data that address metal uptake from application of municipal sludge.

Data from all three of these sources have been compiled in a preliminary plant uptake factor database. The data have been assessed in light of the discussion in Chaney and Ryan (1994) on the development of uptake factors. The following sections describe the data extraction and QA methods and summarize significant issues relevant to the use of these data for development of plant uptake factors.

4.1.1 Data Entry

All retrieved literature was reviewed to determine if the data were appropriate for entry into the database. Data were entered only if they were from a primary source and presented corresponding soil and tissue concentrations. Additionally, only data presented numerically or in a format where reliable estimation of numeric values was possible were entered. Regression data and data for elements reported in combination were not included. Only individual elements were included. For those data determined to be appropriate for entry, the following decisions were made:

Only data from soil depths of 0 to15 cm were included because the risk model assumes a tilling depth of that range.

If presented, the corrected values (adjusted for possible soil contamination from residue soils) were entered.

- Total concentration was entered as opposed to exchangeable ion or any other form of partial measurement.

- Amended soil concentrations were entered, and background concentrations were noted, where available.

- Because of potential variability, plant weights were not included.

- Where available, whether the plant tissue was washed was noted in an attempt to account for possible soil contamination from residue soils.

4.1.2 Quality Assurance

To prevent inaccuracies in the database, a QA assessment was performed on all entered data by an auditor other than the data enterer. The QA assessment consisted of a 100 percent check of the entered data against the original reference. Audit findings were documented on a hardcopy of the data. Upon completion of the QA assessment, the data entry personnel reviewed the comments, made the appropriate changes, and noted on the hardcopy that the changes had been made. When indicated changes were not made, explanations were also noted on the hardcopy.

4.2 Summary of Preliminary Database

The data in the preliminary database include metal concentrations in plants and associated soil concentrations, as well as various soil and plant species descriptors. Table 4-1 lists the data categories included. Table 4-2 shows the metals included in the database and the number of data pairs (plant tissue concentration and soil concentration) for each metal.

4.2.1 Greenhouse versus Field Studies

A significant difference in the data collected concerns whether the data come from field studies or greenhouse studies. As discussed in Chaney and Ryan (1994), greenhouse studies have been shown to result in higher metal uptake rates than do field studies. The CDFA (1998) report also acknowledges that greenhouse study data tend to show higher uptake rates; however, the CDFA (1998) report uses both greenhouse and field studies to develop uptake factors. The report states that use of greenhouse data is assumed to provide more conservative results. Most of the data collected from the CDFA (1998) and Oak Ridge (1997) reports (about 60 percent) are from greenhouse studies. Options for addressing this issue are discussed in Section 4.4.

4.2.2 Plant Categorization

Most of the source studies include information on the part of the plant for which constituent concentrations were determined. Although the terminology used and the level of specificity vary among reports (e.g., above-ground parts, herbage, stems), the plant parts addressed can be divided into a few general categories. These categories are significant because the most relevant concentrations for risk assessment are those associated with edible parts. Furthermore, as described in Section 4.1, metal contaminants are differentially

Table 4-1. Plant Uptake Data Categories

Data Category	Description
Study ID	Identification of source reference
Constituent	Metal
Chemical form	Chemical form of metal measured
Valence state	Valence of measured constituent
Media	Soil or solution
Soil type	Soil classification
Soil pH	Reported range and mean values
Study type	Field or greenhouse study
Plant part	Reported plant part in which concentration was measured
Plant farm food chain (FFC)	FFC category
Plant species	Common name of study plant
Plant uptake category	Root, fruit, grain, herbaceous part, or forage
Organic carbon percentage	Soil organic content
Clay percentage	Soil clay content
Soil concentration	Measured constituent concentration in soil
77Tissue concentration	Measured constituent concentration in plant tissue

Table 4-2. Metals Included in Preliminary Database[1]

Metal	Number of Field Data Pairs	Number of Total Data Pairs
Arsenic	87	104
Arsenic trioxide	16	16
Cadmium	272	1,205
Chromium	153	183
Copper	49	344
Iron	5	28
Lead	169	669
Manganese	3	26
Mercury	14	17
Nickel	6	210
Phosphorus	20	29

Zinc	78	1,180

[1] Less than five data pairs for aluminum, barium, cesium, cobalt, lanthanum, lithium, selenium, sodium, strontium, titanium, vanadium, and yttrium.

translocated throughout the roots and aerial parts of plants. The following plant part categories have been developed to summarize and assess the preliminary database:

- Roots,
- Herbaceous parts (nonreproductive aerial parts),
- Reproductive parts (flowers, fruits, nuts, seeds),
- Grains, and/or
- Forage (plant matter consumed by animals but not humans).

These categories are also proposed as potential divisions for uptake factor development. The categories are based on discussions in the primary data sources and in several of the reports from which data were extracted, general texts on plant uptake mechanisms and translocation (Fitter and Hay, 1983; Raven et al., 1982; Wilkins, 1990), and compatibility with the exposure factors categories.

4.2.3 Data Summary

Table 4-3 presents summary statistics for the data compiled for each metal: the number of data points, the range, the mean, the median, and the standard deviation for uptake factors calculated from each data pair (plant concentration divided by corresponding soil concentration). Metals for which fewer than five data pairs were found are not included in the table; those metals are aluminum, barium, cesium, cobalt, lanthanum, lithium, selenium, sodium, strontium, titanium, vanadium, and yttrium. These Br values, calculated from the preliminary database, are higher than the Br values used for the same metals and analogous plant parts in the CKD analysis (see Table 4-4). For all but the lead leafy vegetation and forage uptake values and the chromium root uptake value, these preliminary Br values are at least an order of magnitude higher than the corresponding CKD Br value.

Table 4-3. Summary Statistics by Metal and Plant Uptake Category for Plant-Soil Uptake Database

	Field					Greenhouse				
	Forage	**Fruit**	**Grain**	**Herbage**	**Roots**	**Forage**	**Fruit**	**Grain**	**Herbage**	**Roots**
Arsenic										
Number of data points	26	12	0	22	23	0	2	0	7	6
Maximum value	0.445454545	0.011538462	NA	0.333333333	1.169565217	NA	0.001916667	NA	17.5	114
Minimum value	0.000140187	0.000571429	NA	0.001	0.000897959	NA	8.33333E-05	NA	0.000916667	49.3
Mean	0.073922959	0.003760832	NA	0.068801184	0.098550804	NA	0.001	NA	10.69775	82.03611111
Median	0.061585562	0.001918367	NA	0.034057971	0.004571429	NA	0.001	NA	12	82.075
Standard deviation	0.084492921	0.004063167	NA	0.081741554	0.254507247	NA	0.001296362	NA	6.032144816	2.70E+01
Arsenic trioxide										
Number of data points	0	3	0	11	2	0	0	0	0	0
Maximum value	NA	1.36E-03	NA	1.65E-02	4.75E-03	NA	NA	NA	NA	NA
Minimum value	NA	2.30E-04	NA	3.85E-04	1.99E-03	NA	NA	NA	NA	NA
Mean	NA	6.56E-04	NA	4.10E-03	3.37E-03	NA	NA	NA	NA	NA
Median	NA	3.75E-04	NA	1.81E-03	3.37E-03	NA	NA	NA	NA	NA
Standard deviation	NA	6.17E-04	NA	5.18E-03	1.95E-03	NA	NA	NA	NA	NA
Cadmium										
Number of data points	43	2	161	37	49	166	93	73	319	135
Maximum value	1.74E+01	7.50E-02	9.00E+00	4.00E+00	4.00E+00	2.71E+02	5.00E+01	2.80E+00	5.28E+01	4.34E+01
Minimum value	1.17E-03	2.50E-03	2.50E-03	2.50E-03	1.25E-02	4.18E-04	7.28E-03	9.09E-05	5.27E-04	1.43E-03
Mean	1.34E+00	3.88E-02	2.43E-01	7.21E-01	7.78E-01	6.12E+00	4.34E+00	2.00E-01	2.94E+00	2.16E+00
Median	2.98E-02	3.88E-02	1.10E-01	3.78E-01	4.29E-01	6.45E-01	1.02E+00	6.00E-02	4.73E-01	5.99E-01

(continued)

Table 4-3. (continued)

	Field					Greenhouse				
	Forage	Fruit	Grain	Herbage	Roots	Forage	Fruit	Grain	Herbage	Roots
Standard deviation	3.08E+00	5.13E-02	7.32E-01	9.26E-01	8.61E-01	2.32E+01	8.97E+00	4.32E-01	7.06E+00	5.03E+00
Chromium										
Number of data points	42	5	4	95	6	0	18	9	0	0
Maximum value	3.53E-01	1.82E-03	1.43E-04	6.91E-02	2.31E-03	NA	6.57E-02	1.18E-01	NA	NA
Minimum value	3.32E-05	4.40E-05	4.82E-05	1.20E-05	7.64E-05	NA	4.59E-03	1.34E-02	NA	NA
Mean	1.13E-02	4.51E-04	9.27E-05	3.17E-03	1.08E-03	NA	2.57E-02	5.24E-02	NA	NA
Median	4.39E-04	1.18E-04	8.99E-05	1.23E-03	9.49E-04	NA	1.44E-02	5.17E-02	NA	NA
Standard deviation	5.49E-02	7.68E-04	4.16E-05	7.65E-03	8.85E-04	NA	2.14E-02	3.80E-02	NA	NA
Copper										
Number of data points	2	10	2	9	21	22	54	42	139	35
Maximum value	4.61E-01	6.55E-01	1.80E+00	2.31E+00	8.11E-01	1.28E+02	3.36E+00	6.82E-01	9.20E-01	4.70E-01
Minimum value	4.03E-01	1.29E-01	1.53E+00	1.28E-01	6.04E-02	3.74E-02	4.56E-03	1.64E-02	6.39E-03	7.30E-03
Mean	4.32E-01	4.43E-01	1.66E+00	6.07E-01	4.52E-01	2.16E+01	5.70E-01	1.30E-01	1.29E-01	6.45E-02
Median	4.32E-01	4.96E-01	1.66E+00	4.49E-01	4.80E-01	7.03E+00	1.98E-01	1.04E-01	7.52E-02	3.10E-02
Standard deviation	4.09E-02	1.92E-01	1.91E-01	6.66E-01	2.30E-01	3.60E+01	7.69E-01	1.29E-01	1.82E-01	9.10E-02
Lead										
Number of data points	25	12	5	35	92	83	43	31	222	92
Maximum value	1.65E+00	3.48E-01	7.79E-02	4.68E-01	4.81E-01	1.77E+01	2.71E-01	8.37E-02	3.21E+00	8.77E-01
Minimum value	3.55E-02	2.17E-03	6.96E-03	5.22E-04	6.45E-04	4.43E-03	1.11E-04	5.54E-04	5.54E-04	5.54E-04
Mean	2.16E-01	6.71E-02	2.81E-02	6.03E-02	4.64E-02	2.27E+00	5.31E-02	1.42E-02	3.14E-01	1.35E-01

(continued)

Table 4-3. (continued)

	Field					Greenhouse				
	Forage	**Fruit**	**Grain**	**Herbage**	**Roots**	**Forage**	**Fruit**	**Grain**	**Herbage**	**Roots**
Median	1.40E-01	4.09E-02	1.30E-02	2.30E-02	1.86E-02	8.20E-01	2.59E-02	9.15E-03	5.49E-02	4.68E-02
Standard deviation	3.13E-01	9.82E-02	2.93E-02	9.52E-02	7.40E-02	3.38E+00	7.23E-02	1.67E-02	5.97E-01	1.82E-01
Manganese										
Number of data points	2	0	0	1	0	0	16	0	1	0
Maximum value	1.55E+00	NA	NA	6.73E-01	NA	NA	1.02E+00	NA	5.24E-01	NA
Minimum value	1.00E+00	NA	NA	NA	NA	NA	2.29E-01	NA	NA	NA
Mean	1.27E+00	NA	NA	NA	NA	NA	4.35E-01	NA	NA	NA
Median	1.27E+00	NA	NA	NA	NA	NA	4.16E-01	NA	NA	NA
Standard deviation	3.86E-01	NA	NA	NA	NA	NA	1.79E-01	NA	NA	NA
Mercury										
Number of data points	4	2	3	3	2	0	2	0	1	0
Maximum value	1.76E+00	1.43E-02	1.14E-01	1.57E+00	4.29E-02	NA	8.13E-03	NA	1.25E-02	NA
Minimum value	7.92E-02	1.43E-02	7.14E-02	7.14E-02	2.86E-02	NA	1.88E-03	NA	NA	NA
Mean	7.19E-01	1.43E-02	9.05E-02	7.34E-01	3.57E-02	NA	5.00E-03	NA	NA	NA
Median	5.16E-01	1.43E-02	8.57E-02	5.59E-01	3.57E-02	NA	5.00E-03	NA	NA	NA
Standard deviation	7.55E-01	0.00E+00	2.18E-02	7.65E-01	1.01E-02	NA	4.42E-03	NA	NA	NA
Nickel										
Number of data points	5	0	0	1	0	4	50	23	91	23
Maximum value	2.00E-01	NA	NA	1.97E-02	NA	1.66E-01	1.63E+00	9.50E-01	1.08E+00	1.17E-01
Minimum value	1.55E-02	NA	NA	NA	NA	6.59E-02	5.07E-03	1.01E-02	5.07E-03	5.07E-03

(continued)

Table 4-4. (continued)

	Field					Greenhouse				
	Forage	Fruit	Grain	Herbage	Roots	Forage	Fruit	Grain	Herbage	Roots
Mean	6.86E-02	NA	NA	NA	NA	1.16E-01	1.83E-01	3.27E-01	9.21E-02	3.93E-02
Median	3.49E-02	NA	NA	NA	NA	1.16E-01	1.24E-01	3.14E-01	4.31E-02	3.08E-02
Standard deviation	7.55E-02	NA	NA	NA	NA	5.78E-02	2.38E-01	2.71E-01	1.74E-01	3.14E-02
Zinc										
Number of data points	21	0	10	21	26	18	86	45	169	63
Maximum value	3.43E+01	NA	4.88E+00	2.57E+00	4.60E-01	4.84E+00	5.75E+01	2.43E+00	1.40E+01	1.23E+01
Minimum value	1.69E-03	NA	1.33E-01	4.72E-02	8.42E-03	7.15E-02	1.76E-02	1.94E-02	1.76E-02	1.18E-02
Mean	2.13E+00	NA	9.70E-01	5.07E-01	1.35E-01	1.20E+00	6.62E+00	4.90E-01	9.14E-01	1.14E+00
Median	1.19E-02	NA	1.67E-01	2.59E-01	1.30E-01	8.76E-01	1.76E+00	2.39E-01	3.30E-01	3.75E-01
Standard deviation	7.46E+00	NA	1.61E+00	6.96E-01	9.73E-02	1.31E+00	1.32E+01	6.03E-01	1.77E+00	2.09E+00

Table 4-3. CKD Uptake Factors

CAS	Name	Plant-soil rcf-root veg (ug/g WW plant)/ (ug/mL soil water)	Plant-soil bcf-leafy veg (ug/g DW plant)/ (ug/g soil)	Plant-soil bcf-forage (ug/g DW plant)/ (ug/g soil)
7439-92-1	Lead	9.0E-03	1.3E-05	1.3E-05
7439-97-6	Mercury	1.4E-02	8.0E-03	2.0E-03
7440-02-0	Nickel	8.0E-03	3.2E-02	1.1E-01
7440-38-2	Arsenic	8.0E-03	3.6E-02	6.0E-02
7440-43-9	Cadmium	6.4E-02	3.6E-01	1.4E-01
7440-47-3	Chromium VI	4.5E-03	7.5E-03	7.5E-03

WW - wet weight
DW - dry weight

The summary statistics indicate that, for most metals, fewer than five data pairs from field data have been found for grains and fruits. In some cases, inclusion of the greenhouse study data fills these data gaps (e.g., cadmium uptake in fruits, lead uptake in grains). In other cases, however, the combined greenhouse and field data still contain gaps (e.g., arsenic and arsenic trioxide uptake in grains or manganese uptake in grains, herbage, and roots). Field study data are lacking for all plant categories for manganese, mercury, and nickel. The ranges for the uptake values are, in most cases, greater than one order of magnitude. This degree variation is not unexpected, based on other Br values in the literature.

4.3 Issues and Options

Study Type – As discussed in Section 4.3.1, combining data from greenhouse studies and field studies is not recommended. The majority of data retrieved from the primary sources, however, are from greenhouse studies; therefore, excluding greenhouse data would leave a relatively limited amount of data from which to derive uptake factors. Research Triangle Institute (RTI) considered the option of further literature searches. A search of online literature sources from 1996 to the present produced 114 titles. A sample of about 25 percent of these titles showed none that have been included in the preliminary database; about half of the sample titles are potentially relevant to this risk assessment. Ascertaining from the titles or abstracts whether the data are from greenhouse or field studies is not always possible. Results of this literature search are presented in Appendix C. This sampling indicates that a more in-depth literature search may provide additional field-derived data to support development of uptake factors.

Limited Data for Metal-Soil-Crop Combinations – Ideally, uptake factors will be developed for particular soil-crop combinations that reflect actual agricultural practices. As noted in Section 4.3.3, however, significant data gaps exist in the current preliminary database, particularly for field study data. It is unclear whether adequate data are available for all such combinations of interest. Therefore, data may need to be combined (for example, for all root crops or for all soils with a particular organic matter content). Care will be taken to combine data in such a way that only reasonable combinations of soils and crops are assumed, however. Plant concentrations will not be combined with soil concentrations for soils on which a particular plant or crop would never be grown.

4.4 References

California Department of Food and Agriculture. 1998. *Development of Risk-Based Concentrations for Arsenic, Cadmium, and Lead in Inorganic Commercial Fertilizers*. Prepared by Foster Wheeler Environmental Corporation, Sacramento, CA.

Chaney, R.L., and J.A. Ryan. 1994. *Risk Based Standards for Arsenic, Lead, and Cadmium in Urban Soils*. Frankfurt am Main, Germany: DECHEMA.

Fitter, A.H., and R.K.M. Hay. 1983. *Environmental Physiology of Plants*. New York: Academic Press.

Miller, J.E., J.J. Hassett, and D.E. Koeppe. 1976. Uptake of cadmium by soybeans as influenced by soil cation exchange capacity, pH, and available phosphorus. *Journal of Environmental Quality* 5:2.

Raven, P.H., R.F. Evert, and H. Curtis. 1982. *Biology of Plants*. Third Edition. New York: Worth Publishers, Inc.

Sample, B.E., M.S. Alpin, R.A. Efroymson, G.W. Suter, and C.J.E. Welsh. 1997. *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants*. Environmental Sciences Division Publication No. 4650. Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, TN.

Wilkins, M.B. 1990. *Advanced Plant Physiology*. New York: John Wiley and Sons.

5.0 GIS Data Options for Fertilizer Risk Assessment

Geographic information systems (GIS) are useful tools to combine and analyze different national data sets. Therefore, GIS could be effectively used to support the data collection efforts for the fertilizer risk assessment. The following section describes the methodologies and data sources that can be used to provide data on crop-specific soil types. Research Triangle Institute (RTI) uses ESRI GIS products, so all GIS data would be processed with Arc/Info run on a Sun Microsystems server or with Arc/View run on a common Pentium-based personal computer (PC), should the U.S. Environmental Protection Agency (EPA) decide to use GIS to obtain more site-specific data.

5.1 Available Data Sets

In order to determine soil qualities specific to certain crop types or groups, GIS can be used to analyze spatial data. As an example, three national data sets were processed to determine the soil type related to the crop type. The three data sources for this example are

Geographic Information Retrieval and Analysis System (GIRAS) land use data — 1:250,000 scale quadrangles of land use/land cover GIRAS spatial data in the conterminous United States — http://nsdi.epa.gov/nsdi/projects/giras.htm

State Soil Geographic (STATSGO) soils data — http://www.ftw.nrcs.usda.gov/stat_data.html

U.S. Department of Agriculture, 1992 Census of Agriculture — http://www.nass.usda.gov/census/census92/agrimenu.htm

The object of this example was to overlay the three data sources and to determine what soil attributes exist in areas where potatoes are farmed. The first step was to use the Census of Agriculture to determine where potatoes are grown throughout the United States. The Census of Agriculture provides data at the county summary level, and, therefore, counties with at least one acre of potatoes reported for 1992 (the year of this particular census) were selected. Figure 5-1 illustrates the counties that reported potatoes grown in 1992.

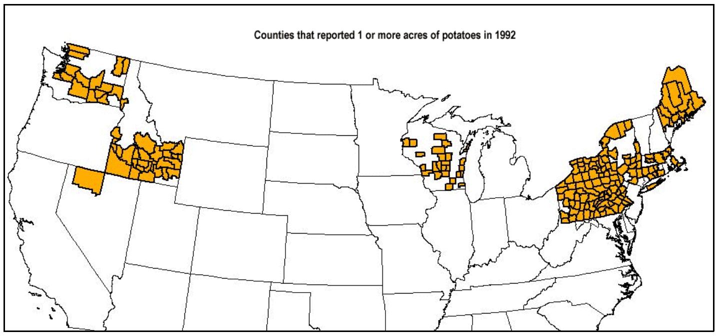

Figure 5-1. Potato farm counties identified from 1992 Census of Agriculture.

The next step was to overlay these selected counties with GIRAS land use quads to refine the county areas to only a farming land use type. The land use data available for the entire United States are classified with Anderson level II land use codes. The following example is a subset of the Anderson land use codes:

Level I	**Level II**
2 Agricultural Land	21 Cropland and Pasture
	22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
	23 Confined Feeding Operations
	24 Other Agricultural Land

For this example, Anderson level II land use number 21, Cropland and Pasture, was used. Figure 5-2 shows a zoomed-in view of the potato counties of Washington State and the cropland land use areas.

The potato county farming land use areas were then overlaid with the national STATSGO soil layer (Figure 5-3.) This gives an approximation of the soil qualities specifically where potatoes are grown.

The product of this example is a spreadsheet of unique identifiers for soil area polygon map unit identifications (MUIDs) and their respective areas. The spreadsheet can then be used by a soil expert to extract relevant data from the STATSGO soil database.

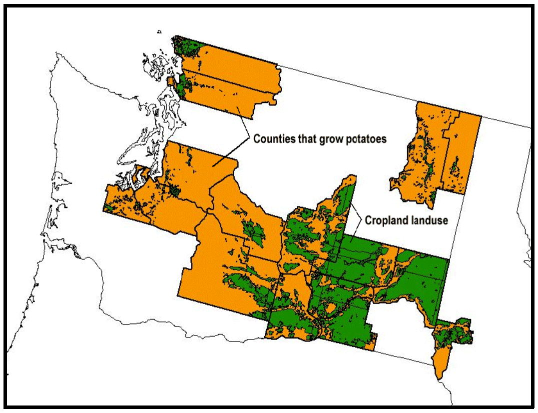

Figure 5-2. Potato counties and cropland land use areas.

Figure 5-3. Soils overlaid with cropland land use and potato counties.

Benefits of this approach are as follows:

- RTI has all the data needed in-house; further data acquisition and processing would not be needed.
- These data are automatable for a large variety of crop types and/or categories of crops such as grains or root vegetables.

Specific issues for this approach:

- # Currency of data: GIRAS land use is from the mid-1970's, and the Census of Agriculture is from 1992.

- # Scale: Census of Agriculture data are county-level data, which reflect a much smaller scale than land use or soil data. (Soil and land use data are delineated with greater spatial resolution.)

5.2 Issues

Issues associated with the use of GIS for risk analysis include questions regarding the scale and currency of various data sets that would be combined. The soil, crop, and land use data sets are mapped at different scales. Furthermore, some data sets (e.g., the Soil Survey Geographic [SSURGO] database) are not available with nationwide coverage. The various data sets have also been compiled at different times and may not be consistent. For example, GIRAS data may report an agricultural land use for an area that is no longer reported as farmed in the Census of Agriculture.

In addition, using GIS to identify soil types associated with certain crop types results in an approximation only. Without data on the specific location of actual farms (such data are not available), more rigorous correlations of soils and crops are not possible.

Attachment 1 to Appendix B

Literature Search Results for K_d

19/6/1 (Item 1 from file: 89)
02255424 GEOREF NO.: 98-66655
TITLE: Systematic evaluation of the partitioning of cesium, strontium, and cobalt in natural soils and reference clays
MONOGRAPH TITLE: Geological Society of America, 1997 annual meeting
DATE: 1997

19/6/4 (Item 4 from file: 89)
02209889 GEOREF NO.: 98-19431
TITLE: Metal-induced sulfate adsorption by soils; III, Applications of Langmuir equations
DATE: 199703

19/6/5 (Item 5 from file: 89)
02197160 GEOREF NO.: 98-04437
TITLE: Isothermal coupled transport processes in soils and clays
DATE: 199506

19/6/6 (Item 6 from file: 89)
02186483 GEOREF NO.: 97-71094
TITLE: Calculation of soil-water and benthic sediment partition coefficients for mercury
DATE: 199708

19/6/8 (Item 8 from file: 89)
02178364 GEOREF NO.: 97-01699
MONOGRAPH TITLE: Determination of site specific distribution coefficients of mixed waste contaminants using an in-situ approach
DATE: 1993

19/6/9 (Item 9 from file: 89)
02161529 GEOREF NO.: 97-48525
TITLE: Cu2+ adsorption in Wyoming soils; Kd vs surface complexation models
MONOGRAPH TITLE: Geological Society of America, 28th annual meeting
DATE: 1996

19/6/10 (Item 10 from file: 89)
02147494 GEOREF NO.: 97-34397
TITLE: Cadmium and nickel distribution coefficients for sandy aquifer materials
DATE: 199610

19/6/11 (Item 11 from file: 89)
02144746 GEOREF NO.: 97-33334
MONOGRAPH TITLE: Adsorption and desorption reactions of mercury(II) and methylmercury at the soil-solution interface
DATE: 1996

19/6/13 (Item 13 from file: 89)
02142019 GEOREF NO.: 97-30438
TITLE: The influence of dissolved organic carbon, suspended particulates, and hydrology on the concentration, partitioning and variability of trace metals in two contrasting Wisconsin watersheds (U.S.A.)
DATE: 19970327

19/6/19 (Item 19 from file: 89)
02097472 GEOREF NO.: 96-62434
TITLE: Metal ion binding by natural organic matter; from the model to the field
DATE: 199607

19/6/20 (Item 20 from file: 89)
02090205 GEOREF NO.: 96-55076
TITLE: Soil partition coefficients for Cd by column desorption and comparison to batch adsorption measurements
DATE: 199508

19/6/22 (Item 22 from file: 89)
02051628 GEOREF NO.: 96-14795
MONOGRAPH TITLE: A comparative study of the retention and leaching of lead and cadmium in several New Jersey soils
DATE: 1994

19/6/23 (Item 23 from file: 89)
02051553 GEOREF NO.: 96-14697
TITLE: Zinc adsorption by a Calcareous soil; copper interaction
DATE: 199601

19/6/28 (Item 28 from file: 89)
01975841 GEOREF NO.: 95-01449
MONOGRAPH TITLE: Metal-induced sulfate adsorption by soils
DATE: 1993

19/6/29 (Item 29 from file: 89)
01971435 GEOREF NO.: 94-53853
MONOGRAPH TITLE: Groundwater geochemistry and the potential migration of contaminants in the Hualapai Basin, northern Arizona
DATE: 1992

19/6/36 (Item 36 from file: 89)
01664308 GEOREF NO.: 90-05207
TITLE: Associations between the fluctuations of the distribution coefficients of Cs, Zn, Sr, Co, Cd, Ce, Ru, Tc and I in the upper two horizons of a Podzol forest soil
DATE: 1989

19/6/42 (Item 42 from file: 89)
01567475 GEOREF NO.: 88-67106
TITLE: Distribution coefficients of Cd, Co, Ni, and Zn in soils
DATE: 198803

19/6/43 (Item 43 from file: 89)
01549873 GEOREF NO.: 88-48849
TITLE: Zinc, lead, and cadmium adsorption by soils
DATE: 1988

19/6/44 (Item 44 from file: 89)
01419585 GEOREF NO.: 86-86865
TITLE: Distribution coefficients for nickel and zinc in soils
DATE: 1986
19/6/50 (Item 1 from file: 40)
00546052 ENVIROLINE NUMBER: 98-02198
Equilibrium Partitioning of Heavy Metals in Dutch Field Soils. I. Relationship Between Metal Partition Coefficients and Soil Characteristics
Dec 97

19/6/52 (Item 3 from file: 40)
00445182 ENVIROLINE NUMBER: 97-02196
Distribution Coefficients of Platinum Group Metals Between Soil and Liquid Phases
Oct 96

19/6/53 (Item 4 from file: 40)
00416659 ENVIROLINE NUMBER: 93-12665
Adsorption and Mobility of Cadmium in Natural, Uncultivated Soils
Oct-Dec 93

19/6/54 (Item 5 from file: 40)
00392481 ENVIROLINE NUMBER: 92-03014
Sorption of Strontium, Selenium, Cadmium, and Mercury in Soil
1991

19/6/55 (Item 6 from file: 40)
00372003 ENVIROLINE NUMBER: 89-04486
Cadmium Soil Sorption at Low Concentrations: VIII. Correlation with Soil Parameters
Mar 89

19/6/56 (Item 7 from file: 40)
00366172 ENVIROLINE NUMBER: 88-71155
Variablility of the Sorption of Cs, Zn, Sr, Co, Cd, Ce, Ru, Te, and I at Trace Concentrations by a Forest Soil Along a Transect
1987

19/6/57 (Item 8 from file: 40)
00361625 ENVIROLINE NUMBER: 87-33579
Cadmium Soil Sorption at Low Concentrations: V. Evidence of Competition by Other Heavy Metals
Jul 87
19/6/59 (Item 2 from file: 68)
00576479 Environmental Bibliography Number: 2624601
Distribution coefficients of platinum group metals between soil solid and liquid phases
PUBLICATION YEAR: 1996

19/6/60 (Item 3 from file: 68)
00576428 Environmental Bibliography Number: 2624550
Predicting soil-water partition coefficients for cadmium
PUBLICATION YEAR: 1996

19/6/63 (Item 3 from file: 117)
00817243 WRA NUMBER: 4221703
Partitioning of metals to sediment organic carbon
1996

19/6/74 (Item 2 from file: 10)
3579652 20567946 Holding Library: AGL
The geochemistry of chromium migration and remediation in the subsurface

1995

19/6/75 (Item 3 from file: 10)
3549799 20544790 Holding Library: AGL
Adsorption of IIB- metals by three common soil fungi--comparison and assessment of importance for metal distribution in natural soil systems
1996 Jul

19/6/77 (Item 5 from file: 10)
3351024 20378467 Holding Library: AGL
Influence of cattle-manure slurry application on the solubility of cadmium, copper, and zinc in a manured acidic, loamy-sand soil
1993 Oct

19/6/78 (Item 6 from file: 10)
3233479 92070043 Holding Library: AGL
Effect of cropping systems on adsorption of metals by soils. II. Effect of pH
1992 Mar

19/6/80 (Item 2 from file: 203)
01551504
Effect of compost on distribution coefficients for Zn and Cd in soil [in Emilia-Romagna]
1989

19/6/82 (Item 4 from file: 203)
01127194
Cadmium soil sorption at low concentrations, 4: Effect of waste leachates on distribution coefficients
1985

19/6/83 (Item 5 from file: 203)
00825466
Adsorption, desorption and extractability of Zn in some Algerian soils under orange cultivation
1980

19/6/84 (Item 1 from file: 50)
03496178 CAB Accession Number: 981903142
Review and performance of four models to assess the fate of radionuclides and heavy metals in surface soil.

19/6/85 (Item 2 from file: 50)
03465090 CAB Accession Number: 971913532
Ion exchange resin and MINTEQA2 speciation of Zn and Cu in alkaline sodic and acidic soil extracts.

19/6/87 (Item 4 from file: 50)
03167021 CAB Accession Number: 961900308
Metal -induced sulfate adsorption by soils: II. Effects of metal type, valence, and concentration.

19/6/89 (Item 6 from file: 50)
03095421 CAB Accession Number: 951909747
Field-based partition coefficients for trace elements in soil solutions.

19/6/91 (Item 8 from file: 50)
02862643 CAB Accession Number: 941903552
The solid-solution equilibria of lead and cadmium in polluted soils.

19/6/93 (Item 10 from file: 50)
02531201 CAB Accession Number: 921964055
Effects of pH, solid/solution ratio, ionic strength, and organic acids on Pb and Cd sorption on kaolinite.

19/6/94 (Item 11 from file: 50)
02531198 CAB Accession Number: 921964052
Affinity constants and behaviour of Cd sorption in some acid soils.

19/6/95 (Item 12 from file: 50)
02519950 CAB Accession Number: 921963787
A field study of diffusion controlled migration of copper, zinc and cadmium in a clay formation.

19/6/96 (Item 13 from file: 50)
02519874 CAB Accession Number: 921963485
Lead in boreal soils and food plants.

19/6/97 (Item 14 from file: 50)
02519808 CAB Accession Number: 921962865
Kinetics of ion sorption on humic substances.

19/6/100 (Item 17 from file: 50)
02227706 CAB Accession Number: 901941983
Correlation of Freundlich Kd and n retention parameters with soils and elements.

19/6/101 (Item 18 from file: 50)
02062651 CAB Accession Number: 891929708
Variability of the sorption of Cs, Zn, Sr, Co, Cd, Ce, Ru, Tc and I at trace concentrations by a forest soil along a transect.

19/6/102 (Item 19 from file: 50)
01903340 CAB Accession Number: 871916024
Tilted-bed simulation of erosion and chemical runoff from agricultural fields: I. Runoff of sediment and sediment-associated copper and zinc.

19/6/103 (Item 20 from file: 50)
01589846 CAB Accession Number: 851994374
Parameters controlling the distribution of Cd, Co, Ni and Zn in soils. Heavy metals in the environment. Volume 2.

19/6/104 (Item 21 from file: 50)
01589831 CAB Accession Number: 851994355
Uptake of heavy metals by crops in relation to their concentration in the soil solution. Heavy metals in the environment. Volume 2.

19/6/106 (Item 23 from file: 50)
01540525 CAB Accession Number: 841990466
The relative affinities of Cd, Ni and Zn for different soil clay fractions and goethite.

19/6/110 (Item 3 from file: 5)
10749815 BIOSIS NO.: 199799370960
Effect of dissolved organic carbon on the mobility of cadmium, nickel and zinc in leachate polluted groundwater.
1996

19/6/111 (Item 4 from file: 5)
10721339 BIOSIS NO.: 199799342484
Estimation of partition coefficients for five trace metals in sandy sediments and application to sediment quality criteria.
1996

19/6/124 (Item 17 from file: 5)
08431184 BIOSIS NO.: 000094138388
COMPARISON OF FOUR EQUATIONS TO DESCRIBE THE KINETICS OF LEAD DESORPTION FROM SOILS
1992

19/6/129 (Item 22 from file: 5)
06792242 BIOSIS NO.: 000088101680
ASSOCIATIONS BETWEEN THE FLUCTUATIONS OF THE DISTRIBUTION COEFFICIENTS OF CESIUM ZINC STRONTIUM COBALT CADMIUM CERIUM RUBIDIUM TECHNETIUM AND IODINE IN THE UPPER TWO HORIZONS OF A PODZOL FOREST SOIL
1989

19/6/130 (Item 23 from file: 5)
06218981 BIOSIS NO.: 000086053163
VARIABILITY OF THE SORPTION OF CESIUM ZINC STRONTIUM COBALT CADMIUM CERIUM RUTHENIUM TECHNETIUM AND IODINE AT TRACE CONCENTRATIONS BY A FOREST SOIL ALONG A TRANSECT
1987 1988

19/6/134 (Item 27 from file: 5)
05722932 BIOSIS NO.: 000084071338
CADMIUM SOIL SORPTION AT LOW CONCENTRATIONS VI. A MODEL FOR ZINC COMPETITION
1987

19/6/135 (Item 28 from file: 5)
05128606 BIOSIS NO.: 000081086731
SURFACE LOADING EFFECT ON CADMIUM AND ZINC SORPTION BY KAOLINITE AND MONTMORILLONITE FROM LOW CONCENTRATION SOLUTIONS
1986

19/6/136 (Item 29 from file: 5)
04269358 BIOSIS NO.: 000077095404
CADMIUM SOIL SORPTION AT LOW CONCENTRATIONS 1. EFFECT OF TIME CADMIUM LOAD PH AND CALCIUM
1984

19/6/138 (Item 31 from file: 5)
03263812 BIOSIS NO.: 000071076923
THE RELEASE OF ARSENIC FROM CONTAMINATED SEDIMENTS AND MUDS
1981

19/6/139 (Item 1 from file: 41)
255392 98-00000
Solvent extraction of metal ions from contaminated soil Publ.Yr:
19970000

19/6/141 (Item 1 from file: 292)
1233987 97J-99999
Predicting soil-water partition coefficients for cadmium
1996

19/6/142 (Item 2 from file: 292)
1106740 95J-13314
Metal-induced sufate adsorption by soils: I. Effect of pH and ionic strength
1995

19/6/143 (Item 3 from file: 292)
0521716 85A-1565
The chemical forms of trace metals in soils. In: Applied environmental geochemistry
1983

19/6/145 (Item 2 from file: 6)
1728764 NTIS Accession Number: DE93003378
Behavior of mercury, lead, cesium, and uranyl ions on four SRS soils
20 Mar 92

19/6/146 (Item 3 from file: 6)
1628441 NTIS Accession Number: DE91640150
Critical compilation and review of default soil solid/liquid partition coefficients, K(sub d), for use in environmental assessments
Mar 90

19/6/147 (Item 4 from file: 6)
1581298 NTIS Accession Number: DE91763375
Data acquisition and application of the soil chemistry model ECCES to forest soil
Dec 90

19/6/149 (Item 6 from file: 6)
1032216 NTIS Accession Number: DE82703277
Barium and Radium Migration in Unconsolidated Canadian Geological Materials
May 81

19/6/150 (Item 1 from file: 8)
04727036
Title: Adsorption of Cd and Zn on montmorillonite in the presence of a cationic pesticide
Publication Year: 1996

19/6/153 (Item 4 from file: 8)
02989706
Title: Critical compilation and review of default soil solid/liquid partition coefficients, K//d, for use in environmental assessments.
Publication Year: 1990

19/6/154 (Item 5 from file: 8)
02798718
Title: Cadmium soil sorption at low concentrations. VII: Effect of stable solid waste leachate complexes.
Publication Year: 1989

19/6/155 (Item 6 from file: 8)
02213858
Title: RETROSPECTIVE ANALYSIS OF AN ARCHIVED SOIL COLLECTION. I. METALS.
Publication Year: 1987

19/6/158 (Item 9 from file: 8)
01908647
Title: SORPTION OF Cd AND Zn ON KAOLINITE AND MONTMORILLONITE.
Conference Title: International Conference - Heavy Metals in the Environment.
Publication Year: 1983

Attachment 2 to Appendix B

Plant Uptake Data Sources

Plant Uptake Data Sources

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Attachment 3 to Appendix B
Literature Search Results for Br

Literature Search Results for Br

18/6/1 (Item 1 from file: 156)
03467809 Subfile: BIOSIS-98-23703
Extractability and plant uptake of heavy metals in alum shale soils.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1998

18/6/2 (Item 2 from file: 156)
03467411 Subfile: BIOSIS-98-23305
Zinc , lead and cadmium accumulation and tolerance in Typha latifolia as affected by iron plaque on the root surface.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1998

XXX
18/6/3 (Item 3 from file: 156)
03458008 Subfile: BIOSIS-98-20360
The uptake and transfer of caesium-137, strontium-90 and zinc-65 from soil to food crops in tropical environment.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1998

18/6/4 (Item 4 from file: 156)
03456534 Subfile: BIOSIS-98-18885
Uptake of traffic-related heavy metals and platinum group elements (PGE) by plants.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1998

XXX
18/6/5 (Item 5 from file: 156)
03437532 Subfile: BIOSIS-98-13398
Cadmium accumulation in crops.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1998

18/6/6 (Item 6 from file: 156)
03437125 Subfile: BIOSIS-98-12991
Bioavailability and uptake of arsenic by wetland vegetation: Effects on plant growth and nutrition.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1998

18/6/7 (Item 7 from file: 156)
03436926 Subfile: BIOSIS-98-12792
Effect of organic materials on partitioning, extractability and plant uptake of metals in an alum shale soil.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1998

18/6/8 (Item 8 from file: 156)
03436868 Subfile: BIOSIS-98-12734
Mercury accumulation in transplanted Hypogymnia physodes lichens downwind of Wisconsin chlor-alkali plant.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1998

18/6/9 (Item 9 from file: 156)
03436725 Subfile: BIOSIS-98-12591
Zinc uptake by plants on amended polluted soils.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

XXX
18/6/10 (Item 10 from file: 156)
03430825 Subfile: TOXBIB-98-131789
Lead uptake and effects on seed germination and plant growth in a Pb hyperaccumulator Brassica pekinensis Rupr.
Publication Year: 1998

XXX
18/6/11 (Item 11 from file: 156)
03418877 Subfile: BIOSIS-98-09305
Cadmium accumulation and distribution in sunflower plant.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1998

18/6/12 (Item 12 from file: 156)
03416491 Subfile: BIOSIS-98-06919
Solubility and plant uptake of metals with and without liming of sludge-amended soils.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1998

XXX
18/6/13 (Item 13 from file: 156)
03414016 Subfile: BIOSIS-98-04443
The influence of arsenite concentration on arsenic accumulation in tomato and bean plants.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

18/6/14 (Item 14 from file: 156)
02700662 Subfile: BIOSIS-97-33907
VARIATION AND RANGE OF MERCURY UPTAKE INTO PLANTS AT A MERCURY
-CONTAMINATED ABANDONED MINE SITE
BIOSIS COPYRIGHT: BIOL ABS. RRM
Publication Year: 1997

18/6/15 (Item 15 from file: 156)
02700391 Subfile: BIOSIS-97-33636
Heavy metal accumulation in plants grown in heavily polluted soils.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

18/6/16 (Item 16 from file: 156)
02699314 Subfile: BIOSIS-97-32558
Effect of apatite amendments on plant uptake of lead from contaminated soil.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

18/6/17 (Item 17 from file: 156)
02698675 Subfile: BIOSIS-97-31918
ARABIDOPSIS THALIANA AS A MODEL SYSTEM FOR STUDYING LEAD ACCUMULATION
AND TOLERANCE IN PLANTS
BIOSIS COPYRIGHT: BIOL ABS. RRM
Publication Year: 1997

XXX
18/6/18 (Item 18 from file: 156)
02697578 Subfile: BIOSIS-97-30821
Arsenic uptake, distribution, and accumulation in bean plants: Effect of arsenite and salinity on plant growth and yield.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

18/6/19 (Item 19 from file: 156)
02696410 Subfile: BIOSIS-97-29653
De novo synthesis and accumulation of apoplastic proteins in leaves of heavy metal-exposed barley seedlings.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

18/6/20 (Item 20 from file: 156)
02695970 Subfile: BIOSIS-97-29213
Accumulation of heavy metals by plants as affected by application of organic wastes.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/21 (Item 21 from file: 156)
02693645 Subfile: BIOSIS-97-26886
Cadmium accumulation and toxicity in submerged plant Hydrilla verticillata (L.F.) Royle.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

18/6/22 (Item 22 from file: 156)
02693322 Subfile: BIOSIS-97-26563
Copper and nickel uptake, accumulation and tolerance in Typha latifolia with and without iron plaque on the root surface.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

XXX
18/6/23 (Item 23 from file: 156)
02692800 Subfile: BIOSIS-97-26041
PHYTOREMEDIATION AND MECHANISMS OF METAL ACCUMULATION IN PLANTS
BIOSIS COPYRIGHT: BIOL ABS. RRM
Publication Year: 1997

XXX
18/6/24 (Item 24 from file: 156)
02692772 Subfile: BIOSIS-97-26013
DEFINING A METAL -HYPERACCUMULATOR PLANT THE RELATIONSHIP BETWEEN
METAL UPTAKE ALLOCATION AND TOLERANCE
BIOSIS COPYRIGHT: BIOL ABS. RRM
Publication Year: 1997

XXX
18/6/25 (Item 25 from file: 156)
02690539 Subfile: BIOSIS-97-23779
Cadmium uptake by crops from the subsoil.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

18/6/26 (Item 26 from file: 156)
02690354 Subfile: BIOSIS-97-23594
Study of interaction of iron and lead during their uptake process in wheat roots by total-reflection X-ray fluorescence spectrometry.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

XXX
18/6/27 (Item 27 from file: 156)
02684077 Subfile: BIOSIS-97-17311
Heavy metal pollutants in reclaimed wetland soil and pesticidal spray affecting development of leaf blight disease and metal uptake by maize (Zea mays L.).
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/28 (Item 28 from file: 156)
02680865 Subfile: BIOSIS-97-14097
Uptake of 109Cd by roots and hyphae of a Glomus mosseae/Trifolium subterraneum mycorrhiza from soil amended with high and low concentrations of cadmium.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

XXX
18/6/29 (Item 29 from file: 156)
02679176 Subfile: BIOSIS-97-12407
Accumulation of seleno-amino acids in legume and grass plant species grown in selenium-laden soils.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

XXX
18/6/30 (Item 30 from file: 156)
02678012 Subfile: BIOSIS-97-11243
Effect of cadmium and zinc interaction on metal uptake and regeneration of tolerant plants in linseed.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

XXX
18/6/31 (Item 31 from file: 156)
02677660 Subfile: BIOSIS-97-10891
Effect of phosphate fertiliser type on the accumulation and plant availability of cadmium in grassland soils.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/32 (Item 32 from file: 156)
02676391 Subfile: BIOSIS-97-09612
Studies on arsenic rich mine dumps: II. The heavy element uptake by vegetation.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1997

18/6/33 (Item 33 from file: 156)
02674027 Subfile: BIOSIS-97-07248
Contribution of an arbuscular mycorrhizal fungus to the uptake of cadmium and nickel in bean and maize plants.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/34 (Item 34 from file: 156)
02673519 Subfile: BIOSIS-97-06739
Uptake of heavy metals by plants from airborne deposition and polluted soils.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/35 (Item 35 from file: 156)
02673065 Subfile: BIOSIS-97-06285
Transport and accumulation of heavy metals in soil and plants of a wetland ecosystem.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

XXX
18/6/36 (Item 36 from file: 156)
02672459 Subfile: BIOSIS-97-05676
Effect of selenite and selenate on plant uptake and translocation of mercury by tomato (Lycopersicum esculentum).
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/37 (Item 37 from file: 156)
02671070 Subfile: BIOSIS-96-07370
On heavy metals in soil; rationalization of extractions by dilute salt solutions, comparison of the extracted concentrations with uptake by ryegrass and lettuce, and the possible influence of pyrophosphate on plant uptake.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/38 (Item 38 from file: 156)
02670634 Subfile: BIOSIS-96-06934
Regions of lead uptake in Lemna minor plants and localization of the metal within selected parts of the root.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

XXX
18/6/39 (Item 39 from file: 156)
02667110 Subfile: BIOSIS-97-03235
Study of mercury- selenium (Hg-Se) interactions and their impact on Hg uptake by the radish (Raphanus sativus) plant.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/40 (Item 40 from file: 156)
02666227 Subfile: BIOSIS-97-02351
METAL UPTAKE BY AGRICULTURAL PLANT SPECIES GROWN IN SLUDGE-AMENDED
SOIL FOLLOWING ECOSYSTEM RESTORATION PRACTICES
BIOSIS COPYRIGHT: BIOL ABS. RRM
Publication Year: 1996

18/6/41 (Item 41 from file: 156)
02657832 Subfile: BIOSIS-96-32710
USING ARABIDOPSIS TO STUDY LEAD ACCUMULATION AND TOLERANCE IN PLANTS
BIOSIS COPYRIGHT: BIOL ABS. RRM
Publication Year: 1996

XXX
18/6/42 (Item 42 from file: 156)
02655878 Subfile: BIOSIS-96-30756
Trace metals uptake and distribution in corn plants grown on a 6-year urban waste compost amended soil.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/43 (Item 43 from file: 156)
02641185 Subfile: BIOSIS-96-16053
Cadmium accumulation in Eurasian watermilfoil plants.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/44 (Item 44 from file: 156)
02641033 Subfile: BIOSIS-96-15901
Comparison of chromium and nickel uptake of plants grown in different soils.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/45 (Item 45 from file: 156)
02640343 Subfile: BIOSIS-96-15211
SALINITY-HEAVY METAL INTERACTIONS AS EVALUATED BY SOIL EXTRACTION AND
PLANT UPTAKE
BIOSIS COPYRIGHT: BIOL ABS. RRM
Publication Year: 1996

18/6/46 (Item 46 from file: 156)
02638092 Subfile: BIOSIS-96-12960
Effect of urban solid wastes on dry matter yield, uptake of micronutrients and heavy metals by maize plant.
BIOSIS COPYRIGHT: BIOL ABS.
Publication Year: 1996

18/6/47 (Item 47 from file: 156)
02096387 Subfile: TOXBIB-97-111373
Genetic evidence that induction of root Fe(III) chelate reductase activity is necessary for iron uptake under iron deficiency.
Publication Year: 1996

XXX
18/6/48 (Item 48 from file: 156)
02096317 Subfile: TOXBIB-96-423363
Effect of selenite and selenate on plant uptake of cadmium by maize (Zea mays).
Publication Year: 1996

18/6/49 (Item 1 from file: 143)
0873106 H.W. WILSON RECORD NUMBER: BBAI98044855
Relationship between ammonium accumulation and senescence of detached rice leaves caused by excess copper
19980300

18/6/50 (Item 2 from file: 143)
0824664 H.W. WILSON RECORD NUMBER: BBAI96010405
Plant tolerance to nickel toxicity: I. Influx, transport, and accumulation of nickel in four species
19960000

18/6/51 (Item 3 from file: 143)
0788390 H.W. WILSON RECORD NUMBER: BBAI97062414
Influence of increasing bicarbonate concentrations on plant growth, organic acid accumulation in roots and iron uptake by barley, sorghum, and maize
19970000

XXX
18/6/52 (Item 4 from file: 143)
0694981 H.W. WILSON RECORD NUMBER: BBAI97022360
Effect of sodium arsenite on arsenic accumulation and distribution in leaves and fruit of Vitis vinifera
19970000

18/6/53 (Item 5 from file: 143)
0665159 H.W. WILSON RECORD NUMBER: BBAI97006548
The role of ligand exchange in the uptake of iron from microbial siderophores by gramineous plants
19961100

18/6/54 (Item 6 from file: 143)
0657730 H.W. WILSON RECORD NUMBER: BBAI96059296
Accumulation of selenium by different plant species grown under increasing sodium and calcium chloride salinity
19960600

18/6/55 (Item 7 from file: 143)
0635785 H.W. WILSON RECORD NUMBER: BBAI96049777
Effect of primary leaves on 59Fe uptake by roots and 59Fe distribution in the shoot of iron sufficient and iron deficient bean (Phaseolus vulgaris L.) plants
19960500

XXX
18/6/56 (Item 8 from file: 143)
0632373 H.W. WILSON RECORD NUMBER: BBAI96046301
Effect of soil cadmium application and pH on growth and cadmium accumulation in roots, leaves and fruit of strawberry plants (Fragaria [times] ananassa Duch.)
19960300

18/6/57 (Item 9 from file: 143)
0610541 H.W. WILSON RECORD NUMBER: BBAI96040523
Critical evaluation of organic acid mediated iron dissolution in the rhizosphere and its potential role in root iron uptake
19960300

18/6/58 (Item 10 from file: 143)
0608739 H.W. WILSON RECORD NUMBER: BBAI96038718
Iron uptake by symbiosomes from soybean root nodules
19960700

18/6/59 (Item 11 from file: 143)
0604781 H.W. WILSON RECORD NUMBER: BBAI96003985
The mechanism of zinc uptake in plants. Characterisation of the low-affinity system
19960100

18/6/60 (Item 12 from file: 143)
0571883 H.W. WILSON RECORD NUMBER: BBAI96014622
Free histidine as a metal chelator in plants that accumulate nickel
19960215

18/6/61 (Item 13 from file: 143)
0567261 H.W. WILSON RECORD NUMBER: BBAI96009995
Translocation of copper and other micronutrients in tomato plants (Lycopersicon esculentum Mill.): nicotianamine-stimulated copper transport in the xylem
19960100

18/6/62 (Item 1 from file: 40)
00453400 ENVIROLINE NUMBER: 97-10551
Heavy Metal Uptake by Agricultural Plants on Contaminated Soils
Feb 97

18/6/63 (Item 2 from file: 40)
00438826 ENVIROLINE NUMBER: 96-11838
Study of Metal Accumulation in Wild Plants Using Principal Component Analysis and Ionic Impulsions
1996

18/6/64 (Item 1 from file: 68)

XXX
00574613 Environmental Bibliography Number: 2622735
Effect of soil cadmium application and pH on growth and cadmium accumulation in roots , leaves and fruit of strawberry plants (Fragaria x ananassa Duch.)
PUBLICATION YEAR: 1996

18/6/65 (Item 1 from file: 10)
3669268 21232794 Holding Library: AGL
Soil microorganisms and iron uptake by higher plants
1998

18/6/66 (Item 2 from file: 10)
3667681 21075970 Holding Library: AGL
Iron accumulation in tobacco plants expressing soyabean ferritin gene
1998

18/6/67 (Item 3 from file: 10)
3663042 20907288 Holding Library: AGL
Iron -containing particles accumulate in organelles and vacuoles of leaf and root cells in the nicotianamine-free tomato mutant chloronerva
1998

XXX
18/6/68 (Item 4 from file: 10)
3662789 20906797 Holding Library: AGL
Selenium accumulation and uptake by crop and grassland plant species
1998

XXX
18/6/69 (Item 5 from file: 10)
3629806 20609811 Holding Library: AGL
Study of mercury- selenium (Hg-Se) interactions and their impact and their impact on Hg uptake by the radish (Raphanus sativus) plant
1996

18/6/70 (Item 6 from file: 10)
3611176 20594796 Holding Library: AGL
The uptake of copper , arsenic and zinc by Miscanthus--environmental implications for use as an energy crop
1997

18/6/71 (Item 7 from file: 10)
3563007 20556464 Holding Library: AGL
Supply and accumulation of metals in two Egyptian desert plant species growing on wadi-fill deposits
1996

18/6/72 (Item 8 from file: 10)
3549756 20544745 Holding Library: AGL
Study of the effect of highly heavy metal polluted soils on metal uptake and distribution in plants from genera Artemisia, Draccocephalum, Inula, Ruta, and Symphytum
1996 Aug

18/6/73 (Item 1 from file: 203)
02267769
Mercury accumulation in transplanted Hypogymnia physodes lichens downwind of Wisconsin chlor-alkali plant
1998

18/6/74 (Item 2 from file: 203)
02267761
Uptake of traffic-related heavy metals and platinum group elements (PGE) by plants
1998

XXX
18/6/75 (Item 3 from file: 203)
02263765
Cadmium uptake by crops from the subsoil
1997

18/6/76 (Item 4 from file: 203)
02229596
Evaluation of treatment techniques for increasing the uptake of metal ions from solution by nonliving biomass derived from several strains of lichen, Sphagnum (peat) moss, and Eichhornia crassipes (water hyacinth) root
1997

18/6/77 (Item 5 from file: 203)
02228084
Four root plasmalemma polypeptides under-represented in the maize mutant ys1 accumulate in a Fe-efficient genotype in response to iron -deficiency ([Quatre polypeptides de plasmalemme de racines sous-representes chez le mutant de mais ys1 s'accumulent dans un genotype efficace vis-a-vis du fer en reponse a une deficience en fer])
1997

XXX
18/6/78 (Item 6 from file: 203)
02137579
Accumulation of heavy metals in soils and plants after long-term use of fertilizers and fungicides in Tanzania
1996

18/6/79 (Item 7 from file: 203)
02109498
Uptake and mobility of lead in Urtica dioica L.
1996
Plant root systems and natural vegetation

XXX
18/6/80 (Item 8 from file: 203)
02045984
Tolerance strategies of plants to heavy metals: cellular changes, accumulation pattern and intracellular localization of Cd, Pb, and Zn in Festuca rubra L. cv. Merlin (Red Fescue) and Ocimum sanctum L. (Holy Basil)
1996

18/6/81 (Item 9 from file: 203)
02020872
Regions of lead uptake in Lemna minor plants and localization of this metal within selected parts of the root
1996

18/6/82 (Item 1 from file: 50)
03615810 CAB Accession Number: 981912930
Effect of sludge on the availability of heavy metals in sandy soil. 2. Plant uptake in relation to extracted soil Zn, Cu and Ni fractions.

18/6/83 (Item 2 from file: 50)
03607829 CAB Accession Number: 980710171
Accumulation and volatilization of different chemical species of selenium by plants.

18/6/84 (Item 3 from file: 50)
03607336 CAB Accession Number: 980709678
Accumulation of heavy metals in higher plants.
Book Title: Remediation of soils contaminated with metals . Proceedings of a conference on the biogeochemistry of trace elements, Taipei, Taiwan, 5-10 September 1993.

XXX
18/6/85 (Item 4 from file: 50)
03603846 CAB Accession Number: 980310370
Chromium accumulation, translocation and chemical speciation in vegetable crops.

18/6/86 (Item 5 from file: 50)
03599996 CAB Accession Number: 981911959
Extractable metals and plant uptake with amelioration and revegetation of abandoned copper mine tailings.
Book Title: Remediation of soils contaminated with metals . Proceedings of a conference on the biogeochemistry of trace elements, Taipei, Taiwan, 5-10 September 1993.

18/6/87 (Item 6 from file: 50)
03599791 CAB Accession Number: 981911754
Arsenic in wetland vegetation: availability, phytotoxicity, uptake and effects on plant growth and nutrition.

18/6/88 (Item 7 from file: 50)
03599650 CAB Accession Number: 981911613
A kinetic approach on the estimation of iron uptake by Apium nodiflorum plants.

18/6/89 (Item 8 from file: 50)
03599393 CAB Accession Number: 981911355
Modelling uptake of cadmium by plants in sludge-treated soils.

18/6/90 (Item 9 from file: 50)
03592838 CAB Accession Number: 980709502
Peculiarities of lead accumulation in plants of the Lake Baikal basin.

18/6/91 (Item 10 from file: 50)
03584554 CAB Accession Number: 981909658
Accumulation of heavy metals in two crop seeds due to soil contamination as determined by neutron activation analysis techniques.

XXX
18/6/92 (Item 11 from file: 50)
03536525 CAB Accession Number: 980305705
The accumulation of heavy metals during growing period in leaves and roots of two cultivars.

18/6/93 (Item 12 from file: 50)
03524020 CAB Accession Number: 980704082
Complex evaluation of the effect of the degree of intensification of agriculture on accumulation of radionuclides, heavy metals and nitrates in farm crops.

XXX
18/6/94 (Item 13 from file: 50)
03514671 CAB Accession Number: 981904334
Plant uptake of selenium arsenic and molybdenum from soil treated with coal combustion byproducts.

18/6/95 (Item 14 from file: 50)
03495125 CAB Accession Number: 981901670
Use of single and sequential chemical extractants to assess radionuclide and heavy metal availability from soils for root uptake.

18/6/96 (Item 15 from file: 50)
03486843 CAB Accession Number: 980701636
Four root plasmalemma polypeptides under-represented in the maize mutant ys1 accumulate in a Fe-efficient genotype in response to iron -deficiency.

18/6/97 (Item 16 from file: 50)
03471612 CAB Accession Number: 980700184
Effect of cadmium and zinc interaction on metal uptake and regeneration of tolerant plants in linseed.

18/6/98 (Item 17 from file: 50)
03407038 CAB Accession Number: 971908251
Accumulation of heavy metals by agricultural plants when applying waste-water sludge.

18/6/99 (Item 18 from file: 50)
03381137 CAB Accession Number: 971905173
Effects of environmental pollution on heavy metal uptake by maize plants.

18/6/100 (Item 19 from file: 50)
03368616 CAB Accession Number: 971904538
Comparative lead uptake and responses of some plants grown on lead contaminated soils.

18/6/101 (Item 20 from file: 50)
03347285 CAB Accession Number: 970304028
Investigation of heavy metal accumulation in various medicinal plants and linseed.

XX
18/6/102 (Item 21 from file: 50)
03336807 CAB Accession Number: 970701956
Arsenic uptake, distribution and accumulation in bean plants:
human health risk.

18/6/103 (Item 22 from file: 50)
03307376 CAB Accession Number: 961910256
An evaluation of the effect of some soil properties on root uptake
of four metals.
Superfund risk assessment in soil contamination studies: second volume.

XXX
18/6/104 (Item 23 from file: 50)
03303581 CAB Accession Number: 960711699
Accumulation and distribution pattern of iron in potato plant and
influence of sulphur fertilization.

18/6/105 (Item 1 from file: 55)
11635899 BIOSIS NO.: 199800417630
Bioremediation of contaminated soils - Do plant associated fungi enhance
metal uptake by hyperaccumulating plants?
1998

18/6/106 (Item 2 from file: 55)
11635897 BIOSIS NO.: 199800417628
Bacteria enhanced selenium phytoremediation by increasing plant uptake
and volatilization.
1998

18/6/107 (Item 3 from file: 55)
11617443 BIOSIS NO.: 199800399238
Effects of heavy metal accumulation in apple orchard soils in the
mineralization of humified plant residues.
1998

18/6/108 (Item 4 from file: 55)
11615411 BIOSIS NO.: 199800397200
Relationship between ammonium accumulation and sensescence of detached rice leaves caused by excess copper.
1998

18/6/109 (Item 5 from file: 55)
11407904 BIOSIS NO.: 199800189236
Transferrin, the transferrin receptor, and the uptake of iron by cells.
BOOK TITLE: Metal Ions in Biological Systems; Iron transport and storage in microorganisms, plants, and animals
1998

18/6/110 (Item 6 from file: 55)
11407901 BIOSIS NO.: 199800189233

XXX
Ferritin. Uptake, storage, and release of iron.
BOOK TITLE: Metal Ions in Biological Systems; Iron transport and storage in microorganisms, plants, and animals
1998

18/6/111 (Item 7 from file: 55)
11407899 BIOSIS NO.: 199800189231
The iron responsive element (IRE) family of mRNA regulators: Regulation of iron transport and uptake compared in animals, plants, and microorganisms.
BOOK TITLE: Metal Ions in Biological Systems; Iron transport and storage in microorganisms, plants, and animals
1998

18/6/112 (Item 8 from file: 55)
11357972 BIOSIS NO.: 199800139304
Sub-population of capsaicin sensitive primary afferent neurons in thoracic, lumbar and sacral dorsal root ganglion in young rats revealed by stimulated cobalt uptake.
1996

18/6/113 (Item 9 from file: 55)
10697857 BIOSIS NO.: 199799319002
Post-transcriptional regulation of plant ferritin accumulation in response to iron as observed in the maize mutant ys1.
1996

18/6/114 (Item 10 from file: 55)
10459118 BIOSIS NO.: 199699080263
Plant root cDNA that enhances heavy metal uptake into yeast.
1996

Appendix C

Soil Parameters Affecting Constituent Availability

To:	Rebecca Daiss, U.S. Environmental Protection Agency
From:	Dana Greenwood
Subject:	Soil and Meteorologic Data Options for Fertilizer Risk Assessment
Date:	August 10, 1999

Soil Parameters that Affect Behavior and Availability of Metals and Dioxins

Soil and meteorologic conditions affect the movement of metal and dioxin constituents in the soil. Therefore, parameters describing both soil and climate specifications are needed to estimate the fate and transport of these contaminants in the environment. These important factors are linked geographically.

Some of the parameters that affect the movement of metals and dioxins in the soil environment are

soil texture/type
clay content
cation exchange capacity (CEC)
pH
organic matter content
oxidation-reduction potential.

These data are documented in readily available soil databases already in geographic information systems (GIS); however, many of these parameters are not used directly by the risk analysis tools available for the fertilizer risk assessment. The data that will be required for the analysis and the GIS databases or the data from literature sources (already linked to a GIS database) that will be used for these parameter values are

soil texture/type (continental United States [CONUS]):

  - soil bulk density (calculated)

  - saturated volumetric water content (Carsel and Parrish [1988] based on soil texture)

  - residual water content (Carsel and Parrish [1988] based on soil texture)

fraction organic carbon (U.S. Soils [USSOILS] database)

universal soil loss equation (USLE) rainfall/erosivity factor (State Soil Geographic [STATSGO] database)

- USLE soil erodibility factor (USSOILS database)

- soil pH (STATSGO database).

Soil Databases Recommended for Use

The Natural Resources Conservation Service (NRCS) established two soil geographic databases that could be used for this effort, the State Soil Geographic (STATSGO) database and the Soil Survey Geographic (SSURGO) database. For this project, we recommend using the STATSGO database.

The STATSGO database was designed primarily for regional, multicounty, river basin, state, and multistate resource planning, management, and monitoring. Data for the states have been joined into one complete, seamless database to form statewide coverage. Composition of soil map units was coordinated across state boundaries, so that component identities and relative extents would match.

Examples of information that can be queried from the STATSGO database are the geographic location key, soil pH, available water capacity of the soil, USLE erosivity factor, soil permeability, cumulative thickness of all soil layers, hydrologic characteristics of the soil, quality of drainage, surface slope, liquid limit of the soil, fraction of the area with hydric soils, and annual frequency of flooding. Only the soil pH will be derived from the larger STATSGO database (sources: http://water.usgs.gov/nsdi/usgswrd/ussoils.html#Identification_Information and http://nssc.nrcs.usda.gov/sww/nsdafmap.html).

USSOILS is a smaller database that contains selected variables from the STATSGO data. The USSOILS database was originally compiled to support a national model of water quality. The soil property data that will be obtained from the USSOILS database are the hydrologic group, the fraction organic carbon, the percent slope, and the soil erodibility factor.

The CONUS database also contains selected variables from the STATSGO data set. The CONUS soil data set was compiled by the Earth System Science Center in the College of Earth and Mineral Sciences at Pennsylvania State University for application to a wide range of climate, hydrology, and other environmental models (Miller and White, 1998). Data that will be obtained from the CONUS database are the predominant soil textures.

Data obtained from the databases have previously been linked to soil descriptions of standard soil types in Carsel and Parrish (1988). This reference is used to supply the following soil parameter data:

- hydraulic conductivity (cm/h)
- moisture retention parameter alpha (1/cm)
- moisture retention parameter beta (unitless)
- saturated water content
- residual water content.

These databases and the reference data are currently linked and accessible through the GIS platform. This linkage allows the determination of all of the soil parameters listed above at any geographic point in the United States. These data will be overlaid with other geographically dependent data, such as climate data, agricultural land use, and crop type, to estimate a nationwide distribution of risk from the application of fertilizer products.

<ins>Climate Database</ins>

The climate data required for this analysis are

- annual average precipitation (National Climate Data Center [NCDC])
- average annual runoff (Water Atlas)
- irrigation (Agricultural Census)
- annual average evapotranspiration (calculated)
- infiltration rate (calculated).

Climate data are available from the NCDC World Data Center-A. NCDC is maintained by the National Oceanic and Atmospheric Administration (NOAA) and provides a three-tiered national climate services support program in partnership with regional and state climatologists. These data have been analyzed for use in numerous nationwide risk assessment projects (e.g., air characteristic) as well as site-specific assessments. A statistical analysis of air modeling data for all 200 locations determined that a sample of 29 stations would be sufficient to represent the population of 200 stations and to predict mean air dispersion values with a high (95 percent) degree of confidence. The 29 meteorological stations are distributed among 9 climate regions based on meteorological representativeness and variability across each region. This meteorologic data selection process has been peer-reviewed, and the 29 sites have been judged adequate for use in risk assessments with a nationwide distribution. This sample of 29 meteorologic stations has been used in other Office of Solid Waste (OSW) risk assessments (air characteristics) to represent a nationwide distribution of climatic conditions. Because the objective of the fertilizer risk analysis is to obtain a set of annual average concentrations for a nationwide distribution of sites, the set of 29 sites provides the range of meteorological data appropriate for this analysis. Figure 1 presents a map showing the geographic representation of the 29 climatic regions. Climate data for the 29 regions are already available on the GIS platform and, thus, are linked geographically to the soil parameter data.

These climate data are required for estimating the soil concentration of constituents, but additional meteorologic data are required for air dispersion and deposition modeling. This estimation process requires additional detailed meteorologic data. The Industrial Source Complex Short Term, Version 3 (ISCST3) model used in the cement kiln dust (CKD) analysis requires hourly meteorologic observations. Because the 29 meteorologic locations have been used for other OSW projects, the data have been downloaded from the U.S. Environmental Protection Agency (EPA) Web site and preprocessed for use in the ISCST3 model. This will greatly facilitate the air modeling for this project. The climate data will also be used to estimate re-entrainment of particles from the soil through windblown emissions and soil tilling. This estimation will use the EPA tools described in AP-42.

Land Use Data

Fertilizer application is assumed to be limited to agricultural soils. Agricultural soil use may be determined by overlaying the soil and meteorologic data with a land use database (Geographic Retrieval and Analysis System [GIRAS]) to refine the geographical areas to farming land use. The land use data available for the entire United States are classified with Anderson level II land use codes. The following subset of the Anderson land use codes will be used to identify agricultural lands where fertilizer use is expected:

Level I	**Level II**
2 Agricultural Land	21 Cropland and Pasture
	22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
	23 Confined Feeding Operations
	24 Other Agricultural Land

Geographic Distribution of Crop Categories

Another database that has been incorporated into the Research Triangle Institute (RTI) GIS system is the Agricultural Census. This database indicates the crops produced in each county in the United States. The list of crops in the Agricultural Census will be evaluated and grouped into categories that correspond to plant uptake factor categories (grains, forage, fruit, herbage, and roots). The geographical areas where each crop category is produced will be included in the GIS analysis.

Because GIS is a useful tool to combine and analyze different national data sets, RTI plans to use GIS to support the soil, climate, land use, and crop location data collection and integration efforts for the fertilizer risk assessment.

The product of this GIS data integration effort is a spreadsheet with unique identifiers for each geographical area. This area identifier will be associated with the corresponding soil data, climate data, and crop categories prevalent at each location (limited to those areas with agricultural land use). The spreadsheet can then be used to extract relevant data in the risk assessment model.

Appendix D

Distribution Coefficients

1.0 INTRODUCTION

Partition coefficients for certain metals in environmental media are needed to conduct multimedia exposure and risk assessment modeling for the fertilizer risk assessment. The metals of interest are: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), vanadium (V), and zinc (Zn). Partitioning occurs within environmental media, between solid and aqueous phases. Specifically, the following environmental media partitioning scenarios are important: partitioning between waste (in a waste disposal scenario) and leachate, between watershed soil and soil water, between riverine or lacustrine sediment and porewater, between riverine or lacustrine suspended load and the water column, between riverine or lacustrine dissolved organic carbon (DOC) and the water column, and between sludge (in a land application unit) and infiltrating water.

A literature search was used to determine the range and statistical distribution of values that have been observed in field scenarios. This includes the collection of published partition coefficients for any of the metals in any of the environmental media of interest, or the estimation of partition coefficients from reported metal concentration data when feasible. Also, relevant geochemical parameters (such as pH, sorbent content, etc.) are collected along with the partition coefficients when possible. Paragraphs that follow describe the literature review, which has now been completed, and the partition coefficients collected in it.

2.0 LITERATURE SEARCH FOR METAL PARTITION COEFFICIENTS

The natural-media partition coefficients collected or calculated are those pertaining to partitioning of the metal in soil and soil-water, sediment and sediment-porewater, suspended solids and the associated water column, and DOC and the dissolved inorganic phase. In addition, partition coefficients were sought for equilibrium partitioning of metals between waste matrix material and the associated aqueous phase in landfills, waste piles, treatment lagoons, aerated tanks, and land application units (sludge). The partition coefficients were obtained from the scientific literature, from U.S. EPA reports and reports from other government and university sources. Electronic searches were conducted using the following databases:

- Academic Press Journals (1995 - present)
- AGRICOLA (1970 - present)
- Analytical Abstracts (1980 - present)
- Applied Science and Technology Abstracts
- Aquatic Sciences and Fisheries Abstract Set (1981 - present)
- CAB Abstracts (1987 - present)
- Current Contents (1992 - present)
- Dissertation Abstracts (1981 - present)
- Ecology Abstracts (1982 - present)

- EIS Digest of Environmental Impact Statements (1985 - present)
- EI Tech Index (1987 - present)
- Environmental Engineering Abstracts (1990 - present)
- General Science Abstracts (1984 - present)
- GEOBASE (1980 - present)
- GEOREF (1785 - present)
- National Technical Information Service
- PapersFirst (1993 - present)
- Periodical Abstracts (1986 - present)
- Toxicology Abstracts (1982 - present)
- Water Resources Abstracts (1987 - present)

Two search strings were used in the electronic searches: ”distribution coefficient” and “partition coefficient”. Use of such general strings has the advantage of generating many citations, decreasing the probability that relevant articles will be missed, but also carrying a high labor burden because each citation returned must be examined for useful data. This work was made easier by first reviewing the titles, and, for those that might have useful data, reviewing the abstract, which was usually available on-line. Abstracts of citations that showed promise for partition coefficients were printed and given a code consisting of the first two letters of the lead author’s last name and the last two digits of the year of publication. The code, along with the first few words of the article title, was entered in a log book for tracking. Articles thought to have useful data were scanned and those presenting partition coefficients or data from which they could be derived were copied. Most of the articles were obtained from the University of Georgia Science Library, and the Georgia Institute of Technology Library. Partition coefficients from the articles were entered into an EXCEL 97 spreadsheet, or, if partition coefficients were not reported in the article but sufficient information to calculate them was, that information was entered.

The geochemical parameters most likely to influence the partition coefficient were also entered in the spreadsheet if specified in the source article or report. Examples of these are pH, total concentrations of metal and important metal complexing agents including DOC, and weight fraction of particulate organic matter and other sorbing materials. Physical parameters necessary to convert concentration ratios to partition coefficients in L/kg, including porosity, water content, and bulk density were also recorded when available.

For this fertilizer analysis, EPA used only K_d values derived for settings that most closely approximate the conditions found in agricultural soil based on the information provided in the spread sheet. Soil pH and soil type were used to cull the data set for the fertilizer risk assessment. Other geochemical parameters were also considered for this purpose (e.g., total metal concentration, organic matter content, iron oxide content). This type of information, however, was less consistently reported in the literature. The kd data used for the fertilizer assessment is provided in the following table. The entire spread sheet described above will be available upon publication of the Hazardous Waste Identification Rule in the Fall of 1999.

The complete bibliography of papers, articles, and reports that were copied and reviewed in the literature search for K_d values for all environmental settings is provided below.

Distribution Coefficient (Kd) Values (L/kg) for Soil-Water Systems

Arsenic (V)	*Cadmium*	*Chromium (III)*	*Chromium (V)*	*Copper*	*Mercury (II)*	*Nickel*	*Lead*	*Selenium (IV)*	*Zinc*
1.36E+03	1.08E+03	2.75E+03	2.49E+01	3.50E+01	6.00E+04	2.92E+02	3.43E+03	3.00E+01	7.30E+01
6.08E+03	7.55E+02	1.20E+04	1.33E+01	9.20E+01	6.20E+03	1.66E+03	2.64E+03	4.67E+01	6.04E+02
7.24E+03	5.83E+03	8.12E+03	6.10E+00	7.01E+02	1.40E+04	1.26E+03	3.47E+04	3.20E+01	2.25E+03
3.83E+03	1.38E+03	7.93E+03	2.00E-01	3.22E+02	6.80E+03	2.43E+02	4.23E+04	2.35E+01	2.80E+03
2.91E+03	5.05E+03	5.98E+03	4.54E+01	5.29E+02	6.50E+03	1.84E+03	5.31E+03	7.47E+00	2.44E+03
3.79E+03	3.55E+03	6.75E+03	1.21E+01	4.52E+02	8.00E+03	1.29E+03	1.25E+04	2.17E+00	1.30E+03
6.65E+03	1.44E+02	2.07E+04	2.49E+01	1.03E+03	5.40E+03	3.15E+03	6.03E+04	6.25E+00	6.23E+03
9.00E+01	1.59E+02	3.80E+03	**7**	2.50E+01	3.30E+03	1.15E+02	1.33E+03	2.25E+02	2.30E+01
9.70E+01	5.32E+02	2.42E+03	**1.33E+01**	3.80E+01	3.50E+04	1.30E+02	1.16E+03	3.45E+01	4.10E+01
5.31E+03	1.02E+02	4.22E+03	**2.00E-01**	8.74E+02	1.20E+04	2.36E+02	5.92E+03	7.47E+00	1.54E+02
1.58E+02	6.03E+02	5.24E+02	**1.80E+03**	6.70E+01	7.50E+03	1.85E+02	9.16E+02	1.07E+01	3.40E+01
1.50E+03	2.10E+01	4.71E+03		1.09E+02	3.30E+03	1.09E+03	2.29E+04	1.04E+00	1.29E+03
2.11E+03	9.74E+02	2.36E+03		1.35E+02	3.30E+03	3.76E+02	3.55E+03	9.25E+00	3.80E+01
8.04E+02	4.65E+03	8.91E+03		8.80E+01	**13**	7.44E+02	3.69E+04	1.65E+01	6.00E+00
2.04E+04	9.48E+02	1.98E+04		1.31E+03	**6.80E+03**	1.86E+03	3.74E+04	4.86E+00	4.22E+02
2.02E+03	6.30E+03	1.11E+04		8.38E+02	**1.50E+02**	2.16E+03	2.77E+04	3.50E+01	3.70E+03
3.13E+03	6.45E+03	2.42E+04		9.86E+02	**5.70E+05**	5.75E+03	4.55E+04	5.07E+00	1.28E+03
9.75E+03	1.83E+04	9.52E+03		4.32E+03		4.11E+03	1.70E+04	**17**	5.11E+03
2.52E+03	2.50E+03	9.16E+03		1.25E+03		2.31E+03	6.79E+04	**1.07E+01**	6.76E+03
2.29E+03	1.00E+05	2.98E+02		8.74E+02		**19**	1.98E+01	**5.10E-01**	5.47E+03
6.70E+01	4.00E+01	7.20E+02		**20**		**1.26E+03**	3.00E+04	**2.25E+02**	**20**
21	3.00E+02	5.57E+02		**4.91E+02**		**9.00E+00**	9.00E+03		**1.29E+03**
2.52E+03	7.80E+02	7.88E+02		**1.40E+00**		**5.75E+03**	6.00E+04		**1.00E-01**
1.90E+00	2.50E+02	2.82E+03		**4.32E+03**			6.00E+04		**1.00E+05**
2.04E+04	1.70E+03	5.08E+03					2.10E+04		
	2.25E+02	1.54E+04					9.30E+01		
	2.60E+03	1.43E+04					2.10E+04		
	2.20E+03	1.97E+04					1.90E+01		
	7.70E+02	2.08E+04					3.00E+04		
	7.10E+02	2.40E+04					5.90E+04		
	4.75E+02	2.41E+04					**30**		
	2.18E+03	3.13E+04					**2.10E+04**		
	3.00E+02	3.55E+04					**4.50E+00**		
	1.75E+02	4.76E+04					**1.00E+05**		
	34	5.59E+04							
	8.64E+02	**35**							
	1.26E+00	**8.91E+03**							
	1.00E+05	**1.00E+01**							
		5.59E+04							

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Appendix D

Distribution Coefficients

1.0 INTRODUCTION

Partition coefficients for certain metals in environmental media are needed to conduct multimedia exposure and risk assessment modeling for the fertilizer risk assessment. The metals of interest are: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), vanadium (V), and zinc (Zn). Partitioning occurs within environmental media, between solid and aqueous phases. Specifically, the following environmental media partitioning scenarios are important: partitioning between waste (in a waste disposal scenario) and leachate, between watershed soil and soil water, between riverine or lacustrine sediment and porewater, between riverine or lacustrine suspended load and the water column, between riverine or lacustrine dissolved organic carbon (DOC) and the water column, and between sludge (in a land application unit) and infiltrating water.

A literature search was used to determine the range and statistical distribution of values that have been observed in field scenarios. This includes the collection of published partition coefficients for any of the metals in any of the environmental media of interest, or the estimation of partition coefficients from reported metal concentration data when feasible. Also, relevant geochemical parameters (such as pH, sorbent content, etc.) are collected along with the partition coefficients when possible. Paragraphs that follow describe the literature review, which has now been completed, and the partition coefficients collected in it.

2.0 LITERATURE SEARCH FOR METAL PARTITION COEFFICIENTS

The natural-media partition coefficients collected or calculated are those pertaining to partitioning of the metal in soil and soil-water, sediment and sediment-porewater, suspended solids and the associated water column, and DOC and the dissolved inorganic phase. In addition, partition coefficients were sought for equilibrium partitioning of metals between waste matrix material and the associated aqueous phase in landfills, waste piles, treatment lagoons, aerated tanks, and land application units (sludge). The partition coefficients were obtained from the scientific literature, from U.S. EPA reports and reports from other government and university sources. Electronic searches were conducted using the following databases:

Academic Press Journals (1995 - present)
AGRICOLA (1970 - present)
Analytical Abstracts (1980 - present)
Applied Science and Technology Abstracts
Aquatic Sciences and Fisheries Abstract Set (1981 - present)
CAB Abstracts (1987 - present)
Current Contents (1992 - present)
Dissertation Abstracts (1981 - present)
Ecology Abstracts (1982 - present)

- EIS Digest of Environmental Impact Statements (1985 - present)
- EI Tech Index (1987 - present)
- Environmental Engineering Abstracts (1990 - present)
- General Science Abstracts (1984 - present)
- GEOBASE (1980 - present)
- GEOREF (1785 - present)
- National Technical Information Service
- PapersFirst (1993 - present)
- Periodical Abstracts (1986 - present)
- Toxicology Abstracts (1982 - present)
- Water Resources Abstracts (1987 - present)

Two search strings were used in the electronic searches: ”distribution coefficient” and “partition coefficient”. Use of such general strings has the advantage of generating many citations, decreasing the probability that relevant articles will be missed, but also carrying a high labor burden because each citation returned must be examined for useful data. This work was made easier by first reviewing the titles, and, for those that might have useful data, reviewing the abstract, which was usually available on-line. Abstracts of citations that showed promise for partition coefficients were printed and given a code consisting of the first two letters of the lead author’s last name and the last two digits of the year of publication. The code, along with the first few words of the article title, was entered in a log book for tracking. Articles thought to have useful data were scanned and those presenting partition coefficients or data from which they could be derived were copied. Most of the articles were obtained from the University of Georgia Science Library, and the Georgia Institute of Technology Library. Partition coefficients from the articles were entered into an EXCEL 97 spreadsheet, or, if partition coefficients were not reported in the article but sufficient information to calculate them was, that information was entered.

The geochemical parameters most likely to influence the partition coefficient were also entered in the spreadsheet if specified in the source article or report. Examples of these are pH, total concentrations of metal and important metal complexing agents including DOC, and weight fraction of particulate organic matter and other sorbing materials. Physical parameters necessary to convert concentration ratios to partition coefficients in L/kg, including porosity, water content, and bulk density were also recorded when available.

For this fertilizer analysis, EPA used only K_d values derived for settings that most closely approximate the conditions found in agricultural soil based on the information provided in the spread sheet. Soil pH and soil type were used to cull the data set for the fertilizer risk assessment. Other geochemical parameters were also considered for this purpose (e.g., total metal concentration, organic matter content, iron oxide content). This type of information, however, was less consistently reported in the literature. The kd data used for the fertilizer assessment is provided in the following table. The entire spread sheet described above will be available upon publication of the Hazardous Waste Identification Rule in the Fall of 1999.

The complete bibliography of papers, articles, and reports that were copied and reviewed in the literature search for K_d values for all environmental settings is provided below.

Distribution Coefficient (Kd) Values (L/kg) for Soil-Water Systems

Arsenic (V)	*Cadmium*	*Chromium (III)*	*Chromium (V)*	*Copper*	*Mercury (II)*	*Nickel*	*Lead*	*Selenium (IV)*	*Zinc*
1.36E+03	1.08E+03	2.75E+03	2.49E+01	3.50E+01	6.00E+04	2.92E+02	3.43E+03	3.00E+01	7.30E+01
6.08E+03	7.55E+02	1.20E+04	1.33E+01	9.20E+01	6.20E+03	1.66E+03	2.64E+03	4.67E+01	6.04E+02
7.24E+03	5.83E+03	8.12E+03	6.10E+00	7.01E+02	1.40E+04	1.26E+03	3.47E+04	3.20E+01	2.25E+03
3.83E+03	1.38E+03	7.93E+03	2.00E-01	3.22E+02	6.80E+03	2.43E+02	4.23E+04	2.35E+01	2.80E+03
2.91E+03	5.05E+03	5.98E+03	4.54E+01	5.29E+02	6.50E+03	1.84E+03	5.31E+03	7.47E+00	2.44E+03
3.79E+03	3.55E+03	6.75E+03	1.21E+01	4.52E+02	8.00E+03	1.29E+03	1.25E+04	2.17E+00	1.30E+03
6.65E+03	1.44E+02	2.07E+04	2.49E+01	1.03E+03	5.40E+03	3.15E+03	6.03E+04	6.25E+00	6.23E+03
9.00E+01	1.59E+02	3.80E+03	**7**	2.50E+01	3.30E+03	1.15E+02	1.33E+03	2.25E+02	2.30E+01
9.70E+01	5.32E+02	2.42E+03	**1.33E+01**	3.80E+01	3.50E+04	1.30E+02	1.16E+03	3.45E+01	4.10E+01
5.31E+03	1.02E+02	4.22E+03	**2.00E-01**	8.74E+02	1.20E+04	2.36E+02	5.92E+03	7.47E+00	1.54E+02
1.58E+02	6.03E+02	5.24E+02	**1.80E+03**	6.70E+01	7.50E+03	1.85E+02	9.16E+02	1.07E+01	3.40E+01
1.50E+03	2.10E+01	4.71E+03		1.09E+02	3.30E+03	1.09E+03	2.29E+04	1.04E+00	1.29E+03
2.11E+03	9.74E+02	2.36E+03		1.35E+02	3.30E+03	3.76E+02	3.55E+03	9.25E+00	3.80E+01
8.04E+02	4.65E+03	8.91E+03		8.80E+01	**13**	7.44E+02	3.69E+04	1.65E+01	6.00E+00
2.04E+04	9.48E+02	1.98E+04		1.31E+03	**6.80E+03**	1.86E+03	3.74E+04	4.86E+00	4.22E+02
2.02E+03	6.30E+03	1.11E+04		8.38E+02	**1.50E+02**	2.16E+03	2.77E+04	3.50E+01	3.70E+03
3.13E+03	6.45E+03	2.42E+04		9.86E+02	**5.70E+05**	5.75E+03	4.55E+04	5.07E+00	1.28E+03
9.75E+03	1.83E+04	9.52E+03		4.32E+03		4.11E+03	1.70E+04	**17**	5.11E+03
2.52E+03	2.50E+03	9.16E+03		1.25E+03		2.31E+03	6.79E+04	**1.07E+01**	6.76E+03
2.29E+03	1.00E+05	2.98E+02		8.74E+02		**19**	1.98E+01	**5.10E-01**	5.47E+03
6.70E+01	4.00E+01	7.20E+02		**20**		**1.26E+03**	3.00E+04	**2.25E+02**	**20**
21	3.00E+02	5.57E+02		**4.91E+02**		**9.00E+00**	9.00E+03		**1.29E+03**
2.52E+03	7.80E+02	7.88E+02		**1.40E+00**		**5.75E+03**	6.00E+04		**1.00E-01**
1.90E+00	2.50E+02	2.82E+03		**4.32E+03**			6.00E+04		**1.00E+05**
2.04E+04	1.70E+03	5.08E+03					2.10E+04		
	2.25E+02	1.54E+04					9.30E+01		
	2.60E+03	1.43E+04					2.10E+04		
	2.20E+03	1.97E+04					1.90E+01		
	7.70E+02	2.08E+04					3.00E+04		
	7.10E+02	2.40E+04					5.90E+04		
	4.75E+02	2.41E+04					**30**		
	2.18E+03	3.13E+04					**2.10E+04**		
	3.00E+02	3.55E+04					**4.50E+00**		
	1.75E+02	4.76E+04					**1.00E+05**		
	34	5.59E+04							
	8.64E+02	**35**							
	1.26E+00	**8.91E+03**							
	1.00E+05	**1.00E+01**							
		5.59E+04							

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Appendix E

Farm Sizes—Cumulative Percentile

Item Definitions		Average Size (acres)	Average Size (m^2)	Cumulative Percentile
60001	Farms (number)			
60002	Land in farms (acres)			
60003	Average size of farm (acres)			
60020	Size of farm–1 to 9 acres (farms)	5	20,235	0.084925
60021	Size of farm–1 to 9 acres (acres)			
60022	Size of farm–10 to 49 acres (farms)	29.5	119,387	0.286168
60023	Size of farm–10 to 49 acres (acres)			
60024	Size of farm–50 to 69 acres (farms)	59.5	240,797	0.348485
60025	Size of farm–50 to 69 acres (acres)			
60026	Size of farm–70 to 99 acres (farms)	84.5	341,972	0.433655
60027	Size of farm–70 to 99 acres (acres)			
60028	Size of farm–100 to 139 acres (farms)	119.5	483,617	0.517839
60029	Size of farm–100 to 139 acres (acres)			
60030	Size of farm–140 to 179 acres (farms)	159.5	645,497	0.590251
60031	Size of farm–140 to 179 acres (acres)			
60032	Size of farm–180 to 219 acres (farms)	199.5	807,377	0.639473
60033	Size of farm–180 to 219 acres (acres)			
60034	Size of farm–220 to 259 acres (farms)	239.5	969,257	0.67991
60035	Size of farm–220 to 259 acres (acres)			
60036	Size of farm–260 to 499 acres (farms)	379.5	1,535,837	0.812935
60037	Size of farm–260 to 499 acres (acres)			
60038	**Size of farm–500 to 999 acres (farms)**	**749.5**	**3,033,227**	**0.91**
60039	Size of farm–500 to 999 acres (acres)			
60040	**Size of farm–1,000 to 1,999 acres (farms)**	**1,499.5**	**6,068,477**	**0.963074**
60041	Size of farm–1,000 to 1,999 acres (acres)			
60042	Size of farm–2,000 acres or more (farms)	2,000	8,094,000	1
60043	Size of farm–2,000 acres or more (acres)			

Appendix F

Agricultural Census Data Groupings

Table F-1. Agricultural Census Data Groupings—Harvested/Acres

Forage			
Alfalfa hay	280132	Ladino clover	280062
Chicory	290066	Salt hay	340077
Corn for silage/green chop	280157	Sudangrass	280092
Small grain hay	280137	Tame dry hay	280142
Grass silage, haylage, and green chop hay	280152	Wild hay	280147
Fruit			
Almonds (meats)	310317	Citrus fruits, other	310308
Apples	310002	Coffee	310074
Apricots	310011	Cowpeas, dry	270032
Artichokes	290010	Cowpeas, green southern peas	290078
Austrian winter peas	280012	Cranberries	320027
Avocados	310020	Cucumbers and pickles	290082
Bananas	310029	Currants	320032
Beans, dry edible	270017	Dates	310083
Beans, dry lima	270022	Dill for oil	340007
Beans, green lima	290018	Eggplant	290090
Beans, snap	290022	Figs	310092
Beans, soybeans	270012	Filberts and hazelnuts	310326
Berries	320002	Flaxseed	260072
Blackberries	320007	Grapefruit	310236
Blueberries, tame	320012	Grapes	310101
Blueberries, wild	320017	Greenhouse vegetables (open/acres)	330051
Boysenberries	320022	Greenhouse vegetables (glass, sq ft)	330050
Broccoli	290030	Guar	340022
Canola	260057	Guavas	310110
Cantaloups	290050	Honeydew melons	290110
Cauliflower	290058	Jojaba	340042
Cherries	310038	Kiwifruit	310119

(continued)

Table F-1. (continued)

Fruit (continued)			
Kumquats	310245	Pecans	310344
Lemons	310254	Peppers, hot	290146
Lentils	270037	Peppers, sweet	290150
Limes	310263	Persimmons	310191
Loganberries	320037	Pineapples	340067
Macadamia nuts	310335	Pistachios	310353
Mangoes	310128	Plums and prunes	310200
Mungbeans for beans	340062	Pomegranates	310209
Mushrooms, acres in the open	330035	Pumpkins	290158
Mustard seed	260077	Rapeseed, other	260062
Nectarines	310137	Raspberries	320042
Nuts, other	310371	Safflower	260107
Okra	290134	Soybeans for beans	270012
Olives	310146	Squash	290174
Oranges	310272	Strawberries	320047
Papayas	310155	Sunflower seeds	260112
Passion fruit	310164	Tangelos	310281
Peas, Chinese or ming	290070	Tangerines, honey	310290
Peas, dry edible	270027	Tangerines, other	310299
Peas, green	290142	Tomatoes	290182
Peaches	310173	Walnuts, English	310362
Pears	310182	Watermelons	290202
Herbage			
Asparagus	290014	Celery	290062
Brussels sprouts	290034	Collards	290074
Cabbage, Chinese	290038	Endive	290094
Cabbage, head	290042	Escarole	290098
Cabbage, mustard	290046	Herbs	340027

(continued)

Table F-1. (continued)

Herbage (continued)			
Hops	340037	Rhubarb	290166
Kale	290114	Spinach	290170
Lettuce and romaine	290118	Sugarcane for sugar	270067
Mint for oil	340057	Tobacco	270007
Mustard greens	290122	Turnip greens	290190
Parsley	290138	Watercress	290198
Grain			
Barley for grain	260042	Popcorn	260087
Buckwheat	260047	Rice	260097
Corn for grain/seed	260002	Rice, wild	260122
Corn, sweet	290178	Rye for grain	260102
Emmer and Spelt	260067	Sorghum for syrup	340082
Foxtail millet seed	280052	Triticale	260117
Millet, proso	260092	Wheat (undifferentiated) for grain	260012
Oats for grain	260082		
Root			
Beets, sugar	270057	Onions, dry	290126
Beets, table	290026	Onions, green	290130
Carrots	290054	Peanuts for nuts	270077
Garlic	290102	Potatoes, sweet	270047
Ginger root	340012	Radishes	290162
Ginseng	340017	Taro	340097
Irish potatoes	270042	Turnips	290186
Lotus root	340052		

Appendix G

Soil-to-Plant Uptake Factors for Metals

Appendix G

Soil-to-Plant Uptake Factors for Metals

G.1 Introduction

Plant uptake factors are needed as a component of the fertilizer risk assessment model. In the probabilistic methodology used in the risk assessment, distributions of plant uptake factors are used to estimate plant tissue concentrations to which receptors are exposed. Uptake factors are often calculated from empirical data on constituent concentrations in plant tissue and in the soil in which the plants were grown (uptake factor = tissue concentration/soil concentration). For this risk assessment, an evaluation was performed to assess the adequacy of available plant uptake data for generating uptake factor distributions needed to run the model. A substantial amount of data are available in the literature, and there are also a few instances of existing plant uptake databases compiled from data in the literature. An evaluation of the existing data sets indicated the need for additional data for certain metals and certain types of plants. The following sections describe the development of the fertilizer plant uptake database, the data analysis, and the generation of uptake factor distributions. The plant uptake factor database is presented in Attachment 1 to this Appendix.

G.2 Plant Uptake Factor Database Development

In order to develop the plant uptake database, the U.S. Environmental Protection Agency (EPA) evaluated plant uptake (Br) values used in similar assessments, including the analysis conducted for EPA's Standards for the Use or Disposal of Sewage Sludge (40 *Code of Federal Regulations* [CFR] Part 503) and the fertilizer risk assessment conducted by the state of California (California Department of Food and Agriculture [CDFA], 1998). Uptake factors derived for the Part 503 standards are specific to sewage sludge matrices and are inappropriate for estimating biouptake for inorganic fertilizer-amended soil. The data used to develop the uptake factors used in the fertilizer risk assessment performed by the state of California were selected to be used specifically for fertilizer-amended soils and, therefore, may be appropriate for use. However, the data set is limited to arsenic, cadmium, and lead and includes data from greenhouse and pot studies. Consequently, EPA developed a more comprehensive database on plant uptake of metals specifically for this analysis. Four existing sources of information were examined to collect data for the plant uptake database presented in this appendix. They are as follows:

- CDFA report on risk-based concentrations for certain metals in fertilizers (CDFA, 1998);
- Chaney and Ryan's *Risk Based Standards for Arsenic, Lead, and Cadmium in Urban Soils* (1994);
- Oak Ridge National Laboratory’s *(ORNL’s) Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants* (Sample et al., 1997); and
- ORNL’s *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants* (Bechtel Jacobs, 1998).

G.2.1 Data Review and Quality Assurance

Sources used in CDFA (1998), Sample et al. (1997), and Chaney and Ryan (1994) were acquired for data extraction and entry into the fertilizers database. All retrieved literature was reviewed to determine if the data were appropriate for entry into the database. The data review and extraction methods described in the Bechtel Jacobs report (1998) were reviewed and found to be compatible; these data were entered into the database directly from tables in the ORNL report. Data from all sources were entered only if they were from a primary source and presented corresponding soil and tissue concentrations. Additionally, only data that were presented numerically or in a format where reliable estimation of numeric values was possible were entered. Regression data were not included. Data for elements reported in combination were not included. For those data determined to be appropriate for entry, the following decisions were made:

- Only data from soil depths of 0 to 15 cm were included because the risk model assumes a tilling depth of that range. This depth range corresponds to a typical root zone.
- If presented, the soil concentrations corrected for possible soil contamination were entered.
- Total metal concentration was entered as opposed to exchangeable or any other form of partial measurement.
- Amended soil concentrations were entered and background concentrations were noted where available.
- Because of potential variability, plant weights were not included.
- Where available, it was noted whether the plant tissue was washed or not in an attempt to account for possible soil contamination from residue.

To prevent inaccuracies in the database, a quality assurance (QA) assessment was performed on all entered data. The quality assessment was performed by an auditor other than the data enterer and consisted of a 100 percent check of the entered data against the original reference. Audit findings were documented on the hardcopy printout of the data. Upon completion of the QA assessment, the data entry personnel reviewed the comments, made the appropriate changes, and noted on the hardcopy printout that the changes had been made. Explanations of why any indicated changes were not made were also noted on the hardcopy printout.

G.2.2 Assessment of Appropriateness of Data

The data were further assessed in light of the discussion in Chaney and Ryan (1994) regarding the use of appropriate data for development of uptake factors, and some amendments were made to the database based on that assessment. In particular, data from sewage application studies and data from greenhouse and pot studies were excluded.

G.2.2.1. <u>Exclusion of Sewage Sludge Uptake Data</u>. All data pairs from studies using sewage sludge were excluded from the fertilizer database. This approach is taken because the phytoavailability of metals is significantly lower in sewage sludge-amended soils. The specific metal adsorption capacity of sewage sludge results in increased metal adsorption in sludge-amended soils and, thus, a decreased availability of metals for plant uptake. Several studies have demonstrated that the phytoavailability of added metals is lower in soils amended with sewage sludge (Bechtel Jacobs, 1998; Chaney and Ryan, 1994; U.S. EPA, 1992). This is believed to result from the hydrous Fe, Mn, and Al oxides within the biosolids matrix. Plant uptake rates in sewage sludge-amended soils approach a plateau with increased rates of sludge application; soils amended with metal salts show a linear increase in metal uptake with increased application of metal salts. Furthermore, it has been shown that other soil properties strongly affect metal uptake on metal salt-amended soils but not on sewage sludge-amended soils (U.S. EPA, 1992). Therefore, inclusion of data from sewage sludge studies would result in uptake factors that are not truly representative of uptake mechanisms in inorganic fertilizer-amended soil.

G.2.2.2 <u>Greenhouse Versus Field Studies</u>. Plant uptake rates also vary significantly between greenhouse or pot studies and field studies. Uptake rates for plants grown under greenhouse conditions as well as for plants grown in pots outdoors are higher than those for plants grown under field conditions. This difference is demonstrated when equivalent applications of metals are added to field versus pot or greenhouse plants. Plants grown in pots in greenhouses generally have the highest uptake rates. These higher uptake rates occur due to higher transpiration rates in relatively warm, humid greenhouse conditions. Moreover, test applications of metals are added to a limited soil volume in the pot and thus are more concentrated, increasing the diffusion of metals from soil particles to the roots. When fertilizers containing NH_4-N are applied, rhizosphere acidification in the small volume of the pot can increase metal uptake (U.S. EPA, 1992). Because greenhouse study data tend to show higher uptake rates than field study data and, therefore, may not accurately represent agricultural settings, using only field data to develop plant biouptake factors is generally recommended, if possible (Chaney and Ryan, 1994).

For this assessment, both field and pot study data were initially included in the uptake factor database. However, each data point was tagged as field study-derived or pot study-derived, and two distinct sets of uptake factor distributions were developed: one using all data (field and pot) and one using only field study data. A sensitivity analysis was undertaken to assess the difference in the risk for each metal of concern using soil uptake values based only on field data versus soil uptake values based on field and pot data combined. The 50th and 90th percentile uptake factor values for field only and combined studies were used as inputs to the indirect risk equations. All other factors in the analysis were held constant at central tendency values. The resulting risks to farmers for each pathway and all ingestion pathways were compared. The risk results for the farmer were compared using the 50th percentile Br for field studies only and for field and pot studies combined. The same was done using the 90th percentile Br values. The results of this analysis are presented in Attachment 1. The sensitivity analysis indicates that inclusion of greenhouse study data is not optimal for developing Br values for the fertilizer risk assessment. EPA concluded that uptake factors based only on field study data are most appropriate for use in the fertilizer risk assessment; this conclusion is supported by numerous reports in the literature indicating that pot study data show significantly higher uptake rates.

Available field-derived data are adequate for developing uptake factor distributions for most of the metals assessed in this analysis. Generally, fewer field data are available for fruits and grains than for other crop categories, particularly for mercury, cadmium, chromium, and copper. Field data are not available for nickel for three crop types: fruits, grains, and roots. Field data are also not available for vanadium for fruit, grain, herbage, and root crop types. Therefore, the fertilizer uptake database includes pot study data for these cases where no other data were available. (No uptake values based on sewage sludge data are included in any case, even in the absence of field and pot studies.) Summary statistics comparing the Br values for field study data versus field and pot study data are provided in Appendix J.

G.3 Plant Categories for Uptake Factors

Because the plant uptake database combines four existing data sets, it comprises a particularly wide variety of plant species and plant parts for which concentration data are reported. Furthermore, the terminology used and the level of specificity vary among reports (e.g., above-ground parts, herbage, stems, shoots). In order to develop uptake factor distributions, the concentration data were divided into categories based on the plant part for which the concentration was reported. Distinct uptake factor distributions were then developed for each category for each metal.

The basis for the category divisions was the plant part for which plant tissue concentrations were reported. EPA assumed that plant uptake and translocation of metals is distinct in roots versus above-ground parts and flowering or fruiting structures. This assumption is based on evidence in the primary data sources, several of the reports from which data were extracted, and general texts on plant uptake mechanisms and translocation (Farago, 1994; Fitter and Hay, 1983; Raven et al., 1982; Wilkins, 1990) that metal contaminants are differentially translocated to roots, above-ground leaves and stems, and flowering/fruiting parts. Figure G-1 shows a schematic drawing of the decision process used to assign data to the following five plant part categories:

- Roots,
- Grains,
- Fruits (e.g., fruits, flowers, nuts, and seeds),
- Herbage (nonreproductive aerial parts consumed by humans), and
- Forage (nonreproductive aerial parts consumed by animals but not by humans).

The distinction between grains and other reproductive parts (fruits) reflects the fact that uptake in grains is frequently studied and reported separately, and uptake by grain species is assumed by many investigators to be distinct. For the fertilizers risk assessment, “grains” is defined as edible seeds in the *Poaceae* (grass) family. While livestock feed can consist largely of grains, the grain category does not necessarily include all animal feed. For example, soy beans are common in livestock feed but are in the legume family and are not considered grains.

The distinction between human and nonhuman consumption (herbage versus forage) allows differentiation in the risk model between exposure through ingestion of plant matter and ingestion of animal products (e.g., beef and dairy products). Both of these categories include primarily leaf and stem parts and could arguably be combined. Moreover, the uptake factor distributions for these two categories are generally similar. The forage category includes a larger number of data pairs for each metal, and thus the distributions are wider; for most metals, however, the herbage uptake factor distributions are contained within the forage uptake factor distributions. Further discussion of the relationship between these two categories is presented in Section G.4.

The fruit category by definition includes conventional fruits (e.g., apples) as well as some foods that are commonly thought of as vegetables, such as squash, beans, and peas. The reason for this grouping is that metal uptake and translocation are assumed to be distinguished based on plant morphology (i.e., the physical structure or part) rather than by whether or not the part is eaten by humans. Many vegetables are the product of a fertilized flower and are therefore, botanically speaking, considered fruits. On the other hand, conventional vegetables that are not from the flowering/fruiting portion of a plant (e.g., lettuce and other leafy vegetables) are included in the herbage category, which is defined as above-ground, nonreproductive, edible parts.

G.4 Issues Associated with Relative Soil Concentrations

The relationship between metal concentrations in soils and plants is complex and not entirely understood. As discussed in Section 4.2.4 of the fertilizer risk assessment document, the complex interactions of metals in soil, their bioavailability, and plant uptake cannot all be included in risk assessment models. Instead, the risk assessment methodology intends to reflect the complexity and variability of plant uptake through the use of empirically derived uptake factors. The uptake factor distributions are used to account for the varying interactions among critical parameters such as soil pH, clay content, and cation exchange capacity; different metal interactions that affect bioavailability; and the magnitude of metal concentration in the soil. Discussions in Section 4.2.4 address variability in soil parameters and interactions among metals.

With respect to the effect of soil concentration on plant uptake rates, Bechtel Jacobs (1998) discusses the curvilinear response of plant uptake rates to soil concentrations. In general, plant uptake rates increase linearly with increased soil concentrations, as long as the soil concentrations are relatively low (or nontoxic to the plant). However, as soil concentrations increase to very high levels, uptake rates appear to decrease. Based on this discussion, an ideal data set for developing the fertilizer study uptake factor distributions would consist exclusively of data from agricultural sites amended with fertilizers. However, adequate data of this type are not available for all nine metals of concern, and the plant uptake database was populated with measurements from a variety of species grown under a variety of field conditions, as described in Section G.2. EPA recognizes that the data include measurements from contaminated sites with relatively high soil concentrations (e.g., arsenic data from Porter and Peterson, 1975 and Miller et al., 1976) as well as some measurements from the Bechtel Jacobs study taken from background locations with presumably relatively low concentrations. However, due to the limited availability of data for particular metals, plant parts, and crop types, including some data with relatively high or low soil concentrations along with more representative data apprears to be a reasonable approach to developing the necessary plant uptake factors.

Categorization of Plant Uptake Data

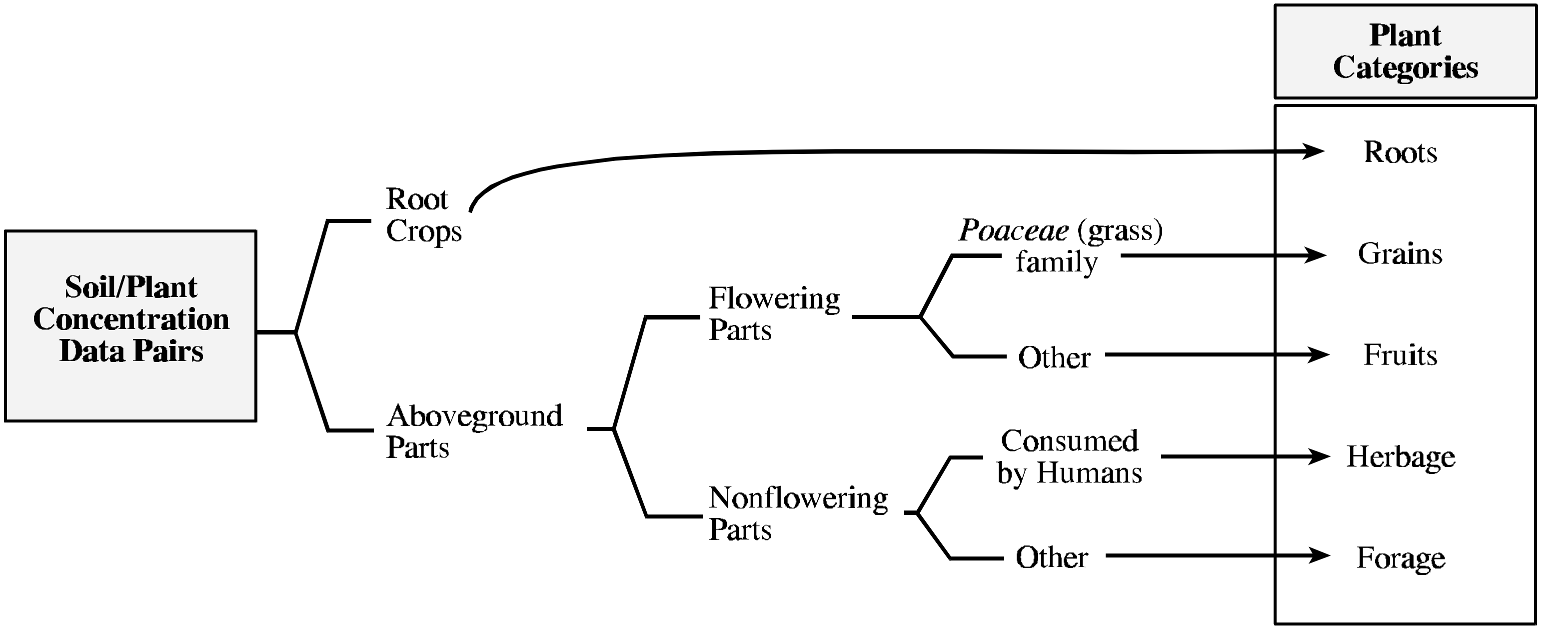


Figure G-1. Categorization of plant uptake data.

Attachment 1 to Appendix G

Sensitivity Analysis - Field vs Pot Data

Sensitivity Analysis - Plant Uptake Values (Brs) Varied Between Field Only Brs and Combined Field and Pot Brs

Median field only													
		Media Concentrations by Pathway					Individual Chemcial Risk or HQ						
Constituent	**soil conc (mg/kg)**	**fruit conc (mg/kg-DW)**	**above-ground vegetable conc (mg/kg-DW)**	**below-ground veg conc (mg/kg)**	**beef conc (mg/kg)**	**milk conc (mg/kg)**	**soil ingestion**	**fruit ingestion**	**veg ingestion**	**root veg ingestion**	**beef ingestion**	**milk ingestion**	**All pathways**
Lead	0.0123203	0.0002925	0.00029217	0.0002293	2.995E-06	3.368E-06	9.00E-09	2.00E-08	1.00E-08	4.00E-09	2.00E-09	9.00E-09	5.40E-08
Mercury	0.015459	0.0077304	0.007729941	0.0005521	9.841E-06	1.862E-05	4.00E-05	1.00E-03	1.00E-03	3.00E-05	6.00E-06	2.00E-04	2.28E-03
Nickel	0.0006261	3.866E-06	3.84733E-06	4.996E-06	2.769E-06	5.232E-07	2.00E-08	1.00E-08	7.00E-09	5.00E-09	1.00E-07	7.00E-08	2.12E-07
Arsenic	0.0305825	0.001011	0.001010048	0.0140679	6.763E-05	0.0002455	4.49E-09	1.13E-08	7.78E-09	5.39E-08	1.06E-08	1.33E-07	2.21E-07
Cadmium	0.0305825	0.0186571	0.018656137	0.0097864	2.707E-05	2.563E-06	2.00E-05	1.00E-03	7.00E-04	2.00E-04	5.00E-06	7.00E-06	1.93E-03
Chromium VI	0.0305825	3.845E-05	3.75251E-05	2.905E-05	9.478E-05	2.281E-05	4.00E-06	4.00E-07	3.00E-07	1.00E-07	1.00E-05	1.00E-05	2.48E-05
Copper	0.0305825	3.845E-05	3.75251E-05	2.905E-05	9.478E-05	2.281E-05	4.00E-06	4.00E-07	3.00E-07	1.00E-07	1.00E-05	1.00E-05	2.48E-05
Vanadium	0.0305825	3.845E-05	3.75251E-05	2.905E-05	9.478E-05	2.281E-05	4.00E-06	4.00E-07	3.00E-07	1.00E-07	1.00E-05	1.00E-05	2.48E-05
Zinc	0.0305825	3.845E-05	3.75251E-05	2.905E-05	9.478E-05	2.281E-05	4.00E-06	4.00E-07	3.00E-07	1.00E-07	1.00E-05	1.00E-05	2.48E-05

Median field and pot													
Media Concentrations by Pathway							Individual Chemcial Risk or HQ						
Constituent	**soil conc (mg/kg)**	**fruit conc (mg/kg-DW)**	**above-ground vegetable conc (mg/kg-DW)**	**below-ground veg conc (mg/kg)**	**beef conc (mg/kg)**	**milk conc (mg/kg)**	**soil ingestion**	**fruit ingestion**	**veg ingestion**	**root veg ingestion**	**beef ingestion**	**milk ingestion**	**All pathways**
Lead	0.0123203	0.0005551	0.000554747	0.0003819	6.496E-06	7.309E-06	9.00E-09	3.00E-08	2.00E-08	7.00E-09	5.00E-09	2.00E-08	9.10E-08
Mercury	0.015459	0.00637	0.006369545	0.0005521	5.436E-06	1.012E-05	4.00E-05	1.00E-03	8.00E-04	3.00E-05	4.00E-06	9.00E-05	1.96E-03
Nickel	0.0006261	2.571E-05	2.56881E-05	1.941E-05	3.979E-06	1.235E-06	2.00E-08	7.00E-08	5.00E-08	2.00E-08	2.00E-07	2.00E-07	5.60E-07
Arsenic	0.0305825	0.0011027	0.001101795	0.000367	7.248E-05	0.0002679	4.49E-09	1.23E-08	8.49E-09	1.41E-09	1.13E-08	1.45E-07	1.83E-07
Cadmium	0.0305825	0.0143755	0.01437459	0.0162087	2.65E-05	2.5E-06	2.00E-05	8.00E-04	5.00E-04	3.00E-04	5.00E-06	7.00E-06	1.63E-03
Chromium VI	0.0305825	3.845E-05	3.75251E-05	2.905E-05	9.619E-05	2.527E-05	4.00E-06	4.00E-07	3.00E-07	1.00E-07	1.00E-05	1.00E-05	2.48E-05
Copper	0.0305825	3.845E-05	3.75251E-05	2.905E-05	9.619E-05	2.527E-05	4.00E-06	4.00E-07	3.00E-07	1.00E-07	1.00E-05	1.00E-05	2.48E-05
Vanadium	0.0305825	3.845E-05	3.75251E-05	2.905E-05	9.619E-05	2.527E-05	4.00E-06	4.00E-07	3.00E-07	1.00E-07	1.00E-05	1.00E-05	2.48E-05
Zinc	0.0305825	3.845E-05	3.75251E-05	2.905E-05	9.619E-05	2.527E-05	4.00E-06	4.00E-07	3.00E-07	1.00E-07	1.00E-05	1.00E-05	2.48E-05

P 90 field only													
	Media Concentrations by Pathway							Individual Chemcial Risk or HQ					
Constituent	soil conc (mg/kg)	fruit conc (mg/kg-DW)	above-ground vegetable conc (mg/kg-DW)	below-ground veg conc (mg/kg)	beef conc (mg/kg)	milk conc (mg/kg)	soil ingestion	fruit ingestion	veg ingestion	root veg ingestion	beef ingestion	milk ingestion	All pathways
Lead	0.0123203	0.0051752	0.005174868	0.0014784	1.516E-05	1.962E-05	9.00E-09	3.00E-07	2.00E-07	3.00E-08	1.00E-08	5.00E-08	5.99E-07
Mercury	0.015459	0.0160783	0.016077826	0.0006338	7.343E-05	0.000145	4.00E-05	3.00E-03	2.00E-03	4.00E-05	5.00E-05	1.00E-03	6.13E-03
Nickel	0.0006261	9.428E-06	9.40879E-06	1.941E-05	5.084E-05	1.319E-05	2.00E-08	3.00E-08	2.00E-08	2.00E-08	2.00E-06	2.00E-06	4.09E-06
Arsenic	0.0305825	0.0051702	0.005169265	0.0076456	0.0007914	0.0035717	4.49E-09	5.77E-08	3.98E-08	2.93E-08	1.24E-07	1.93E-06	2.19E-06
Cadmium	0.0305825	0.0599434	0.059942481	0.0660582	0.0001031	1.041E-05	2.00E-05	3.00E-03	2.00E-03	1.00E-03	2.00E-05	3.00E-05	6.07E-03
Chromium VI	0.0305825	0.0001914	0.000190437	6.422E-05	0.0002274	7.821E-05	4.00E-06	2.00E-06	1.00E-06	2.00E-07	3.00E-05	4.00E-05	7.72E-05
Copper	0.0305825	0.0001914	0.000190437	6.422E-05	0.0002274	7.821E-05	4.00E-06	2.00E-06	1.00E-06	2.00E-07	3.00E-05	4.00E-05	7.72E-05
Vanadium	0.0305825	0.0001914	0.000190437	6.422E-05	0.0002274	7.821E-05	4.00E-06	2.00E-06	1.00E-06	2.00E-07	3.00E-05	4.00E-05	7.72E-05
Zinc	0.0305825	0.0001914	0.000190437	6.422E-05	0.0002274	7.821E-05	4.00E-06	2.00E-06	1.00E-06	2.00E-07	3.00E-05	4.00E-05	7.72E-05

P 90 field and pot													
	Media Concentrations by Pathway							Individual Chemcial Risk or HQ					
Constituent	soil conc (mg/kg)	fruit conc (mg/kg-DW)	above-ground vegetable conc (mg/kg-DW)	below-ground veg conc (mg/kg)	beef conc (mg/kg)	milk conc (mg/kg)	soil ingestion	fruit ingestion	veg ingestion	root veg ingestion	beef ingestion	milk ingestion	All pathways
Lead	0.0123203	0.0113354	0.01133503	0.0032033	7.774E-05	9.918E-05	9.00E-09	6.00E-07	4.00E-07	6.00E-08	6.00E-08	3.00E-07	1.43E-06
Mercury	0.015459	0.0151508	0.015150283	0.0006338	6.371E-05	0.0001251	4.00E-05	3.00E-03	2.00E-03	4.00E-05	4.00E-05	1.00E-03	6.12E-03
Nickel	0.0006261	8.769E-05	8.76745E-05	5.322E-05	6.676E-05	1.776E-05	2.00E-08	2.00E-07	2.00E-07	5.00E-08	3.00E-06	2.00E-06	5.47E-06
Arsenic	0.0305825	0.3669915	0.366990552	2.2233461	0.0006808	0.0030642	4.49E-09	4.10E-06	2.83E-06	8.51E-06	1.06E-07	1.66E-06	1.72E-05
Cadmium	0.0305825	0.1987879	0.198786928	0.1253882	0.0003583	3.477E-05	2.00E-05	1.00E-02	7.00E-03	2.00E-03	7.00E-05	9.00E-05	1.92E-02
Chromium VI	0.0305825	0.0001914	0.000190437	6.422E-05	0.0002339	8.948E-05	4.00E-06	2.00E-06	1.00E-06	2.00E-07	4.00E-05	5.00E-05	9.72E-05
Copper	0.0305825	0.0001914	0.000190437	6.422E-05	0.0002339	8.948E-05	4.00E-06	2.00E-06	1.00E-06	2.00E-07	4.00E-05	5.00E-05	9.72E-05
Vanadium	0.0305825	0.0001914	0.000190437	6.422E-05	0.0002339	8.948E-05	4.00E-06	2.00E-06	1.00E-06	2.00E-07	4.00E-05	5.00E-05	9.72E-05
Zinc	0.0305825	0.0001914	0.000190437	6.422E-05	0.0002339	8.948E-05	4.00E-06	2.00E-06	1.00E-06	2.00E-07	4.00E-05	5.00E-05	9.72E-05

Comparison of medians

		Media Concentrations by Pathway							Individual Chemcial Risk or HQ				
Constituent	soil conc (mg/kg)	fruit conc (mg/kg-DW)	above-ground vegetable conc (mg/kg-DW)	below-ground veg conc (mg/kg)	beef conc (mg/kg)	milk conc (mg/kg)	soil ingestion	fruit ingestion	veg ingestion	root veg ingestion	beef ingestion	milk ingestion	All Pathways
Lead	1	0.5269892	0.5266714	0.6004032	0.4611068	0.46077903	1	0.666666667	0.5	0.571428571	0.4	0.45	0.59340659
Mercury	1	1.2135625	1.2135782	1	1.8104701	1.840762519	1	1	1.25	1	1.5	2.222222222	1.15885947
Nickel	1	0.1503976	0.1497711	0.2574194	0.6959189	0.423816629	1	0.142857143	0.14	0.25	0.5	0.35	0.37857143
Arsenic	1	0.916799	0.9167291	38.333333	0.9330905	0.916231813	1	0.916799018	0.916729149	38.33333333	0.933090539	0.916231813	1.20663452
Cadmium	1	1.2978361	1.2978552	0.6037736	1.0217345	1.024828823	1	1.25	1.4	0.666666667	1	1	1.18382353
Chrom VI	1	1	1	1	0.9852805	0.902476028	1	1	1	1	1	1	1
Copper	1	1	1	1	0.9852805	0.902476028	1	1	1	1	1	1	1
Vanadium	1	1	1	1	0.9852805	0.902476028	1	1	1	1	1	1	1
Zinc	1	1	1	1	0.9852805	0.902476028	1	1	1	1	1	1	1

Comparison of 90P

	Media Concentrations by Pathway								Individual Chemcial Risk or HQ				
Constituent	soil conc (mg/kg)	fruit conc (mg/kg-DW)	above-ground vegetable conc (mg/kg-DW)	below-ground veg conc (mg/kg)	beef conc (mg/kg)	milk conc (mg/kg)	soil ingestion	fruit ingestion	veg ingestion	root veg ingestion	beef ingestion	milk ingestion	All Pathways
Lead	1	0.4565556	0.4565377	0.4615385	0.1950118	0.197825625	1.00E+00	5.00E-01	5.00E-01	5.00E-01	1.67E-01	1.67E-01	4.19E-01
Mercury	1	1.0612209	1.0612228	1	1.1525395	1.159099372	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.25E+00	1.00E+00	1.00E+00
Nickel	1	0.1075079	0.1073151	0.3647059	0.761653	0.742799564	1.00E+00	1.50E-01	1.00E-01	4.00E-01	6.67E-01	1.00E+00	7.48E-01
Arsenic	1	0.014088	0.0140856	0.0034388	1.1623903	1.165614891	1.00E+00	1.41E-02	1.41E-02	3.44E-03	1.16E+00	1.17E+00	1.27E-01
Cadmium	1	0.3015446	0.3015414	0.5268293	0.2876619	0.29946254	1.00E+00	3.00E-01	2.86E-01	5.00E-01	2.86E-01	3.33E-01	3.16E-01
Chrom VI	1	1	1	1	0.9723312	0.874077245	1.00E+00	1.00E+00	1.00E+00	1.00E+00	7.50E-01	8.00E-01	7.94E-01
Copper	1	1	1	1	0.9723312	0.874077245	1.00E+00	1.00E+00	1.00E+00	1.00E+00	7.50E-01	8.00E-01	7.94E-01
Vanadium	1	1	1	1	0.9723312	0.874077245	1.00E+00	1.00E+00	1.00E+00	1.00E+00	7.50E-01	8.00E-01	7.94E-01
Zinc	1	1	1	1	0.9723312	0.874077245	1.00E+00	1.00E+00	1.00E+00	1.00E+00	7.50E-01	8.00E-01	7.94E-01

Sensitivity Analysis -- Soil-Plant Uptake Factor Statistics

	Field and Pot						Field				
Summary Statistics	**Forage**	**Fruits**	**Grains**	**Herbage**	**Roots**		**Forage**	**Fruits**	**Grains**	**Herbage**	**Roots**
Lead											
Mean	0.775116	0.158768	0.052061	0.28403	0.086487		0.14423	0.242332	0.109238	0.122829	0.046393
Median	0.11	0.040234	0.02125	0.045148	0.03125		0.023075	0.054198	0.095745	0.023687	0.018613
Geometric Mean	0.091512	0.024173	0.019622	0	0.025136		0.027468	0.062689	0.074926	0.033699	0.017053
Std. Deviation	2.078325	0.450263	0.065666	0.555338	0.133846		0.404427	0.316648	0.073798	0.195354	0.07399
Minimum	0.000647	0.000111	0.000554	0.000522	0.000554		0.000113	0.002174	0.006957	0.000522	0.000645
Maximum	17.66	3.28	0.255319	3.208	0.695652		4.370588	1.02	0.255319	0.90625	0.480645
Number of Datapoints	285	61	44	266	183		156	17	17	50	92
P 90	1.807828	0.348092	0.162054	0.921225	0.260032		0.311735	0.659574	0.202128	0.417341	0.12168
Mercury											
Mean	1.336965	1.973835	0.3851	0.473467	0.035714		1.519135	3.931092	0.567857	0.518456	0.035714
Median	0.34062	0.014286	0.078571	0.412354	0.035714		0.655355	0.014286	0.1	0.5	0.035714
Geometric Mean	0.276236	0.033655	0.085587	0.224611	0.034993		0.339725	0.133904	0.193413	0.284935	0.034993
Std. Deviation	2.313954	4.796545	0.792044	0.452314	0.010102		2.428051	6.784108	0.954928	0.450193	0.010102
Minimum	0.00093	0.001875	0.009449	0.011509	0.028571		0.00145	0.014286	0.071429	0.011509	0.028571
Maximum	12.23009	11.76471	2	1.571429	0.042857		12.23009	11.76471	2	1.571429	0.042857
Number of Datapoints	147	6	6	22	2		128	3	4	20	2
P 90	4.47	5.902218	1.057143	0.983333	0.041429		5.15	9.414622	1.434286	1.03875	0.041429
Nickel											
Mean	0.647317	0.182592	0.326502	0.092608	0.039309		0.725904			0.008564	
Median	0.035892	0.124205	0.313653	0.040527	0.03075		0.019231			0.006118	
Geometric Mean	0.053556	0.112181	0.18287	0.044307	0.028555		0.034161			0.006396	
Std. Deviation	2.353322	0.238063	0.270698	0.17351	0.031403		2.719769			0.007679	
Minimum	0.000632	0.005066	0.010132	0.002275	0.005066		0.000632			0.002275	
Maximum	22.21429	1.633333	0.95	1.08	0.116851		22.21429			0.019746	
Number of Datapoints	156	50	23	97	23		115			4	
P 90	1.485645	0.321333	0.672364	0.137761	0.084871		1.137441			0.015781	
Arsenic											
Summary Statistics	Forage	Fruits	Grains	Herbage	Roots		Forage	Fruits	Grains	Herbage	Roots
Mean	0.401894	0.015163	0.014445	2.466199	17.05115		0.471999	0.0071	0.004955	0.065331	0.098551
Median	0.06	0.001979	0.005	0.0364	0.0119		0.052632	0.002041	0.00464	0.033333	0.004571
Geometric Mean	0.060724	0.002876	0.005526	0.086497	0.066502		0.055322	0.002876	0.004055	0.030612	0.010518
Std. Deviation	1.23467	0.037325	0.030099	0.033059	35.65882		1.371536	0.012653	0.002724	0.078998	0.254507
Minimum	5.56E-05	8.33E-05	0.000667	0.000917	0.000898		5.56E-05	0.000571	0.000667	0.001	0.000898
Maximum	9.074074	0.14831	0.1076	17.5	114		9.074074	0.047174	0.01	0.333333	1.169565
Number of Datapoints	155	16	21	31	29		124	13	19	24	23

P 90	0.936664	0.029356	0.01	12	72.67		1.103448	0.011231	0.009227	0.169051	0.247347
Cadmium											
Mean	3.633641	4.091166	0.418878	2.636366	1.869733		0.921713	0.03875	0.504211	0.811259	0.747691
Median	0.430114	0.902824	0.109589	0.473008	0.5269		0.438194	0.03875	0.119118	0.606314	0.318182
Geometric Mean	0.230561	0.657143	0.084583	0.376986	0.38471		0.322261	0.013693	0.151202	0.42148	0.344899
Std. Deviation	16.35284	8.852958	1.131637	6.546588	4.527101		2.804336	0.051265	1.298058	0.833377	0.948421
Minimum	0.000418	0.0025	9.09E-05	0.000527	0.001432		0.008696	0.0025	0.0025	0.0025	0.0125
Maximum	271	50	9	52.8	43.4375		22.87879	0.075	9	4	3.705882
Number of Datapoints	352	96	256	377	171		151	2	184	54	35
P 90	6.418	10	0.856211	6.470588	4.117647		1.781746	0.06775	0.945433	1.962542	2.158491
Chromium											
Mean	0.032934	0.020204	0.036336	0.003166	0.001077		0.032934	0.000451	9.27E-05	0.003166	0.001077
Median	0.005167	0.011478	0.017877	0.001232	0.000949		0.005167	0.000118	8.99E-05	0.001232	0.000949
Geometric Mean	0.003437	0.006719	0.005928	0.001036	0.000662		0.003437	0.000176	8.55E-05	0.001036	0.000662
Std. Deviation	0.073474	0.021633	0.039964	0.007646	0.000885		0.073474	0.000768	4.16E-05	0.007646	0.000885
Minimum	3.32E-05	4.4E-05	4.82E-05	1.2E-05	7.64E-05		3.32E-05	4.4E-05	4.82E-05	1.2E-05	7.64E-05
Maximum	0.480159	0.065714	0.118286	0.069118	0.002311		0.480159	0.001824	0.000143	0.069118	0.002311
Number of Datapoints	70	23	13	95	6		70	5	4	95	6
P 90	0.07461	0.051724	0.082229	0.006212	0.00209		0.07461	0.001156	0.000133	0.006212	0.00209
Copper											
Mean	3.023772	0.549993	0.209599	0.156381	0.210008		0.418262	0.443288	1.661909	0.280411	0.452469
Median	0.185325	0.222727	0.10625	0.081858	0.070231		0.150084	0.495764	1.661909	0.168333	0.480226
Geometric Mean	0.212564	0.200619	0.101294	0.076397	0.087835		0.141003	0.389339	1.656427	0.147135	0.377333
Std. Deviation	14.2695	0.710604	0.363669	0.251789	0.245533		0.930176	0.192415	0.190752	0.443181	0.230077
Minimum	0.0011	0.004562	0.016423	0.006387	0.007299		0.0011	0.128571	1.527027	0.020605	0.060377
Maximum	127.8	3.3625	1.796791	2.307692	0.810734		7.4	0.65534	1.796791	2.307692	0.810734
Number of Datapoints	178	64	40	166	56		153	10	2	32	21
P 90	3.076	1.557577	0.362133	0.396541	0.628636		0.687841	0.622716	1.769815	0.591064	0.712621
Vanadium											
Mean	0.005478						0.005478				
Median	0.004854						0.004854				
Geometric Mean	0.004798						0.004798				
Std. Deviation	0.003081						0.003081				
Minimum	0.001727						0.001727				
Maximum	0.014493						0.014493				
Number of Datapoints	21						21				
P 90	0.009662						0.009662				
Zinc											
Mean	1.119286	6.078037	0.62072	0.905742	0.830101		0.79196		0.970158	0.774081	0.134567
Median	0.360667	1.55	0.253982	0.345912	0.181423		0.314063		0.166878	0.361111	0.129854
Geometric Mean	0.300698	1.365519	0.316715	0.354164	0.238541		0.241916		0.365882	0.417303	0.101067

Std. Deviation	2.899898	12.27825	0.893935	1.70487	1.820744		2.651111		1.613094	1.172904	0.097307
Minimum	0.001689	0.017647	0.041176	0.017647	0.00842		0.001689		0.1328	0.047246	0.00842
Maximum	34.28571	57.5	4.880952	13.9604	12.27		34.28571		4.880952	6.25	0.460145
Number of Datapoints	220	83	51	196	88		207		10	33	26
P 90	2.018732	26.9	1.718333	2.460437	1.817023		1.278389		3.087373	1.865728	0.23044

Attachment 2 to Appendix G

Plant Uptake Database

Data Provide in a Separate Excel Spread Sheet

Appendix H

Industrial Source Complex Short Term, Version 3, Results

Table H-1. Industrial Source Complex Short Term, Version 3 (ISCST3), Results for 29 Meteorological Stations

Meteorological Location	Particles				Vapors	
	Air Concentration (µg/m³/µg/s-m²)	Dry Deposition (g/m²/yr)/ (µg/s-m²)	Wet Deposition (g/m²/yr)/ (µg/s-m²)	Combined Deposition (g/m²/yr)/ (µg/s-m²)	Air Concentration (µg/m³/µg/s-m²)	Wet Deposition (g/m²/yr)/ (µg/s-m²)
Albuquerque, NM	28.8	81.7	0.1	81.8	28.8	0.02
Atlanta, GA	28.6	206.4	0.3	206.7	28.7	0.1
Bismark, ND	28.3	32.5	0.1	32.6	28.3	0.03
Boise, ID	31.0	93.0	0.1	93.1	31.0	0.04
Boulder, CO	32.1	114.6	0.2	114.8	32.2	0.05
Casper, WY	22.1	38.8	0.1	38.9	22.1	0.03
Chicago, IL	25.2	200.6	0.2	200.8	25.2	0.08
Charleston, SC	29.4	192	0.3	192.3	29.4	0.1
Cleveland, OH	26.1	182.3	0.3	182.6	26.1	0.1
Fresno, CA	37.7	93.9	0.1	94.0	37.7	0.03
Grand Island, NE	22.3	37.1	0.1	37.2	22.3	0.06
Harrisburg, PA	27.6	75.5	0.3	75.8	27.6	0.1
Hartford, CT	32.5	74.0	0.4	74.4	31.8	0.2
Houston, TX	31.8	69.6	0.2	69.7	32.5	0.08
Huntington, WV	37.5	94.2	0.3	94.5	37.6	0.1
Los Angeles, CA	34.2	128.1	0.05	128.2	34.2	0.02

(continued)

Table H-1. (continued)

Meteorological Location	Particles				Vapors	
	Air Concentration ($\mu g/m^3/\mu g/s\text{-}m^2$)	Dry Deposition ($(g/m^2/yr)/(\mu g/s\text{-}m^2)$)	Wet Deposition ($(g/m^2/yr)/(\mu g/s\text{-}m^2)$)	Combined Deposition ($(g/m^2/yr)/(\mu g/s\text{-}m^2)$)	Air Concentration ($\mu g/m^3/\mu g/s\text{-}m^2$)	Wet Deposition ($(g/m^2/yr)/(\mu g/s\text{-}m^2)$)
Las Vegas, NV	26.2	46.1	0.03	46.1	26.2	0.01
Memphis, TN	31.4	163.7	0.3	164.0	31.5	0.1
Miami, FL	30.2	132.7	0.3	133.0	30.3	0.1
Minneapolis, MN	24.7	161.4	0.2	161.6	24.7	0.06
Philadelphia, PA	27.7	83.1	0.3	83.4	27.7	0.1
Phoenix, AZ	39.1	50.4	0.1	50.5	39.1	0.02
Portland, ME	32.5	155.1	0.3	155.4	32.5	0.1
Raleigh-Durham, NC	32.3	237.9	0.3	238.2	32.4	0.1
Seattle, WA	27.7	193.9	0.3	194.2	27.7	0.1
San Francisco, CA	25.7	76.0	0.1	76.1	25.8	0.03
Salt Lake City, UT	28.3	119.3	0.1	119.4	28.3	0.04
Salem, OR	31.9	83.1	0.3	83.4	32.0	0.09
Winnemucca, NV	33.7	17.9	0.1	18.0	33.7	0.03

Table H-2. Analysis of ISCST3 Modeling: Impact of Using Dry Depletion Option (16 Receptors)

Location		**Concentration** **($\mu g/m^3/\mu g/s\text{-}m^2$)**	**Wet Deposition** **($g/m^2/yr)/(\mu g/s\text{-}m^2$)**	**Dry Deposition** **($g/m^2/yr)/(\mu g/s\text{-}m^2$)**	**Combined Deposition** **($g/m^2/yr)/(\mu g/s\text{-}m^2$)**
Average Impacts for Particles					
Atlanta, GA	Without dry plume depletion	21.3	0.25	157.9	158.2
	With dry plume depletion	10.4	0.09	26.6	26.7

Table H-3. Analysis of ISCST3 Modeling: Comparison of 121 Receptors Versus 16 and 441 Receptors

Location	Concentration (µg/m^3/µg/s-m^2)			Wet Deposition (g/m^2/yr)/(µg/s-m^2)			Dry Deposition (g/m^2/yr)/(µg/s-m^2)			Combined Deposition (g/m^2/yr)/(µg/s-m^2)		
	441 Receptors	**121 Receptors**	**16 Receptors**	**441 Receptors**	**121 Receptors**	**16 Receptors**	**441 Receptors**	**121 Receptors**	**16 Receptors**	**441 Receptors**	**121 Receptors**	**16 Receptors**
Average Impacts for Particles												
Minneapolis, MN	26.4	24.7	18.3	0.15	0.15	0.12	170.5	161.4	123.5	170.7	161.6	123.6
Hartford, CT	34.7	32.5	24.0	0.37	0.35	0.29	78.3	74.0	56.3	78.7	74.4	56.6
Fresno, CA	40.2	37.7	28.0	0.07	0.07	0.06	99.1	93.9	72.3	99.2	94.0	72.3
Atlanta, GA	30.6	28.6	21.2	0.31	0.30	0.25	218.1	206.4	157.9	218.4	206.7	158.2
Average Impacts for Vapors												
Minneapolis, MN	26.4	24.7	18.4	0.06	0.06	0.05	NA	NA	NA	NA	NA	NA
Hartford, CT	34.8	32.5	24.0	0.15	0.15	0.12	NA	NA	NA	NA	NA	NA
Fresno, CA	40.2	37.7	28.0	0.03	0.03	0.02	NA	NA	NA	NA	NA	NA
Atlanta, GA	30.9	28.7	21.3	0.17	0.13	0.11	NA	NA	NA	NA	NA	NA

Table H-4. Comparison of ISCST3 Results for Several Field Sizes (121 Receptors)

		Particles				Vapors	
Location	**Field Size (percentile)**	**Air Concentration (μg/m³/μg/s-m²)**	**Dry Deposition (g/m²/yr)/ (μg/s-m²)**	**Wet Deposition (g/m²/yr)/ (μg/s-m²)**	**Combined Deposition (g/m²/yr)/ (μg/s-m²)**	**Air Concentration (μg/m³/μg/s-m²)**	**Wet Deposition (g/m²/yr)/ (μg/s-m²)**
Minneapolis, MN	(25th percentile)	16.1	82.0	0.04	82.0	16.1	0.01
	(50th percentile)	19.4	113.1	0.07	113.2	19.4	0.03
	(80th percentile)	22.6	142.1	0.1	142.2	22.6	0.05
	(90th percentile)	**24.7**	**161.4**	**0.2**	**161.6**	**24.7**	**0.06**
	(95th percentile)	27.1	182.5	0.2	182.7	27.1	0.08
Hartford, CT	(25th percentile)	21.2	37.8	0.09	37.9	21.2	0.03
	(50th percentile)	25.6	52.0	0.2	52.2	25.6	0.06
	(80th percentile)	29.7	65.2	0.3	65.5	29.7	0.1
	(90th percentile)	**32.5**	**74.0**	**0.4**	**74.4**	**32.5**	**0.2**
	(95th percentile)	34.6	104.3	0.6	104.9	35.7	0.2
Fresno, CA	(25th percentile)	24.5	46.9	0.02	47.0	24.5	0.01
	(50th percentile)	29.6	65.4	0.03	65.4	29.6	0.01
	(80th percentile)	34.4	82.5	0.05	82.6	34.4	0.02
	(90th percentile)	**37.7**	**93.9**	**0.07**	**94.0**	**37.7**	**0.03**
	(95th percentile)	41.4	106.4	0.09	106.5	41.4	0.04

(continued)

Table H-4. (continued)

Location	Field Size (percentile)	Particles				Vapors	
		Air Concentration (µg/m^3/µg/s-m^2)	Dry Deposition (g/m^2/yr)/ (µg/s-m^2)	Wet Deposition (g/m^2/yr)/ (µg/s-m^2)	Combined Deposition (g/m^2/yr)/ (µg/s-m^2)	Air Concentration (µg/m^3/µg/s-m^2)	Wet Deposition (g/m^2/yr)/ (µg/s-m^2)
Atlanta, GA	(25th percentile)	18.7	104.3	0.8	104.3	18.7	0.03
	(50th percentile)	22.6	144.3	0.2	144.5	22.6	0.6
	(80th percentile)	26.2	181.7	0.2	182.0	26.2	0.1
	(90th percentile)	**28.6**	**206.4**	**0.3**	**206.7**	**28.7**	**0.1**
	(95th percentile)	31.4	233.5	0.4	233.9	31.5	0.2

Field sizes modeled:

25th percentile - 350 m x 350 m
50th percentile - 700 m x 700 m
80th percentile - 1,240 m x 1,240 m
90th percentile - 1,740 m x 1,740 m (field size modeled in estimating risk)
95th percentile - 2,460 m x 2,460 m

Appendix I

Indirect Exposure Model Equations

Table I-1.1. Total Load to Waterbody

Fisher Scenario

$$L_T = L_R + L_E$$

Parameter	Definition	Central Tendency	High End
L_T	Total constituent load to the waterbody (g/yr)		
L_R	Runoff load from pervious surfaces (g/yr)	Calculated (see Table **I**-1.2)	
L_E	Soil erosion load (g/yr)	Calculated (see Table **I**-1.5)	

Description

This equation calculates the total average waterbody load from runoff and erosion loads.

Table I-1.2. Pervious Runoff Load to Waterbody

Fisher Scenario

$$L_R = R \times (A_{BF} \times C_{BF} + A_F \times C_F) \times \frac{BD}{\theta + K_d s \times BD} \times 0.01$$

Parameter	**Definition**	**Central Tendency**	**High End**
L_R	Pervious surface runoff load (g/yr)		
R	Average annual surface runoff (cm/yr)	Climate region-specific	
BD	Soil bulk density (g/cm^3)	1.5	
A_F	Area of field (m^2)	Ag field = 3,000,000	
C_F	Constituent concentration in field (mg/kg)	Calculated (see Partitioning Model)	
$K_d s$	Soil-water partition coefficient (L/kg) or (cm^3/g)	Chemical-specific (see Appendix D)	
0.01	Units conversion factor (kg-cm^2/mg-m^2)		
θ	Volumetric soil-water content (cm^3/cm^3)	Calculated (see Table I-1.3)	

Description

This equation calculates the average runoff load to the waterbody from pervious soil surfaces in the sub-basin.

Table I-1.3. 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)	0.43	
q	Average annual recharge rate (cm/yr)	Calculated (see Table I-1.4)	
K_s	Saturated hydraulic conductivity (cm/yr)	808	
b	Soil-specific exponent representing water retention (unitless)	5.4	

Table I-1.4. Average Annual Recharge

All Exposure Scenarios

$$q = P + I - E_v - R_f$$

Parameter	Definition	Central Tendency	High End
q	Average annual recharge rate (cm/yr)		
P	Average annual precipitation (cm/yr)	Climate region-specific	
I	Average annual irrigation (cm/yr)	Climate region-specific	
E_v	Average annual evapotranspiration (cm/yr)	Climate region-specific	
R_f	Average annual runoff (cm/yr)	Climate region-specific	

Table I-1.5. Erosion Load to Waterbody

Fisher Scenario

$$L_E = [(X_{e,F} \text{ x } A_F \text{ x } C_F) + (X_{e,BF} \text{ x } A_{BF} \text{ x } C_{BF})] \text{ x } SD_{SB} \text{ x } ER \frac{K_d s \text{ x } BD}{\theta + K_d s \text{ x } BD} \text{ x } 0.001$$

Parameter	Definition	Central Tendency	High End
L_E	Constituent load via soil erosion load (g/yr)		
$X_{e,WF}$	Unit soil loss from the field (kg/m^2/yr)	Calculated (see Table I-1.6)	
A_F	Field area (m^2)	Ag field = 3,000,000	
C_F	Source field constituent concentration (mg/kg)	Chemical-specific (see Appendix B)	
SD_{SB}	Sediment delivery ratio for sub-basin (unitless)	Calculated (see Table I-1.7)	
ER	Soil enrichment ratio (unitless)	Organics = 3 Metals = 1	
$K_d s$	Soil-water partition coefficient (L/kg) or (cm^3/g)	Chemical-specific (see Appendix B)	
BD	Soil bulk density (g/cm^3)	1.5	
θ	Volumetric soil water content (cm^3/cm^3)	Calculated (see Table I-1.3)	
0.001	Units conversion factor (g/mg)		

Description

This equation calculates the load to the waterbody resulting from soil erosion.

Table I-1.6. Universal Soil Loss Equation (USLE) for the Source Field

All Exposure Scenarios

$$X_{e,F} = R_F \times K_F \times LS_F \times C_F \times P_F \times \frac{907.18}{4{,}047}$$

Parameter	Definition	Central Tendency	High End
$X_{e,F}$	Unit soil loss from the source field (kg/m^2/yr)		
R_F	USLE rainfall (or erosivity) factor (1/yr)	Site-specific	
K_F	USLE erodibility factor (ton/acre)	Site-specific	
LS_F	USLE length-slope factor (unitless)	Site-specific	
C_F	USLE cover management factor (unitless)	0.5	
P_F	USLE supporting practice factor (unitless)	1	
907.18	Conversion factor (kg/ton)		
4,047	Conversion factor (m^2/acre)		

Description

This equation calculates the soil loss rate from the source field using the USLE; the result is used in the soil erosion load equation.

Table I-1.7. Sub-basin Sediment Delivery Ratio

All Exposure Scenarios

$$SD_{SB} = a \ x \ (A_F)^{-b}$$

Parameter	Definition	Central Tendency	High End
SD_{SB}	Sub-basin sediment delivery ratio for sub-basin (unitless)		
a	Empirical intercept coefficient	Depends on sub-basin area; see table below	
A_F	Area of source field of interest (m^2)	Ag. field = 3,000,000	
b	Empirical slope coefficient	0.125	

Description

This equation calculates the sediment delivery ratio for the sub-basin; the result is used in the soil erosion load equation.

Values for Empirical Intercept Coefficient, a

Sub-basin (A_F)	coefficient a (unitless)
$\leq$0.1	2.1
1	1.9
10	1.4
100	1.2
1,000	0.6
1 sq. mile = 2.59×10^6 m^2	

Table I-1.8. Total Waterbody Concentration

Fisher Scenario

$$C_{wtot} = \frac{L_T}{Vf_x \ x \ f_{water} + k_{wt} \ x \ WA_w \ x \ (d_w + d_b)}$$

Parameter	Definition	Input Value
C_{wtot}	Total waterbody concentration, including water column and bed sediment (mg/L) or (g/m^3)	
L_T	Total chemical load into waterbody, including runoff and erosion (g/yr)	Calculated (see Table I-1.1)
Vf_x	Average volumetric flow rate through waterbody (m^3/yr)	3x10^8
f_{water}	Fraction of total waterbody constituent concentration that occurs in the water column (unitless)	Calculated (see Table I-1.9)
k_{wt}	Overall total waterbody dissipation rate constant (1/yr)	Calculated (see Table I-1.10)
WA_w	Waterbody surface area (m^2)	1.0x10^6
d_w	Depth of water column (m)	0.64
d_b	Depth of upper benthic layer (m)	0.03

Description

This equation calculates the total waterbody concentration, including both the water column and the bed sediment.

Table I-1.9. Fraction in Water Column and Benthic Sediment

Fisher Scenario

$$f_{water} = \frac{(1 + K_{d,sw} \text{ x } TSS \text{ x } 10^{-6}) \text{ x } d_w/d_z}{(1 + K_{d,sw} \text{ x } TSS \text{ x } 10^{-6}) \text{ x } d_w/d_z + (\theta_{bs} + K_{d,bs} \text{ x } BS) \text{ x } d_b/d_z}$$

$$f_{benth} = 1 - f_{water}$$

Parameter	Definition	Central Tendency	High End
f_{water}	Fraction of total waterbody constituent concentration that occurs in the water column (unitless)		
$K_{d,sw}$	Suspended sediment/surface water partition coefficient (L/kg)	Chemical-specific (see Appendix K)	
TSS	Total suspended solids (mg/L)	80	
10^{-6}	Conversion factor (kg/mg)		
d_w	Depth of the water column (m)	0.64	
d_z	Total waterbody depth (m)	Calculated (d_w+d_b)	
d_b	Depth of the upper benthic layer (m)	0.03	
θ_{bs}	Bed sediment porosity (L_{water}/L)	0.6	
$K_{d,bs}$	Bed sediment/sediment pore-water partition coefficient (L/kg) or (g/cm^3)	Chemical-specific (see Appendix K)	
BS	Bed sediment concentration (g/cm^3)	1.0	
f_{benth}	Fraction of total waterbody constituent concentration that occurs in the benthic sediment (unitless)		

Description

These equations calculate the fraction of total waterbody concentration occurring in the water column and the bed sediments.

Table I-1.10. Overall Total Waterbody Dissipation Rate Constant

Fisher Scenario

$$k_{wt} = f_{water} \times k_v + k_b$$

Parameter	Definition	Central Tendency	High End
k_{wt}	Overall total waterbody dissipation rate constant (1/yr)		
f_{water}	Fraction of total waterbody constituent concentration that occurs in the water column	Calculated (see Table I-1.9)	
k_v	Water column volatilization rate constant (1/yr)	Calculated (see Table I-1.11)	
k_b	Benthic burial rate constant (1/yr)	Calculated (see Table I-1.14)	

Description

This equation calculates the overall dissipation rate of the constituent in surface water due to volatilization and benthic burial.

Table I-1.11. Water Column Volatilization Loss Rate Constant

Fisher Scenario

$$k_v = \frac{K_v}{d_z \times (1 + K_{d,sw} \times TSS \times 10^{-6})}$$

Parameter	Definition	Central Tendency	High End
k_v	Water column volatilization rate constant (1/yr)		
K_v	Overall transfer rate (m/yr)	Calculated (see Table I-1.12)	
d_z	Total waterbody depth (m)	Calculated (d_w+d_b)	
$K_{d,sw}$	Suspended sediment/surface water partition coefficient (L/kg)	Chemical-specific (see Appendix K)	
TSS	Total suspended solids (mg/L)	80	
10^{-6}	Conversion factor (kg/mg)		

Description

This equation calculates the water column constituent loss due to volatilization.

Table I-1.12. Overall Transfer Rate

Fisher Scenario

$$K_v = \left[K_L^{-1} + \left(K_G \frac{H}{R \ x \ T_k} \right)^{-1} \right]^{-1} \ x \ \theta^{(T_k - 293)}$$

Parameter	Definition	Central Tendency	High End
K_v	Overall transfer rate (m/yr)		
K_L	Liquid-phase transfer coefficient (m/yr)	Calculated (see Table I-1.13)	
K_G	Gas-phase transfer coefficient (m/yr) – flowing stream or river	36,500	
H	Henry's law constant (atm-m^3/mol)	Chemical-specific (see Appendix K)	
R	Universal gas constant (atm-m^3/mol-K)	8.205x10^{-5}	
T_k	Waterbody temperature (K)	298	
θ	Temperature correction factor (unitless)	1.026	

Description

This equation calculates the overall transfer rate of the constituent from the liquid and gas phases in surface water.

Table I-1.13. Liquid-Phase Transfer Coefficient

Fisher Scenario

- Flowing stream or river

$$K_L = \sqrt{\frac{10^{-4} \text{ x } D_w \text{ x } u}{d_z}} \text{ x } 3.15 \text{ x } 10^7$$

Parameter	Definition	Central Tendency	High End
K_L	Liquid-phase transfer coefficient (m/yr)		
D_w	Diffusivity of chemical in water (cm^2/s)	Chemical-specific (see Appendix K)	
u	Current velocity (m/s)	0.7	
d_z	Total waterbody depth (m)	Calculated (d_w+d_b)	
$3.15x10^7$	Conversion constant (s/yr)		
10^{-4}	Units conversion factor (m^2/cm^2)		

Description

This equation calculates the transfer rate of the constituent from the liquid phase for a flowing system.

Table I-1.14. Benthic Burial Rate Constant

Fisher Scenario

$$k_b = f_{benth} \times \left(\frac{W_b}{d_b} \right)$$

Parameter	Definition	Central Tendency	High End
k_b	Benthic burial rate constant (1/yr)		
f_{benth}	Fraction of total waterbody constituent concentration that occurs in the benthic sediment	Calculated (see Table I-1.9)	
W_b	Burial rate (m/yr)	Calculated (see Table I-1.15)	
d_b	Depth of upper benthic sediment layer (m)	0.03	

Description

This equation calculates the water column constituent loss due to burial in benthic sediment.

Table I-1.15. Benthic Burial Rate Constant

Fisher Scenario

$$W_b = W_{dep} \quad x \quad \left(\frac{TSS \quad x \quad 10^{-6}}{BS} \right)$$

Parameter	Definition	Central Tendency	High End
W_b	Benthic burial rate constant (m/yr)		
W_{dep}	Deposition rate to bottom sediment (m/yr)	Calculated (see Table I-1.16)	
TSS	Total suspended solids (mg/L)	80	
10^{-6}	Units conversion factor (kg/mg)		
BS	Bed sediments concentration (kg/L)	1	

Description

This equation is used to determine the loss of the constituent from the benthic sediment layer.

Table I-1.16. Deposition Rate to Bottom Sediment

Fisher Scenario

$$W_{dep} \;=\; \left(\frac{X_{e,SB} \;\mathrm{x}\; A_{SB} \;\mathrm{x}\; SD_{SB} \;\mathrm{x}\; 1{,}000 \;-\; Vf_{x} \;\mathrm{x}\; TSS}{WA_{w} \;\mathrm{x}\; TSS} \right)$$

Parameter	Definition	Central Tendency	High End
W_{dep}	Deposition rate to bottom sediment (m/yr)		
$X_{e,SB}$	Unit soil loss from the sub-basin (kg/m^2/yr)	Calculated (see Table I-1.17)	
A_{SB}	Area of sub-basin (m^2)	Calculated (see Table I-1.18)	
SD_{SB}	Sub-basin sediment delivery ratio (unitless)	Calculated (see Table I-1.7)	
Vf_x	Average volumetric flow rate (m^3/yr)	3.0×10^8	
TSS	Total suspended solids (g/m^3)	80	
1,000	Units conversion factor (g/kg)		
WA_w	Waterbody surface area (m^2)	1×10^6	

Description

This equation is used to determine the loss of the constituent from the waterbody as it deposits onto the benthic sediment.

Table I-1.17. USLE for the Sub-Basin

All Exposure Scenarios

$$X_{e,SB} = R_{SB} \times K_{SB} \times LS_{SB} \times C_{SB} \times P_{SB} \times \frac{907.18}{4{,}047}$$

Parameter	Definition	Central Tendency	High End
$X_{e,SB}$	Unit soil loss from the sub-basin (kg/m^2-yr)		
R_{SB}	USLE rainfall factor (1/yr)	Climate region-specific	
K_{SB}	USLE erodibility factor (ton/acre)	Climate region-specific	
LS_{SB}	USLE length-slope factor (unitless)	1.5	
C_{SB}	USLE cover factor (unitless)	0.5	
P_{SB}	USLE erosion control practice factor (unitless)	1.0	
907.18	Units conversion factor (kg/ton)		
4,047	Units conversion factor (m^2/acre)		

Description

This equation is used to calculate the soil loss rate from the sub-basin using the USLE.

Table I-1.18. Sub-basin Area

Fisher Scenario

$$A_{SB} = A_F + A_{BF}$$

Parameter	Definition	Central Tendency	High End
A_{SB}	Area of sub-basin		
A_F	Area of source field of interest (m^2)	Ag field = 3,000,000	

Description

This equation is used to calculate the area of the sub-basin.

Table I-1.19. Total Water Column Concentration

Fisher Scenario

$$C_{wt} = f_{water} \times C_{wtot} \times \frac{d_w + d_b}{d_w}$$

Parameter	Definition	Central Tendency	High End
C_{wt}	Total concentration in water column (mg/L)		
f_{water}	Fraction of total waterbody constituent concentration that occurs in the water column (unitless)	Calculated (see Table I-1.9)	
C_{wtot}	Total water concentration in surface water system, including water column and bed sediment (mg/L)	Calculated (see Table I-1.8)	
d_b	Depth of upper benthic layer (m)	0.03	
d_w	Depth of the water column (m)	0.64	

Description

This equation calculates the total water column concentration of the constituent; this includes both dissolved constituent and constituent sorbed to suspended solids.

Table I-1.20. Dissolved Water Concentration

Fisher Scenario

$$C_{dw} = \frac{C_{wt}}{1 + K_{d,sw} \text{ x } TSS \text{ x } 10^{-6}}$$

Parameter	Definition	Central Tendency	High End
C_{dw}	Dissolved-phase water concentration (mg/L)		
C_{wt}	Total concentration in water column (mg/L)	Calculated (see Table I-1.19)	
$K_{d,sw}$	Suspended sediment/surface water partition coefficient (L/kg)	Chemical-specific (see Appendix K)	
10^{-6}	Units conversion factor (kg/mg)		
TSS	Total suspended solids (mg/L)	80	

Description

This equation calculates the concentration of the constituent dissolved in the water column.

Table I-1.21. Concentration Sorbed to Bed Sediment

Fisher Scenario

$$C_{bs} = f_{benth} \text{ x } C_{wtot} \text{ x } \frac{K_{d,bs}}{\theta_{bs} + K_{d,bs} \text{ x } BS} \text{ x } \frac{d_w + d_b}{d_b}$$

Parameter	Definition	Central Tendency	High End
C_{bs}	Concentration sorbed to bed sediments (mg/kg)		
f_{benth}	Fraction of total waterbody constituent concentration that occurs in the bed sediment (unitless)	Calculated (see Table I-1.9)	
C_{wtot}	Total water concentration in surface water system, including water column and bed sediment (mg/L)	Calculated (see Table I-1.8)	
d_w	Total depth of water column (m)	0.64	
d_b	Depth of the upper benthic layer (m)	0.03	
θ_{bs}	Bed sediment porosity (unitless)	0.6	
$K_{d,bs}$	Bed sediment/sediment pore-water partition coefficient (L/kg)	Chemical-specific (see Appendix K)	
BS	Bed sediment concentration (kg/L)	1.0	

Description

This equation calculates the concentration of the constituent sorbed to bed sediments.

Table I-1.22. Fish Concentration from Dissolved Water Concentration

Fisher Scenario

$$C_{fish} = C_{dw} \times BCF$$

Parameter	Definition	Central Tendency	High End
C_{fish}	Fish concentration (mg/kg)		
C_{dw}	Dissolved water concentration (mg/L)	Calculated (see Table I-1.20)	
BCF	Bioconcentration factor (L/kg)	Chemical-specific (see Appendix K)	

Description

This equation calculates the fish concentration from the dissolved water concentration using a bioconcentration factor.

Table I-1.23. Fish Concentration from Dissolved Water Concentration

Fisher Scenario

$$C_{fish} = C_{wt} \times BAF$$

Parameter	Definition	Central Tendency	High End
C_{fish}	Fish concentration (mg/kg)		
C_{wt}	Dissolved water concentration (mg/L)	Calculated (see Table I-1.19)	
BAF	Bioconcentration factor (L/kg)	Chemical-specific (see Appendix K)	

Description

This equation calculates the fish concentration from the dissolved water concentration using a bioconcentration factor.

Table I-1.24. Fish Concentration from Bottom Sediment Concentration

Fisher Scenario

$$C_{fish} = \frac{C_{BS} \text{ x } BSAF \text{ x } f_{lipid}}{OC_{BS}}$$

Parameter	Definition	Central Tendency	High End
C_{fish}	Fish concentration (mg/kg)		
C_{BS}	Dissolved water concentration (mg/L)	Calculated (see Table I-1.21)	
BSAF	Biota-to-sediment accumulation factor (L/kg)	Chemical-specific (see Appendix K)	
f_{lipid}	Fish lipid content (fraction)	0.05	
OC_{BS}	Fraction organic carbon in bed sediment (unitless)	$2.34\text{x}10^{-3}$	$6.88\text{x}10^{-3}$

Description

This equation calculates the fish concentration from the bottom sediment concentration using a bioaccumulation factor.

Table I-2.1. Exposed Vegetables Concentration Due to Direct Deposition

Farmer Scenario

$$Pd = \frac{(D_{dep} \text{ x } D_v \text{ x } 315.36) \text{ x } Rp \text{ x } [(1.0 - \exp(-kp \text{ x } Tp)]}{Yp \text{ x } kp}$$

Parameter	Definition	Central Tendency	High End
Pd	Concentration in plant due to direct deposition (mg/kg) or (µg/g)		
D_{dep}	Dry deposition of particles (g/m^2/yr)	Modeled (see Appendix H)	
315.36	Units conversion factor (mg-m-s/µg-cm-yr)		
Rp	Interception fraction of edible portion of plant (dimensionless)	0.074	
kp	Plant surface loss coefficient (1/yr)	18	
Tp	Length of plant exposure to deposition of edible portion of plant, per harvest (yrs)	0.16	
Yp	Yield or standing crop biomass of the edible portion of the plant (kg DW/m^2)	3	

Description

This equation calculates the contaminant concentration in exposed vegetation due to wet and dry deposition of the contaminant on the plant surface.

Table I-2.2. Exposed Vegetable Concentration Due to Air-to-Plant Transfer

Farmer Scenario

$$Pv = \frac{Cv \ x \ Bv \ x \ VG_{ag}}{\rho_a}$$

Parameter	Definition	Default Value
Pv	Concentration of pollutant in the plant due to air-to-plant transfer (mg/kg) or (µg/g)	
Cv	Air concentration of vapor (µg/m^3)	Product and climate region-specific
Bv	Air-to-plant biotransfer factor ([mg pollutant/kg plant tissue DW]/[µg pollutant/g air])	Chemical-specific (see Appendix K)
VG_{ag}	Empirical correction factor for exposed vegetables (dimensionless)	0.01
ρ_a	Density of air (g/cm^3)	$1.2x10^{-3}$

Description

This equation calculates the contaminant concentration in exposed vegetation due to the direct uptake of vapor phase contaminants into the plant leaves.

Table I-2.3. Exposed Vegetable Concentration Due to Root Uptake

Farmer Scenario

$$Pr = Sc \times Br$$

Parameter	Definition	Central Tendency	High End
Pr	Concentration of pollutant in the plant due to direct uptake from soil (mg/kg)		
Sc	Average soil concentration of pollutant over exposure duration (mg/kg)	Calculated	
Br	Plant-soil bioconcentration factor for exposed vegetables [µg/g DW]/[µg/g soil]	Chemical-specific distribution (see Appendix G)	

Description

This equation calculates the contaminant concentration in exposed vegetation due to direct uptake of contaminants from the soil.

Table I-2.4. Exposed Fruit Concentration Due to Direct Deposition

Farmer Scenario

$$Pd = \frac{(D_{dep} \text{ x } D_v \text{ x } 315.36) \text{ x } Rp \text{ x } [(1.0 - \exp(-kp \text{ x } Tp)]}{Yp \text{ x } kp}$$

Parameter	Definition	Central Tendency	High End
Pd	Concentration in plant due to direct deposition (mg/kg) or (µg/g)		
D_{dep}	Dry deposition of particles (g/m^2/yr)	Modeled (see Appendix H)	
315.36	Units conversion factor (mg-m-s/µg-cm-yr)		
Rp	Interception fraction of edible portion of plant (dimensionless)	0.01	
kp	Plant surface loss coefficient (1/yr)	18	
Tp	Length of plant exposure to deposition of edible portion of plant, per harvest (yrs)	0.16	
Yp	Yield or standing crop biomass of the edible portion of the plant (kg DW/m^2)	0.12	

Description

This equation calculates the contaminant concentration in exposed fruit due to wet and dry deposition of the contaminant on the plant surface.

Table I-2.5. Exposed Fruit Concentration Due to Air-to-Plant Transfer

Farmer Scenario

$$Pv = \frac{Cv \ x \ Bv \ x \ VG_{ag}}{\rho_a}$$

Parameter	Definition	Default Value
Pv	Concentration of pollutant in the plant due to air-to-plant transfer (mg/kg) or (µg/g)	
Cv	Air concentration of vapor (µg/m^3)	Product and climate region-specific
Bv	Air-to-plant biotransfer factor ([mg pollutant/kg plant tissue DW]/[µg pollutant/g air])	Chemical-specific (see Appendix K)
VG_{ag}	Empirical correction factor for exposed vegetables (dimensionless)	0.01
ρ_a	Density of air (g/cm^3)	1.2×10^{-3}

Description

This equation calculates the contaminant concentration in exposed fruit due to direct uptake of vapor-phase contaminants into the plant leaves.

Table I-2.6. Exposed Fruit Concentration Due to Root Uptake

Farmer Scenario

$$Pr = Sc \times Br$$

Parameter	Definition	Central Tendency	High End
Pr	Concentration of pollutant in the plant due to direct uptake from soil (mg/kg)		
Sc	Average soil concentration of pollutant over exposure duration (mg/kg)	Calculated (see Partitioning Model)	
Br	Plant-soil bioconcentration factor for exposed vegetables [µg/g DW]/[µg/g soil]	Chemical-specific (see Appendix G)	

Description

This equation calculates the contaminant concentration in exposed fruit due to direct uptake of contaminants from the soil.

Table I-2.7. Root Vegetable Concentration Due to Root Uptake

Farmer Scenario

$$Pr_{bg} = \frac{Sc \ x \ RCF}{K_d s} \qquad \text{(organics)}$$

$$Pr_{bg} = Sc \ x \ Br \qquad \text{(metals)}$$

Parameter	Definition	Central Tendency	High End
Pr_{bg}	Concentration of pollutant in below-ground plant parts due to root uptake (mg/kg)		
Sc	Soil concentration of pollutant (mg/kg)	Calculated (see Partitioning Model)	
RCF	Ratio of concentration in roots to concentration in soil pore water ([mg pollutant/kg plant tissue FW] /[µg pollutant/mL pore water])	Chemical-specific (see Appendix K)	
Br	Soil-to-plant biotransfer factor for root vegetables (µg pollutant/g plant tissue DW)/(mg pollutant/ g soil)	Chemical-specific (see Appendix G)	
$K_d s$	Soil-water partition coefficient (mL/g)	Chemical-specific (see Appendix D)	

Description

This equation calculates the contaminant concentration in root vegetables due to uptake from the soil water.

Table I-3.1. Beef Concentration Due to Plant and Soil Ingestion

Farmer Scenario

$$A_{beef} = (\Sigma F \text{ x } Qp_i \text{ x } P_i + Qs \text{ x } Sc) \text{ x } Ba_{beef}$$

Parameter	Definition	Central Tendency	High End
A_{beef}	Concentration of pollutant in beef (mg/kg)		
F	Fraction of plant grown on contaminated soil and eaten by the animal (dimensionless)	1	
Qp_i	Quantity of plant eaten by the animal each day (kg plant tissue DW/d) - beef grain - beef silage - beef forage	 0.47 2.5 8.8	
P_i	Total concentration of pollutant in each plant species eaten by the animal (mg/kg) = Pd + Pv + Pr	Calculated (see Tables I-3.3, I-3.4, I-3.5)	
Qs	Quantity of soil eaten by the foraging animal (kg soil/d)	0.5	
Sc	Soil concentration (mg/kg)	Calculated (see Partitioning Model)	
Ba_{beef}	Biotransfer factor for beef (d/kg)	Chemical-specific (see Appendix K)	

Description

This equation calculates the concentration of the contaminant in beef from ingestion of forage, silage, grain, and soil.

Table I-3.2. Milk Concentration Due to Plant and Soil Ingestion

Farmer Scenario

$$A_{milk} = (\Sigma F \text{ x } Qp_i \text{ x } P_i + Qs \text{ x } Sc) \text{ x } Ba_{milk}$$

Parameter	Definition	Central Tendency	High End
A_{milk}	Concentration of pollutant in milk (mg/kg)		
F	Fraction of plant grown on contaminated soil and eaten by the animal (dimensionless)	1	
Qp_i	Quantity of plant eaten by the animal each day (kg plant tissue DW/d) - grain - silage - forage	 3.0 4.1 13.2	
P_i	Total concentration of pollutant in each plant species eaten by the animal (mg/kg) = Pd + Pv + Pr	Calculated (see Tables I-3.3, I-3.4, I-3.5)	
Qs	Quantity of soil eaten by the foraging animal (kg soil/d)	0.4	
Sc	Soil concentration (mg/kg)	Calculated (see Partitioning Model)	
Ba_{milk}	Biotransfer factor for milk (d/kg)	Chemical-specific (see Appendix K)	

Description

This equation calculates the concentration of the contaminant in milk from ingestion of forage, silage, grain, and soil.

Table I-3.3. Forage (Pasture Grass/Hay) Concentration Due to Direct Deposition

Farmer Scenario

$$Pd = \frac{(D_{dep}) \times Rp \times [(1.0 - \exp(-kp \times Tp)]}{Yp \times kp}$$

Parameter	Definition	Central Tendency	High End
Pd	Concentration in plant due to direct deposition (mg/kg) or (µg/g)		
D_{dep}	Dry deposition of particles (g/m^2/yr)	Modeled (see Appendix H)	
Rp	Interception fraction of edible portion of plant (dimensionless) - forage	0.5	
kp	Plant surface loss coefficient (1/yr)	18	
Tp	Length of the plant exposure to deposition of edible portion of plant per harvest (yrs) - forage	0.12	
Yp	Yield or standing crop biomass of the edible portion of the plant (kg DW/m^2)	0.24	
315.36	Units conversion (mg-m-s/µg-on-yr)		

Description

This equation calculates the contaminant concentration in the plant due to dry particle deposition of the contaminant on the plant surface.

Table I-3.4. Forage (Pasture Grass/Hay) Concentration Due to Air-to-Plant Transfer

Farmer Scenario

$$Pv = \frac{Cv \ x \ Bv \ x \ VG_{ag}}{\rho_a}$$

Parameter	Definition	Central Tendency	High End
Pv	Concentration of pollutant in the plant due to air-to-plant transfer (mg/kg)		
Cv	Vapor-phase air concentration of pollutant in air due to direct emissions (µg pollutant/m^3)	Modeled (see Appendix H)	
Bv	Air-to-plant biotransfer factor ([mg pollutant/kg plant tissue DW]/[µg [pollutant/g air])	Chemical-specific (see Appendix K)	
VG_{ag}	Empirical correction factor (dimensionless)	1.0	
ρ_a	Density of air (g/cm^3)	1.2×10^{-3}	

Description

This equation calculates the contaminant concentration in the plant due to direct uptake of vapor-phase contaminants into the plant leaves.

Table I-3.5. Forage/Silage/Grain Concentration Due to Root Uptake

Farmer Scenario

$$Pr = Sc \times Br$$

Parameter	Definition	Default Value
Pr	Concentration of pollutant in the plant due to direct uptake from soil (mg/kg)	
Sc	Average soil concentration of pollutant over exposure duration (mg/kg)	Calculated (see Partitioning Model)
Br	Plant-soil bioconcentraton factor for plant [µg/g DW]/[µg/g soil]	Chemical-specific (see Appendix G)

Description

This equation calculates the contaminant concentration in the plant due to direct uptake of contaminants from the soil.

Table I-4.1. 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 Partitioning Model)
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 varies with each scenario, and the soil consumption rate varies for children and adults.

Table I-4.2. Contaminant Intake from Exposed Vegetable Intake

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

Parameter	Description	Values
I_{ev}	Daily intake of contaminant from exposed vegetables (mg/kg Fw)	
Pd	Concentration in exposed vegetables due to deposition (mg/kg Dw)	Calculated (see Table I-2.1)
Pv	Concentration in exposed vegetables due to air-to-plant transfer (mg/kg Dw)	Calculated (see Table I-2.2)
Pr	Concentration in exposed vegetables due to root uptake (mg/kg Dw)	Calculated (see Table I-2.3)
CR_{ag}	Consumption rate of exposed vegetables (kg Dw/d)	Varies
F_{ag}	Fraction of exposed vegetables contaminated (unitless)	Varies

Description

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

Table I-4.3. Contaminant Intake from Exposed Fruit Intake

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

Parameter	Description	Values
I_{ef}	Daily intake of contaminant from exposed fruit (mg/kg Fw)	
Pd	Concentration in exposed fruit due to deposition (mg/kg Dw)	Calculated (see Table I-2.4)
Pv	Concentration in exposed fruit due to air-to-plant transfer (mg/kg Dw)	Calculated (see Table I-2.5)
Pr	Concentration in exposed fruit due to root uptake (mg/kg Dw)	Calculated (see Table I-2.6)
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 the contaminant from ingestion of exposed fruit. The consumption rate varies for children and adults. The contaminated fraction and the concentration in exposed fruit vary with each scenario.

Table I-4.4. Contaminant Intake from Root Vegetable Intake

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

Parameter	Description	Values
I_{rv}	Daily intake of contaminant from root vegetables for dioxins (mg/kg Fw); metals (mg/kg Dw)	
Pr_{bg}	Concentration in root vegetables due to deposition for dioxins (mg/kg Fw); metals (mg/kg Dw)	Calculated (see Table I-2.7)
CR_{bg}	Consumption rate of root vegetables for dioxins (kg Fw/d); metals (kg Dw/d)	Varies
F_{rv}	Fraction of root vegetables contaminated (unitless)	

Description

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

Table I-4.5. Contaminant Intake from Beef and Milk

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

Parameter	Description	Values
I_i	Daily intake of contaminant from animal tissue *i* (mg/d)	
A_i	Concentration in animal tissue *i* (mg/kg Fw) for dioxins and (mg/kg Dw) for cadmium	Calculated (see Tables I-3.1 and I-3.2)
CR_i	Consumption rate of animal tissue *i* (kg Fw/d) for dioxins and (kg Dw/d) for cadmium	Varies
F_i	Fraction of animal tissue *i* contaminated (unitless)	Varies

Description

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

Table I-4.6. Contaminant Intake from Fish

$$I_{fish} = C_{fish} \bullet CR_{fish} \bullet F_{fish}$$

Parameter	Description	Values
I_{fish}	Daily intake of contaminant from fish (mg/d)	
C_{fish}	Concentration in fish (mg/kg)	Calculated (see Table I-1.22)
CR_{fish}	Consumption rate of fish (kg/d)	Varies
F_{fish}	Fraction of fish contaminated (unitless)	Varies

Description

This equation calculates the daily intake of the contaminant from ingestion of fish.

Table I-4.7. Total Daily Intake

Farmer and Child of Farmer

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

Fisher

$$I = I_{fish}$$

Parameter	Description	Values
I	Total daily intake of contaminant (mg/d)	
I_{soil}	Daily intake of contaminant from soil (mg/d)	Calculated (see Table I-4.1)
I_{ev}	Daily intake of contaminant from exposed vegetables	Calculated (see Table I-4.2)
I_{ef}	Daily intake of contaminant from exposed fruit (mg/d)	Calculated (see Table I-4.3)
I_{rv}	Daily intake of contaminant from root vegetables	Calculated (see Table I-4.4)
I_{beef}, I_{milk}	Daily intake of contaminant from animal tissue (mg/d)	Calculated (see Table I-4.5)
I_{fish}	Daily intake of contaminant from fish (mg/d)	Calculated (see Table I-4.6)

Description

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

Table I-4.8. Individual Cancer Risk: Carcinogens

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

Parameter	Description	Values
Cancer Risk	Individual lifetime cancer risk (unitless)	
I	Total daily intake of contaminant (mg/d)	Calculated (see Table I-4.6)
ED	Exposure duration (yr)	Varies (see Section 6)
EF	Exposure frequency (d/yr)	350
BW	Body weight (kg)	Varies (see Section 6)
AT	Averaging time (yr)	70
365	Units conversion factor (d/yr)	
CSF	Oral cancer slope factor (per mg/kg/d)	Chemical-specific (see Appendix K)

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

Table I-4.9. 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 Table I-4.6)
BW	Body weight (kg)	Varies
RfD	Reference dose (mg/kg/d)	Chemical-specific (see Appendix K)

Description

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

Table I-4.10. Total Cancer Risk for Farmer Scenario: Carcinogens

$$\text{Total Cancer Risk} = \sum_i \text{Cancer Risk}_i$$

Parameter	Definition	Values
Total Cancer Risk	Total individual lifetime cancer risk for all chemicals (unitless)	
Cancer Risk$_i$	Individual lifetime cancer risk for chemical carcinogen *i* (unitless)	Calculated (see Table I-4.7)

Description

For carcinogens, cancer risks are added across all carcinogenic chemicals.

Table I-4.11. Hazard Index for Specific Organ Effects for Farmer Scenario: Noncarcinogens

$$HI_j = \sum_i HQ_i$$

Parameter	Definition	Values
HI_j	Hazard index for specific organ effect *j* (unitless)	
HQ_i	Hazard quotient for chemical *I* with specific organ effect *j* (unitless)	Calculated (see Table I-4.9)

Description

For noncancer health effects, hazard quotients are added across chemicals when they target the same organ to calculate an overall hard index.

Table I-5.1. Inhalation Cancer Risk for Individual Chemicals from Unit Risk Factor: Carcinogens

$$\text{Cancer Risk} = C_a \bullet \text{URF}$$

Parameter	Description	Values
Cancer Risk	Individual lifetime cancer risk (unitless)	
C_a	Concentration in air (µg/m^3)	Calculated (see Appendix H)
UFR	Inhalation unit risk factor (per µg/m^3)	Chemical-specific

Description

This equation calculates the inhalation cancer risk for individual constituents using the unit risk factor.

Table I-5.2. Inhalation Cancer Risk for Individual Chemicals from Carcinogenic Slope Factor: Carcinogens

$$\text{Cancer Risk} = \text{ADI} \bullet \text{CSF}_{\text{inh}}$$

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

Parameter	Description	Values
Cancer Risk	Individual lifetime cancer risk (unitless)	
ADI	Average daily intake via inhalation (mg/kg/d)	
IR	Inhalation rate (m^3/h)	Varies
ET	Exposure time (h/d)	24
EF	Exposure frequency (d/yr)	350
BW	Body weight (kg)	Varies
AT	Averaging time (yr)	70
CSF_{inh}	Inhalation carcinogenic slope factor (per mg/kg/d)	Chemical-specific (see Appendix K)

Description

This equation calculates the inhalation cancer risk for individual constituents using the carcinogenic slope factor.

Table I-5.3. Inhalation Hazard Quotient for Individual Chemicals: Noncarcinogens

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

Parameter	Description	Values
HQ	Hazard quotient (unitless)	
C_a	Concentration in air ($\mu g/m^3$)	Modeled ISC (see Appendix H)
RfC	Reference concentration (mg/m^3)	Chemical-specific (see Appendix K)

Description

This equation calculates the inhalation hazard quotient for individual constituents.

Table I-5.4 Total Inhalation Cancer Risk: Carcinogens

$$\text{Total Cancer Risk} = \sum_i \text{Cancer Risk}_i$$

Parameter	Definition	Values
Total Cancer Risk	Total individual lifetime cancer risk for all chemicals (unitless)	
Cancer Risk$_i$	Individual lifetime cancer risk for chemical carcinogen *i* (unitless)	Calculated (see Tables I-5.1 and I-5.2)

Description

For carcinogens, cancer risks are added across all carcinogenic chemicals.

Table I-5.5 Hazard Index for Inhalation: Noncarcinogens

$$HI_{inh} = \sum_{i} HQ_i$$

Parameter	Definition	Values
HI_{inh}	Hazard index for inhalation (unitless)	
HQ_i	Hazard quotient for chemical *i* (unitless)	Calculated (see Table I-5.3)

Description

For noncancer health effects, hazard quotients are added across chemicals when they target the same organ to calculate an overall hazard index.

Appendix J

Constituent Concentrations in Fertilizer Products & Application Rates

Boron

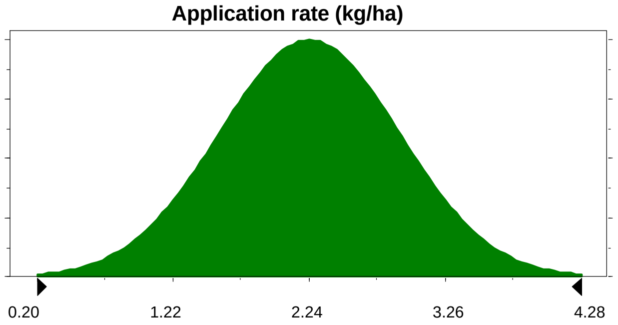
ID	% Boron	Cd	Pb	As	Cr	Hg	Ni	V	Cu	Zn
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
H0753	10	0.75	5.5	1040	1.3	0.17	2.5	16.9	8.1	6
25030	21	0	0	21	NR	NR	NR	NR	0	NR

Assumption: Application rate (kg/ha)

Normal distribution with parameters:

Mean	2.24
95% - tile	3.36

Selected range is from 0.00 to 4.48



NR - Not Reported

Source: U.S. EPA, 1998

Gypsum

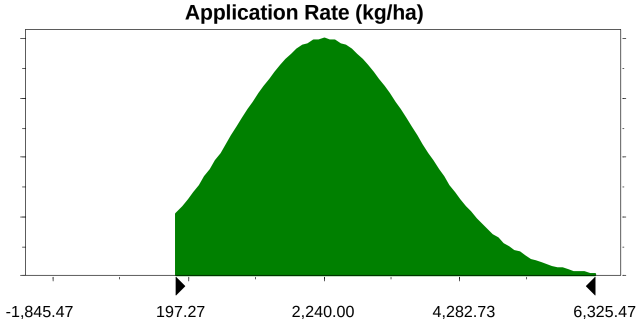
ID	% Gypsum	Cd	Pb	As	Cr	Hg	Ni	V	Cu	Zn
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
H4766	100	0.8	11	8.5	1.4	0.011	3	1.4	7.2	53.8
25855	100	0	3	3	NR	NR	NR	43	25	NR
25854	100	0	3	3.4	NR	NR	NR	41	42	NR
25853	100	2.5	1.5	3	NR	NR	NR	50	20.5	NR

Assumption: Application Rate (kg/ha)

Normal distribution with parameters:

Mean	2,240.00
95% - tile	4,480.00

Selected range is from 0.00 to 8,960.00



NR - Not Reported

Source: U.S. EPA, 1998

Iron Micronutrients

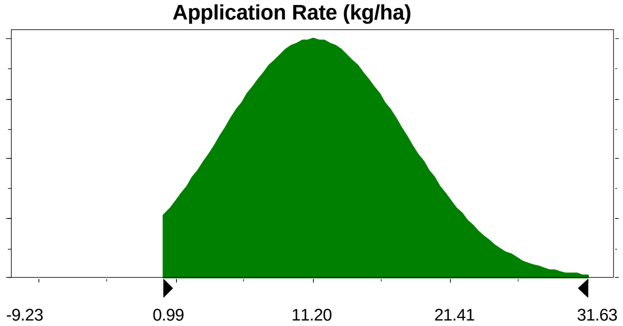
ID	% Fe	Cd mg/kg	Pb mg/kg	As mg/kg	Cr mg/kg	Hg mg/kg	Ni mg/kg	V mg/kg	Cu mg/kg	Zn mg/kg
22334	15	333.5	18750	34.5	NR			NR	1750	
25819	12	20.5	2625	4950	NR			NR	210	
25835	15	0	29	2.5	NR			NR	40	

Assumption: Application Rate (kg/ha)

Normal distribution with parameters:

Mean	11.20
95% - tile	22.40

Selected range is from 0.00 to 33.60



NR - Not Reported

Source: U.S. EPA, 1998

Liming Agents

ID	% CaCO3	Cd	Pb	As	Cr	Hg	Ni	V	Cu	Zn
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
calcite	100	0.7	1.1	1	NR	0.2	1.4	3	2.3	NR
dolomite	100	0.1	0.7	1.2	32.3	0.2	3.3	15	NR	8.01
H2529	33	1.5	10	15	2.5	0.01	5	1	5	7.7
H4763	85	3.6	150	37	73	0.041	18	49	158	1770
H4775	7.6	0.75	125	48	34	0.414	23	41	116	424
H4759	96	1.5	1	15	2.5	0.01	5	1	5	16
H4764	91	1.5	10	15	2.5	0.01	5	1	5	21
H2550	100	0.75	49	7.5	1.25	0.22	2.5	1.1	3	224
21827	100	8.1	45.5	1.1	NR	NR	NR	NR	38	NR
20882	100	6.5	53	5.1	NR	NR	NR	NR	46	NR

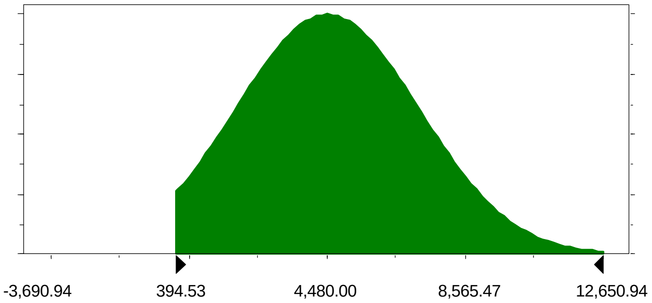
Assumption: Application Rate (kg/ha)

Normal distribution with parameters:

Mean	4,480.00
95% - tile	8,960.00

Selected range is from 0.00 to 16,800.00

Application Rate (kg/ha)



NR - Not Reported

Source: U.S. EPA, 1998

Micronutrients

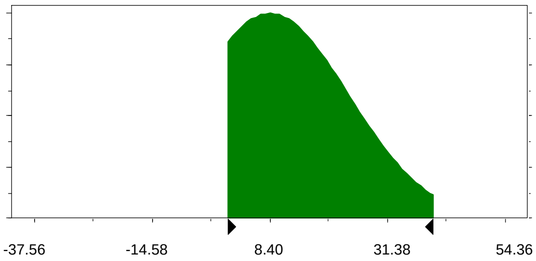
ID	Cd	Pb	As	Cr	Hg	Ni	V	Cu	Zn
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
H4772	0.85	5.5	0.85	3.1	0.03	21	0.5	19400	60300
H4756	55	3590	83	457	0.226	4	33	39900	94300

Assumption: Application Rate (kg/ha)

Normal distribution with parameters:

Mean	8.40
95% - tile	33.60

Selected range is from 0.00 to 40.30


Application Rate (kg/ha)

Source: U.S. EPA, 1998

Mn Micronutrient

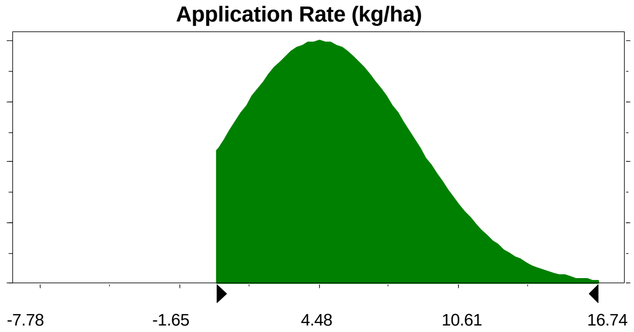
ID	% Mn	Cd mg/kg	Pb mg/kg	As mg/kg	Cr mg/kg	Hg mg/kg	Ni mg/kg	V mg/kg	Cu mg/kg	Zn mg/kg
H4753	29.5	1.5	50	15	10	0.01	50	1.5	21	60.8
21791	24.7	3	5	0.5	NR	NR	NR	NR	1.5	NR

Assumption: Application Rate (kg/ha)

Normal distribution with parameters:

Mean	4.48
95% - tile	11.20

Selected range is from 0.00 to 20.16



NR - Not Reported

Source: U.S. EPA, 1998

NPK applied for N

ID	% N	% P	% K	Cd	Pb	As	Cr	Hg	Ni	V	Cu	Zn
				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
B960246	19	19	19	3.5	2.2	6.6	45.4	0	11.2	85.2	25.6	36
B960244	12	24	24	4.3	4.6	9.8	59	0	14.7	119	49.3	44.5
B960249	7	35	12	4.6	3.9	9.7	66.8	0	20.9	116	45	55.1
B960282	9	44	9	2.3	3.5	13.2	90.7	0	14.5	163	30.1	49.8
B960325	10	21	15	2.7	11.1	7.2	46.3	0.17	13.4	87.7	10.2	872
B960333	8	32	16	3.9	5.3	11.2	68.1	0	14.9	126	22.2	43.9
B960389	19	19	19	1.6	1.4	5.2	43.5	0	0	77.7	0	0
B960412	7	26	26	2.6	2.8	6	51.8	0	11.5	79.4	26.2	37
B960418	19	19	19	2.2	3.8	7.5	62	0	9.2	97.8	13.7	33.1
B960441	9	34	10	3.3	3.6	10.7	67.4	0	12.2	121	16.3	34.6
B960442	9	3	10	3.6	3	9.2	88.8	0	14.5	159	6.6	53.1
B960453	10	20	20	4.3	3	3.6	68.7	0	18	67.1	16.4	60.9
B960475	9	40	5	14.3	422	10	107.9	0	29.2	130	90.5	4442
B960510	9	43	10	5.2	1.7	11.2	79.4	0	17.8	136	7.1	66.2
B960580	10	10	10	1.8	3.6	4.1	51.4	0	14.6	68.8	13.6	803
B960584	10	20	20	2.6	2.5	6.9	52.8	0	15.7	83.4	10.6	0.48
B960599	15	15	15	2.1	2.1	4.9	42.5	0	11	73.2	7.2	0.55
B960611	19	19	19	24.35	1.1	0	160	0	0.4	47.2	3.9	6.93
B960639	6	2	0	5.7	6.9	4.7	40.3	0	36.9	18.6	24.3	1.1
B960708	7	27	11	6.4	153	9	73.2	0	11.2	99.2	544	57.8
B960411	8	24	8	9.5	14	3.5	60.5	0	22.7	47.3	13.6	177
B960713	10	20	10	2.4	6.7	5.4	42	0	11.9	68.9	32	84.5
B960715	15	15	15	2	1.8	4.7	28	0	10.1	49.2	3.9	0.3
B980726	19	19	19	4.1	3.7	7.8	48.8	0	6.2	85.1	7.9	74.5
B960820	26	9	9	2	2.3	4.1	34.2	0	11.5	61.6	14.4	45.7
B960896	10	20	20	3.3	3.6	7	39	0	8	64.5	25.5	23.6
B960900	10	20	20	3.1	3.3	7.4	201	0	8.6	70.3	12.9	25.5
B960909	3	17	40	2.4	2.6	5.1	34.3	0	85.7	64.2	4.9	39.5
B960912	3	17	40	4.3	3.9	10.5	67.4	0	5.7	138	7.8	52.2
B960913	8	41	12	1.5	18	6.2	68.3	0	12	18.4	454	484
B961058	8	17	34	1	2.4	3.1	30.8	0	14.8	27.8	5	18.3
B961321	9	43	10	4.7	6.9	10.7	69.8	0	8.9	152	60.1	44.8
H0751	46	0	0	0.15	1	1.5	2.2	0	13.3	3.12	0.5	7.7
H0752	20	0	0	0.03	0.2	0.3	0.05	0	0.5	0.05	0.27	3.9
H2538	32	0	0	0.03	0.2	0.3	0.15	0	0.1	0.19	0.14	0.5
H1233	17	0	0	0.15	1	1.5	2	0	0.1	0.1	0.2	0.2
H0754	15.5	0	0	0.8	5.5	8	1.4	0	0.5	0.5	2.5	1
H4769	21	0	0	1.2	15	1.5	0.7	0.4	2.5	0.41	0.5	17
H4771	34.5	0	0	0.15	1	1.5	0.25	0	0.5	0.1	0.5	2.5
Urea	46	0	0	0.1	0.2	0.2	NR	0.2	0.5	0.2	0.3	NR
NH4NO3	34	0	0	0.1	0.2	0.2	NR	0.2	0.1	0.1	0.3	NR
NH4SO4	21	0	0	0.1	0.2	0.2	NR	0.2	0.1	0.1	0.3	NR
NH4SO4	21	0	0	0.1	0.2	0.4	2.14	0.2	0.1	0.1	0.3	NR
25042	20	0	0	0	0	0	NR	NR	0.6	NR	4	NR
21575	32	10	10	0	0	0.6	NR	NR	NR	NR	10.5	NR
24276	14	3	7	0	2	1.5	NR	NR	NR	NR	21	NR
23106	7	2	2	0	3	0.15	NR	NR	NR	NR	40.5	NR
22080	34	17	0	47	2.5	4.5	NR	NR	NR	NR	17	NR
22216	9	4	4	12.5	71	4.3	NR	NR	NR	NR	NR	NR
20891	16	4	8	23	255	8.4	NR	NR	NR	NR	265	NR

NPK applied for N

Assumption: Application Rate

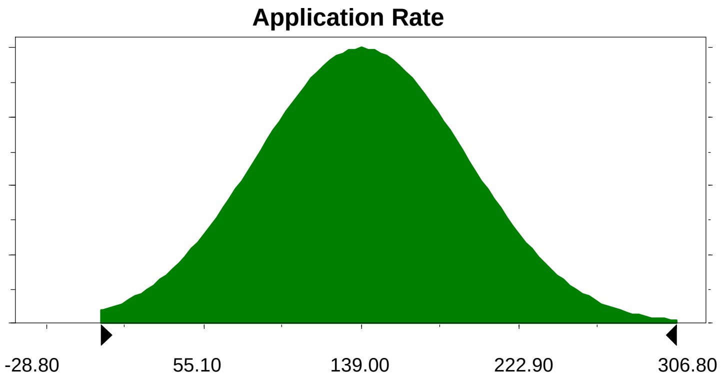
Normal distribution with parameters:

Mean	139.00
95% - tile	231.00

Selected range is from 0.00 to 464.00

NR - Not Reported

Source: U.S. EPA, 1998



NPK Applied for P

ID	% N	% P	% K	Cd mg/kg	Pb mg/kg	As mg/kg	Cr mg/kg	Hg mg/kg	Ni mg/kg	V mg/kg	Cu mg/kg	Zn mg/kg
MAP-1	11	52	0	6.4	4.5	12.1	54	NR	15	NR	0.75	60
MAP-2	11	52	0	6.7	4.5	14.1	55	NR	17	NR	0.75	64
MAP-3	11	52	0	7.3	4.5	17.1	56	NR	20	NR	0.75	67
MAP-4	11	52	0	7.4	4.5	9.5	55	NR	18	NR	0.75	72
MAP-5	11	52	0	7	4.5	12.4	59	NR	17	NR	0.75	70
MAP-6	11	52	0	7	4.5	12.4	55	NR	16	NR	0.75	68
MAP-7	11	52	0	6.7	4.5	16	57	NR	16	NR	0.75	65
MAP-8	11	52	0	7	4.5	8.1	59	NR	15	NR	1.6	81
MAP-9	11	52	0	6.7	4.5	14.9	73	NR	18	NR	0.75	73
MAP-10	11	52	0	6.7	4.5	14.8	58	NR	17	NR	0.75	63
MAP-11	11	52	0	7.1	4.5	16.1	54	NR	15	NR	0.75	78
MAP-12	11	52	0	7.7	4.5	9.9	55	NR	18	NR	0.75	80
MAP-13	11	52	0	8.3	4.5	11.2	57	NR	17	NR	0.75	91
MAP-14	11	52	0	7.4	4.5	10.8	55	NR	16	NR	0.75	80
MAP-15	11	52	0	7	12	8.9	62	NR	19	NR	1.6	83
MAP-16	11	52	0	6.7	4.5	14.3	56	NR	17	NR	0.75	63
MAP-17	11	52	0	7.7	4.5	10.7	56	NR	16	NR	0.75	80
MAP-18	11	52	0	7.3	4.5	10.9	56	NR	19	NR	0.75	76
MAP-19	11	52	0	7.3	4.5	17.8	57	NR	20	NR	0.75	72
MAP-20	11	52	0	6.7	4.5	12.9	51	NR	15	NR	0.75	70
MAP-21	11	52	0	6.7	4.5	15.5	54	NR	19	NR	0.75	76
MAP-22	11	52	0	7	4.5	11.4	58	NR	17	NR	0.75	90
MAP-23	11	52	0	7.7	4.5	11.2	56	NR	17	NR	0.75	95
DAP-1	18	46	0	5.4	12	13.1	53	NR	13	NR	1.6	85
DAP-2	18	46	0	6.7	4.5	15.4	50	NR	11	NR	0.75	86
DAP-3	18	46	0	6.7	12	15.6	48	NR	14	NR	0.75	87
DAP-4	18	46	0	8.9	4.5	13.8	48	NR	16	NR	1.6	80
DAP-5	18	46	0	94	4.5	6.8	616	NR	127	NR	0.75	2193
DAP-6	18	46	0	6.4	4.5	9.9	49	NR	14	NR	0.75	84
DAP-7	18	46	0	6.4	4.5	12.4	48	NR	12	NR	1.6	59
DAP-8	18	46	0	6	4.5	12.5	49	NR	14	NR	0.75	86
DAP-9	18	46	0	7.3	4.5	11.1	45	NR	14	NR	3.2	97
DAP-10	18	46	0	6	12	13.1	45	NR	14	NR	0.75	86
DAP-11	18	46	0	8.6	4.5	11.1	47	NR	15	NR	1.6	96
DAP-12	18	46	0	6	4.5	13.3	47	NR	17	NR	1.6	88
DAP-13	18	46	0	5.7	4.5	11.1	46	NR	15	NR	0.75	86
DAP-14	18	46	0	5.7	4.5	13.5	47	NR	19	NR	1.6	86
DAP-15	18	46	0	7	4.5	13	50	NR	13	NR	0.75	91
DAP-16	18	46	0	6.3	4.5	10.4	50	NR	16	NR	0.75	93
DAP-17	18	46	0	6.7	4.5	12.8	49	NR	14	NR	0.75	89
DAP-18	18	46	0	8.6	4.5	12.2	48	NR	16	NR	2.1	91
DAP-19	18	46	0	7	4.5	11.7	47	NR	15	NR	0.75	85
DAP-20	18	46	0	6.7	4.5	14.2	49	NR	14	NR	0.75	97
DAP-21	18	46	0	6.4	12	15.4	47	NR	13	NR	0.75	96
DAP-22	18	46	0	7.3	12	10.6	51	NR	14	NR	0.75	71
DAP-23	18	46	0	7	12	11.2	50	NR	13	NR	0.75	72
DAP-24	18	46	0	6	4.5	11.2	47	NR	17	NR	1.6	98
DAP-25	18	46	0	6.4	12	11.1	49	NR	16	NR	0.75	72
H4754	11	52	0	0.15	1	6.8	5.8	0.0025	19.2	37.9	3.6	54
H4755	18	46	0	6.9	2.5	18	92	0.025	19.1	174	5.4	81.6
H4762	16	15	15	0.75	5	8	4.3	0.0025	2.5	25.7	80.7	81.6
H2526	11	37	0	0.6	1	1.5	433	0.0025	0.5	31.7	0.5	25.3
H2574	11	30	0	1.6	1	1.5	379	0.0025	13.9	32	5.8	301
H2532	16	20	0	145	4.4	4.2	214	0.024	195	396	16	1480
H2546	10	34	0	25	1	4.8	400	0.0025	0.5	228	3.3	315
MAP-1	11	52	0	0.15	0.1	10.9	16.9	0.2	7.4	146	13.2	10.3
MAP-2	11	52	0	4	2.9	13.7	NR	0.2	22.2	205	1	NR

NPK applied for P

Assumption: Application rate

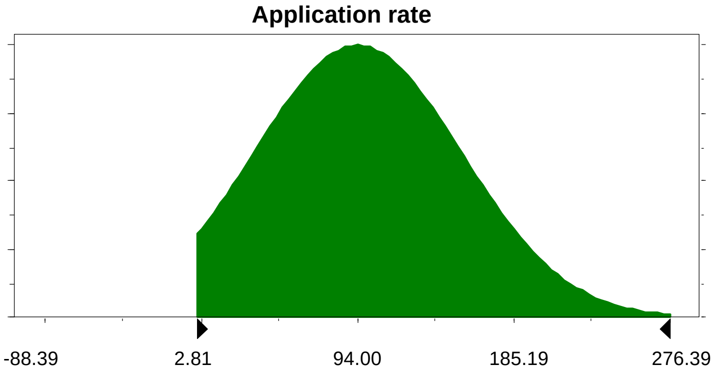
Normal distribution with parameters:

Mean	94.00
95% - tile	194.00

Selected range is from 0.00 to 282.00

NR - Not Reported

Source: U.S. EPA, 1998



Phosphate

ID	% P2O5	Cd	Pb	As	Cr	Hg	Ni	V	Cu	Zn
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
24837	53	1	2	7	NR			NR	3	
24836	53	69.5	2.5	12	NR			NR	2	
24355	53	140	1	14.5	NR			NR	58.5	
24728	53	130	1	13.5	NR			NR	100	
24278	53	150	NR	12.3	NR			NR	52	
23058	53	154	NR	17	NR			NR	51.5	
23189	53	250	NR	14.5	NR			NR	48	
22811	53	133	2	16	NR			NR	57	
22816	53	130	1	17	NR			NR	55	
22818	53	140	2	17	NR			NR	60	
21786	53	151	NR	8	NR			NR	27	
21741	53	140	NR	15.5	NR			NR	55	
26286	53	139	1	16	NR			NR	55	
25864	53	150	NR	9	NR			NR	11	
25731	53	135.5	NR	20.5	NR			NR	59	
25699	53	41	NR	3.5	NR			NR	3	
25167	53	140	1	19	NR			NR	55	
26736	53	162.5	NR	15.5	NR			NR	42.5	
20704	53	NR	1	5.5	NR			NR	2	
20968	53	149	NR	13	NR			NR	NR	
20969	53	145	NR	16.5	NR			NR	NR	
20970	53	150	NR	15	NR			NR	NR	
25108	45	NR	NR	0.5	NR			NR	6.5	
23226	45	120	4	14	NR	NR	132	NR	57	
H4770	45	119	10.5	15.5	516	0.003	151	721	40.2	1260
TSP #1	45	5	11.1	16.2	88.9	0.2	25.2	189	3.2	61.3
TSP #2	45	6.2	13.2	15.3	NR	0.2	15.6	154	3.5	NR
TSP #1	46			12.3	NR			162	NR	
TSP #5	46			13	NR			203	NR	
SP #2	21			7.5	NR			48.7	NR	
SP #4	21			13	NR			194	NR	
TSP-1	45	7.8	12	11.1	63	NR	15	NR	3.7	77
TSP-2	45	9.1	16	12.9	85	NR	19	NR	3.2	108
TSP-3	45	6.8	12	14.7	69	NR	17	NR	2.1	75
TSP-4	45	8.7	16	9.7	68	NR	16	NR	5.8	80
TSP-5	45	8.1	15	9.8	77	NR	19	NR	2.1	85
TSP-6	45	47	4.5	2.7	309	NR	16	NR	3.7	346
TSP-7	45	7.5	12	13.8	70	NR	16	NR	1.6	82
TSP-8	45	6.8	16	13.4	70	NR	18	NR	1.6	77
TSP-9	45	39	4.5	8.8	548	NR	40	NR	12	696
TSP-10	45	7.8	12	10.1	76	NR	17	NR	2.6	82
TSP-11	45	8.1	4.5	9.4	74	NR	16	NR	2.6	95
TSP-12	45	7.8	16	13.2	73	NR	17	NR	2.6	96
TSP-13	45	8.1	12	13.7	70	NR	14	NR	2.6	100
TSP-14	45	8.1	12	9.7	76	NR	14	NR	2.1	98
TSP-15	45	11	12	18.5	72	NR	16	NR	3.2	105
TSP-16	45	8.8	12	9.2	68	NR	14	NR	5.8	92
TSP-17	45	7.2	12	15.8	70	NR	18	NR	3.7	93
TSP-18	45	30	12	4.8	223	NR	17	NR	3.7	242
TSP-19	45	40	12	2.4	373	NR	15	NR	3.2	313
TSP-20	45	8.5	12	10.1	81	NR	17	NR	2.6	191
TSP-21	45	36	4.5	3.1	272	NR	18	NR	2.6	276
TSP-22	45	7.7	15	10	65	NR	16	NR	2.1	100
TSP-23	45	8.1	16	12.4	68	NR	16	NR	4.2	92
TSP-24	45	26	4.5	7.1	159	NR	15	NR	3.7	221
TSP	45	180	18			NR	135	NR	55	1550
25972	20	32	200	13	NR			NR	690	

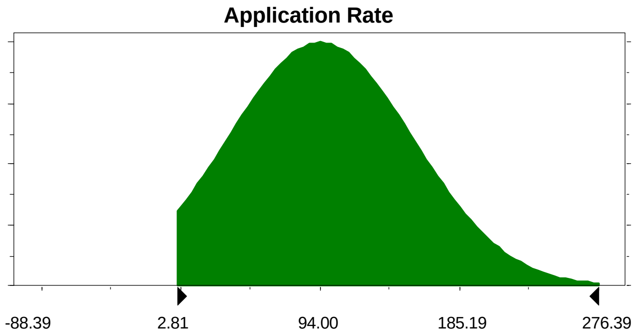
Phosphate

Assumption: Application Rate

Normal distribution with parameters:

Mean	94.00
95% - tile	194.00

Selected range is from 0.00 to 282.00



NR - Not Reported

Source: U.S. EPA, 1998

Potash

ID	% P2O5	Cd mg/kg	Pb mg/kg	As mg/kg	Cr mg/kg	Hg mg/kg	Ni mg/kg	V mg/kg	Cu mg/kg	Zn mg/kg
MP1	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	3
MP2	60	1.6	4.5	NR	NR	NR	3.5	NR	0.75	1.3
MP3	60	1.3	4.5	NR	NR	NR	1.4	NR	0.75	1.1
MP4	60	1.6	4.5	NR	NR	NR	3.5	NR	0.75	1.9
MP5	60	1.6	4.5	NR	NR	NR	2.8	NR	2.1	1.9
MP6	60	1.6	4.5	NR	NR	NR	2.8	NR	0.75	1.6
MP7	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	1.8
MP8	60	1.6	4.5	NR	NR	NR	2.8	NR	0.75	1.3
MP9	60	1.3	4.5	NR	NR	NR	4.4	NR	0.75	1.3
MP10	60	1.6	4.5	NR	NR	NR	2.8	NR	0.75	1.5
MP11	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	1.1
MP12	60	1.3	12	NR	NR	NR	1.4	NR	0.75	1.3
MP13	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	1.3
MP14	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	1.1
MP15	60	1.6	4.5	NR	NR	NR	3.5	NR	0.75	1.3
MP16	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	1.8
MP17	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	1.1
MP18	60	1.6	4.5	NR	NR	NR	2.8	NR	0.75	1.3
MP19	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	1.1
MP20	60	1.9	4.5	NR	NR	NR	1.4	NR	0.75	1.5
MP21	60	1.6	4.5	NR	NR	NR	1.4	NR	2.6	2.6
MP22	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	1
MP23	60	1.9	4.5	NR	NR	NR	1.4	NR	0.75	1.6
MP24	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	1.3
MP25	60	1.6	4.5	NR	NR	NR	1.4	NR	0.75	1.3
8813185	22.6	0.05	0.95	0.05	0.05	0.05	0.05	0.05	0.36	0.69
8813186	22.6	0.05	0.58	0.05	0.05	0.05	0.05	1.1	0.05	0.92
8813187	51.3	0.05	0.74	0.05	0.13	0.05	2.6	0.93	0.19	1.3
8813188	51.3	0.05	0.32	0.05	0.17	0.05	1	0.05	0.34	2.1
8813189	60	0.05	0.2	0.05	0.05	0.05	0.25	1.8	1.1	1.1
8813190	60	0.05	0.05	0.05	0.12	0.05	0.14	1.3	0.05	0.81
8813191	60	0.05	0.05	0.05	0.05	0.05	0.05	2	0.3	0.64
8813192	60	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.39
8813193	60	0.05	0.05	0.05	0.05	0.05	0.05	0.74	0.33	0.72
8813194	60	0.05	0.05	0.05	0.05	0.05	0.82	1.6	0.05	0.19
KCl1	60	0.1	0.2	0.2	0.52	0.2	0.1	0.3	3.5	4.59
KCl2	60	0.1	1	0.2	NR	0.2	0.1	0.1	1	NR
KMgSO4	22.6	0.1	1.4	0.3	2.75	0.2	0.5	0.7	5	8.75
KMgSO4	22.6	0.8	1.1	0.3	NR	0.2	0.3	9	1.4	NR
H4767	62	0.15	1	1.5	0.25	0.003	0.5	0.1	0.5	0.69
H4765	46	0.15	1	1.5	2.5	0.003	1.5	0.1	0.5	0.73
25029	51.3	0	1	0.2	NR	NR	NR	NR	5	NR
MP								NR	3.1	

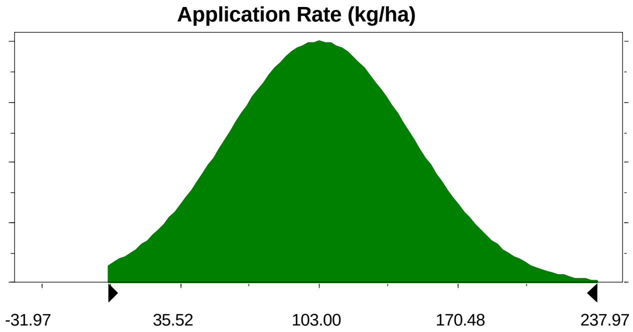
Potash

Assumption: Application Rate (kg/ha)

Normal distribution with parameters:

Mean	103.00
95% - tile	177.00

Selected range is from 0.00 to 534.00



NR - Not Reported

Source: U.S. EPA, 1998

Sulfur as Nutrient

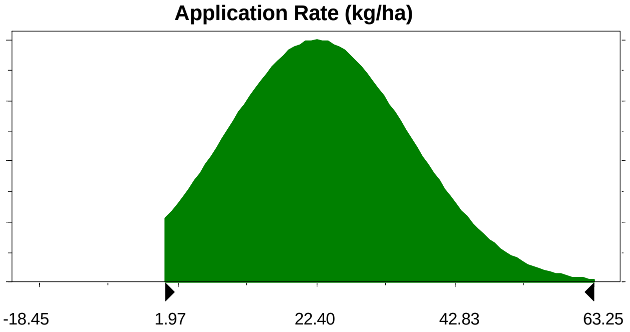
ID	% Sulfur	Cd mg/kg	Pb mg/kg	As mg/kg	Cr mg/kg	Hg mg/kg	Ni mg/kg	V mg/kg	Cu mg/kg	Zn mg/kg
H2547	26	0.03	0.2	0.3	0.05	0.01	0.1	0.055	0.04	0.21
H1231	40	0.03	0.2	0.3	0.05	0	0.1	0.046	0.094	42
H2532	14	145	4.4	4.2	214	0.024	195	396	16	1480
H4769	24	1.2	15	1.5	0.68	0.403	0.5	0.41	0.5	17
26310	100	0	0	0.1	NR	NR	NR	NR	2	
21259	100	0	8.7	2	8.7	NR	NR	NR	109	
21260	100	0	4	0.86	4	NR	NR	NR	61	
24884	100	0	0	17	0	NR	NR	NR	16	
24885	100	0	0	19	0	NR	NR	NR	14	

Assumption: Application Rate (kg/ha)

Normal distribution with parameters:

Mean	22.40
95% - tile	44.80

Selected range is from 0.00 to 67.20



NR - Not Reported

Source: U.S. EPA, 1998

Sulfur as pH Adjustment

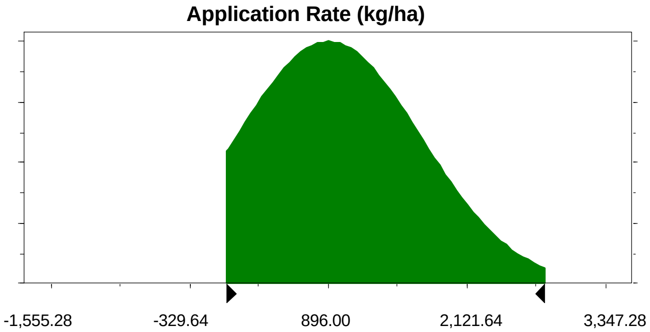
ID	% Sulfur	Cd mg/kg	Pb mg/kg	As mg/kg	Cr mg/kg	Hg mg/kg	Ni mg/kg	V mg/kg	Cu mg/kg	Zn mg/kg
26310	100	0	0	0.1	NR	NR	NR	NR	2	NR
21259	100	0	8.7	2	NR	NR	NR	NR	109	NR
21260	100	0	4	0.86	NR	NR	NR	NR	61	NR
24884	100	0	0	17	NR	NR	NR	NR	16	NR
24885	100	0	0	19	NR	NR	NR	NR	14	NR

Assumption: Application Rate (kg/ha)

Normal distribution with parameters:

Mean	896.00
95% - tile	2,240.00

Selected range is from 0.00 to 2,800.00



NR - Not Reported

Source: U.S. EPA, 1998

Zn Micronutrients

ID	% Zn	Cd	Pb	As	Cr	Hg	Ni	V	Cu	Zn
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
ZnSO4	34	2165	60			NR	92		1680	
ZnOS-1	35.1	590	44000			NR	158		672	
ZnOS-2	41.5	1970	400			NR	19		3	
ZnOBP-1	58.3	243	1900			NR	8950		2050	
ZnOBP-2	34	1420	52000			NR	250		0	
ZnOBP-3	27.7	76	2470			NR	24		0	
Zn-ZnOBP	89	500	11870			NR	10		734	
ZnFeBP1	9.2	4	50			NR	82			
ZnFePB2	13.3	26	1080			NR	60			
ZnSO4	35.5	61	90							
Zn20	20.4	75	158							
Zn27	27.3	43	178							
Zn40	39.9	28	293							
ZnOxS	37.7	43	1866							
ZnOS	17.5	435	23070							
KO61	15	359	19170							
H1906	18	275	11300	17	580	3.36	83	41		
GrZn	18	52	1400	17	97.8	NR	61.6	0.5		
1	26.75	NR	18700							
2	14.5	NR	20300							
3	28.35	NR	1300							
4	18.4	NR	1500							
5	18.9	NR	600							
6	13.8	NR	200							
7	29.2	NR	20700							
8	16.3	NR	10500							
9	16.5	NR	14000							
10	42.8	NR	2300							
11	32	NR	29400							
12	19	NR	15400							
13	21.3	NR	17500							
14	17.1	NR	13000							
15	38.1	NR	0							
16	17.5	NR	9300							
17	28.1	NR	23700							
18	38.2	NR	12500							
19	18.2	NR	6700							
20	16.1	NR	15500							
21	24.7	NR	15400							
22	35.3	NR	0							
23	36	NR	0							
24	16.9	NR	2400							
25	36	NR	0							
26	29.6	NR	700							
27	24.6	NR	1000							
28	22.4	NR	19000							
29	19.5	NR	21400							
30	24.5	NR	14800							
31	40.5	NR	16100							
32	22.5	NR	16500							
33	23.5	NR	19200							
34	19.5	NR	17200							
35	10.5	NR	30							
36	9.5	NR	1400							
37	32.7	NR	30							
38	41	NR	14800							
39	40.7	NR	3700							

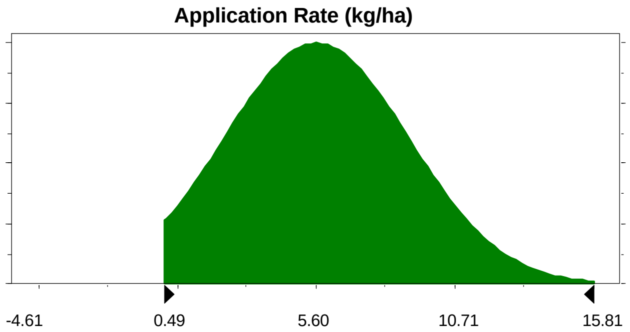
Zn Micronutrients

Assumption: Application Rate (kg/ha)

Normal distribution with parameters:

Mean	5.60
95% - tile	11.20

Selected range is from 0.00 to 22.40



NR - Not Reported

Source: U.S. EPA, 1998

Appendix K

Chemical-Specific Inputs

Table K-1. Chemical-Specific Inputs for Arsenic

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		0	a
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	b
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	c
Transfer Factors				
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables	variable	See Appendix G
		leafy vegetables	variable	See Appendix G
		forage/silage	variable	See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		0.002	Baes et al., 1984
Ba_{milk}	Biotransfer factor for milk (d/kg)		6E-05	Baes et al., 1984
Ba_{pork}	Biotransfer factor for pork (d/kg)		0.002	d
BCF	Fish bioconcentration factor (L/kg)		3.5	Stephan, 1993
BAF	Fish bioaccumulation factor (L/kg)		NA	
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.2	e
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		1.5	U.S. EPA, 1998
RfD	Reference dose (mg/kg/d)		0.0003	U.S. EPA, 1998
URF	Unit risk factor (per µg/m^3)		0.0043	U.S. EPA, 1998
RfC	Reference concentration (mg/m^3)		NA	

NA = Not applicable.

[a] Constituent is a nonvolatile metal; therefore, it is assumed to be 100 percent in the particulate phase and 0 percent in the vapor phase.

[b] Set equal to K_ds. For organics, the K_d values for soil and suspended sediments differ due to differing levels of organic carbon in soil versus suspended sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[c] Set equal to K_ds. For organics, the K_d values for soil and bottom sediments differ due to differing levels of organic carbon in soil versus bottom sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[d] The pork biotransfer factor was assumed to equal the biotransfer factor for beef because no biotransfer factor for pork was available for this chemical.

[e] Derived from data in Hoffman et al., 1992. Hoffman and colleagues (1992) present experimental values of what they term the "interception fraction," which corresponds in the methodology used here to the product of Rp and F_w. F_w values were estimated from the Hoffmann et al. values by dividing by an Rp of 0.47 for forage. The values used here apply to anions and correspond to moderate rainfall.

Table K-2. Chemical-Specific Inputs for Cadmium

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		0	a
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	b
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	c
Transfer Factors				
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables leafy vegetables forage/silage	variable variable variable	See Appendix G See Appendix G See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		0.0004	Lorber and Rice, 1995
Ba_{milk}	Biotransfer factor for milk (d/kg)		0.0001	Lorber and Rice, 1995
Ba_{pork}	Biotransfer factor for pork (d/kg)		6E-4	Lorber and Rice, 1995
BCF	Fish bioconcentration factor (L/kg)		187	RTI, 1995
BAF	Fish bioaccumulation factor (L/kg)		NA	
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	d
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		1E-3 soil 5E-4 water	U.S. EPA, 1998
URF	Unit risk factor (per µg/m^3)		0.0018	U.S. EPA, 1998
RfC	Reference concentration (mg/m^3)		NA	

NA = Not applicable.

[a] Constituent is a nonvolatile metal; therefore, it is assumed to be 100 percent in the particulate phase and 0 percent in the vapor phase.

[b] Set equal to K_ds. For organics, the K_d values for soil and suspended sediments differ due to differing levels of organic carbon in soil versus suspended sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[c] Set equal to K_ds. For organics, the K_d values for soil and bottom sediments differ due to differing levels of organic carbon in soil versus bottom sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[d] Derived from data in Hoffman et al., 1992. Hoffman and colleagues (1992) present experimental values of what they term the "interception fraction," which corresponds in the methodology used here to the product of Rp and F_w. F_w values were estimated from the Hoffmann et al. values by dividing by an Rp of 0.47 for forage. The values used here apply to anions and correspond to moderate rainfall.

Table K-3. Chemical-Specific Inputs for Chromium III

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		0	a
K_ss	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	b
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	c
Transfer Factors				
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables leafy vegetables forage/silage	variable variable variable	See Appendix G See Appendix G See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		5.5E-3	Baes et al., 1984
Ba_{milk}	Biotransfer factor for milk (d/kg)		0.0015	Baes et al., 1984
Ba_{pork}	Biotransfer factor for pork (d/kg)		5.5E-3	d
BCF	Fish bioconcentration factor (L/kg)		0.6	Stephan, 1993
BAF	Fish bioaccumulation factor (L/kg)		NA	
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	e
Health Benchmarks				
CSF	Cancer slope $_{\text{factor}}$ (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		1	U.S. EPA, 1998
URF	Unit risk factor (per µg/m^3)		NA	
RfC	Reference concentration (mg/m^3)		NA	

NA = Not applicable.

[a] Constituent is a nonvolatile metal; therefore, it is assumed to be 100 percent in the particulate phase and 0 percent in the vapor phase.

[b] Set equal to K_ds. For organics, the K_d values for soil and suspended sediments differ due to differing levels of organic carbon in soil versus suspended sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[c] Set equal to K_ds. For organics, the K_d values for soil and bottom sediments differ due to differing levels of organic carbon in soil versus bottom sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[d] The pork biotransfer factor was assumed to equal the biotransfer factor for beef because no biotransfer factor for pork was available for this chemical.

[e] Derived from data in Hoffman et al., 1992. Hoffman and colleagues (1992) present experimental values of what they term the "interception fraction," which corresponds in the methodology used here to the product of Rp and F_w. F_w values were estimated from the Hoffmann et al. values by dividing by an Rp of 0.47 for forage. The values used here apply to anions and correspond to moderate rainfall.

Table K-4. Chemical-Specific Inputs for Chromium VI

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		0	a
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	b
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	c
Transfer Factors				
B_r	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables	variable	See Appendix G
		leafy vegetables	variable	See Appendix G
		forage/silage	variable	See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		0.0055	Baes et al., 1984
Ba_{milk}	Biotransfer factor for milk (d/kg)		0.0015	Baes et al., 1984
Ba_{pork}	Biotransfer factor for pork (d/kg)		0.0055	d
BCF	Fish bioconcentration factor (L/kg)		0.6	Stephan, 1993
BAF	Fish bioaccumulation factor (L/kg)		NA	
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	e
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		0.005	U.S. EPA, 1998
URF	Unit risk factor (per µg/m^3)		0.012	U.S. EPA, 1998
RfC	Reference concentration (mg/m^3)		NA	

NA = Not applicable.

[a] Constituent is a nonvolatile metal; therefore, it is assumed to be 100 percent in the particulate phase and 0 percent in the vapor phase.

[b] Set equal to K_ds. For organics, the K_d values for soil and suspended sediments differ due to differing levels of organic carbon in soil versus suspended sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[c] Set equal to K_ds. For organics, the K_d values for soil and bottom sediments differ due to differing levels of organic carbon in soil versus bottom sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[d] The pork biotransfer factor was assumed to equal the biotransfer factor for beef because no biotransfer factor for pork was available for this chemical.

[e] Derived from data in Hoffman et al., 1992. Hoffman and colleagues (1992) present experimental values of what they term the "interception fraction," which corresponds in the methodology used here to the product of Rp and F_w. F_w values were estimated from the Hoffmann et al. values by dividing by an Rp of 0.47 for forage. The values used here apply to anions and correspond to moderate rainfall.

Table K-5. Chemical-Specific Inputs for Copper

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		0	a
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	b
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	c
Transfer Factors				
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables	variable	See Appendix G
		leafy vegetables	variable	See Appendix G
		forage/silage	variable	See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		1.0E-2	Baes et al., 1984
Ba_{milk}	Biotransfer factor for milk (d/kg)		1.5E-3	Baes et al., 1984
Ba_{pork}	Biotransfer factor for pork (d/kg)		1.0E-2	d
BCF	Fish bioconcentration factor (L/kg)		0	Stephan, 1993
BAF	Fish bioaccumulation factor (L/kg)		NA	
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	e
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		NA	
URF	Unit risk factor (per µg/m^3)		NA	
RfC	Reference concentration (mg/m^3)		NA	

NA = Not applicable.

[a] Constituent is a nonvolatile metal; therefore, it is assumed to be 100 percent in the particulate phase and 0 percent in the vapor phase.

[b] Set equal to K_ds. For organics, the K_d values for soil and suspended sediments differ due to differing levels of organic carbon in soil versus suspended sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[c] Set equal to K_ds. For organics, the K_d values for soil and bottom sediments differ due to differing levels of organic carbon in soil versus bottom sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[d] The pork biotransfer factor was assumed to equal the biotransfer factor for beef because no biotransfer factor for pork was available for this chemical.

[e] Derived from data in Hoffman et al., 1992. Hoffman and colleagues (1992) present experimental values of what they term the "interception fraction," which corresponds in the methodology used here to the product of Rp and F_w. F_w values were estimated from the Hoffmann et al. values by dividing by an Rp of 0.47 for forage. The values used here apply to anions and correspond to moderate rainfall.

Table K-6. Chemical-Specific Inputs for Lead

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		0	a
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	b
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	c
Transfer Factors				
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables	variable	See Appendix G
		leafy vegetables	variable	See Appendix G
		forage/silage	variable	See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		3E-4	Baes et al., 1984
Ba_{milk}	Biotransfer factor for milk (d/kg)		2.5E-4	Baes et al., 1984
Ba_{pork}	Biotransfer factor for pork (d/kg)		3e-4	d
BCF	Fish bioconcentration factor (L/kg)		NA	
BAF	Fish bioaccumulation factor (L/kg)		46	Stephan, 1993
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	e
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		NA	
URF	Unit risk factor (per µg/m^3)		NA	
RfC	Reference concentration (mg/m^3)		NA	

NA = Not applicable.

[a] Constituent is a nonvolatile metal; therefore, it is assumed to be 100 percent in the particulate phase and 0 percent in the vapor phase.

[b] Set equal to K_ds. For organics, the K_d values for soil and suspended sediments differ due to differing levels of organic carbon in soil versus suspended sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[c] Set equal to K_ds. For organics, the K_d values for soil and bottom sediments differ due to differing levels of organic carbon in soil versus bottom sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[d] The pork biotransfer factor was assumed to equal the biotransfer factor for beef because no biotransfer factor for pork was available for this chemical.

[e] Derived from data in Hoffman et al., 1992. Hoffman and colleagues (1992) present experimental values of what they term the "interception fraction," which corresponds in the methodology used here to the product of Rp and F_w. F_w values were estimated from the Hoffmann et al. values by dividing by an Rp of 0.47 for forage. The values used here apply to anions and correspond to moderate rainfall.

Table K-7. Chemical-Specific Inputs for Mercury—Divalent

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		site-specific	
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	See Appendix D
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	See Appendix D
H	Henry's law constant (atm-m^3/mol)		7.1E-10	U.S. EPA, 1997c
D_a	Diffusivity in air (cm^2/s)		5.5E-2	U.S. EPA, 1997c
D_w	Diffusivity in water (cm^2/s)		8.0E-6	U.S. EPA, 1988
Transfer Factors				
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue]/[µg pollutant/g air])	leafy vegetables forage/silage	2.1E+4 1.8E+4	U.S. EPA, 1997c
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables leafy vegetables forage/silage	variable variable variable	See Appendix G See Appendix G See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		2.0E-2	U.S. EPA, 1997c
Ba_{milk}	Biotransfer factor for milk (d/kg)		2.0E-2	U.S. EPA, 1997c
Ba_{pork}	Biotransfer factor for pork (d/kg)		1.3E-4	U.S. EPA, 1997c
BCF	Fish bioconcentration factor (L/kg)		NA	
BAF	Fish bioaccumulation factor (L/kg)		NA	
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	U.S. EPA, 1997c
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		3.0E-4	U.S. EPA, 1998
URF	Unit risk factor (per µg/m^3)		NA	
RfC	Reference concentration (mg/m^3)		NA	

NA = Not applicable.

Table K-8. Chemical-Specific Inputs for Mercury—Elemental

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		1	U.S. EPA, 1997c
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	See Appendix D
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	See Appendix D
H	Henry's law constant (atm-m^3/mol)		7.1E-3	U.S. EPA, 1997c
D_a	Diffusivity in air (cm^2/s)		5.5E-2	U.S. EPA, 1997c
D_w	Diffusivity in water (cm^2/s)		8.0E-6	U.S. EPA, 1988
Transfer Factors				
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue]/[µg pollutant/g air])	leafy vegetables forage/silage	0	U.S. EPA, 1997c
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables leafy vegetables forage/silage	variable	See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		2.0E-2	U.S. EPA, 1997c
Ba_{milk}	Biotransfer factor for milk (d/kg)		2.0E-2	U.S. EPA, 1997c
Ba_{pork}	Biotransfer factor for pork (d/kg)		1.3E-4	U.S. EPA, 1997c
BCF	Fish bioconcentration factor (L/kg)		NA	
BAF	Fish bioaccumulation factor (L/kg)		NA	
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	U.S. EPA, 1997c
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		NA	
URF	Unit risk factor (per µg/m^3)		NA	
RfC	Reference concentration (mg/m^3)		3E-4	U.S. EPA, 1998

NA = Not applicable.

Table K-9. Chemical-Specific Inputs for Methylmercury

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		NA	
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	See Appendix D
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	See Appendix D
H	Henry's law constant (atm-m^3/mol)		4.7E-7	U.S. EPA, 1997c
D_a	Diffusivity in air (cm^2/s)		5.3E-2	U.S. EPA, 1997c
D_w	Diffusivity in water (cm^2/s)		8.0E-6	U.S. EPA, 1988
Transfer Factors				
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue]/[µg pollutant/g air])	leafy vegetables forage/silage	2.4E+3 5.0E+3	U.S. EPA, 1997c U.S. EPA, 1997c
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables leafy vegetables forage/silage	variable variable variable	See Appendix G See Appendix G See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		2.0E-2	U.S. EPA, 1997c
Ba_{milk}	Biotransfer factor for milk (d/kg)		2.0E-2	U.S. EPA, 1997c
Ba_{pork}	Biotransfer factor for pork (d/kg)		1.3E-4	U.S. EPA, 1997c
BAF	Fish bioaccumulation factor - Trophic Level 3 (L/kg)		1.6E+6	U.S. EPA, 1997c
BAF	Fish bioaccumulation factor - Trophic Level 4 (L/kg)		6.8E+6	U.S. EPA, 1997c
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	a
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		1.0E-4	U.S. EPA, 1998
URF	Unit risk factor (per µg/m^3)		NA	
RfC	Reference concentration (mg/m^3)		NA	

NA = Not applicable.

[a] Derived from data in Hoffman et al., 1992. Hoffman and colleagues (1992) present experimental values of what they term the "interception fraction," which corresponds in the methodology used here to the product of Rp and F_w. F_w values were estimated from the Hoffmann et al. values by dividing by an Rp of 0.47 for forage. The values used here apply to anions and correspond to moderate rainfall.

Table K-10. Chemical-Specific Inputs for Nickel

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		0	a
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	b
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	c
Transfer Factors				
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables	variable	See Appendix G
		leafy vegetables	variable	See Appendix G
		forage/silage	variable	See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		0.006	Baes et al., 1984
Ba_{milk}	Biotransfer factor for milk (d/kg)		0.001	Baes et al., 1984
Ba_{pork}	Biotransfer factor for pork (d/kg)		0.006	d
BCF	Fish bioconcentration factor (L/kg)		0.8	Stephan, 1993
BAF	Fish bioaccumulation factor (L/kg)		NA	
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	e
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		0.02	U.S. EPA, 1998
URF	Unit risk factor (per µg/m^3)		2.4E-4	U.S. EPA, 1998
RfC	Reference concentration (mg/m^3)		NA	

NA = Not applicable.

[a] Constituent is a nonvolatile metal; therefore, it is assumed to be 100 percent in the particulate phase and 0 percent in the vapor phase.

[b] Set equal to K_ds. For organics, the K_d values for soil and suspended sediments differ due to differing levels of organic carbon in soil versus suspended sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[c] Set equal to K_ds. For organics, the K_d values for soil and bottom sediments differ due to differing levels of organic carbon in soil versus bottom sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[d] The pork biotransfer factor was assumed to equal the biotransfer factor for beef because no biotransfer factor for pork was available for this chemical.

[e] Derived from data in Hoffman et al., 1992. Hoffman and colleagues (1992) present experimental values of what they term the "interception fraction," which corresponds in the methodology used here to the product of Rp and F_w. F_w values were estimated from the Hoffmann et al. values by dividing by an Rp of 0.47 for forage. The values used here apply to anions and correspond to moderate rainfall.

Table K-11. Chemical-Specific Inputs for Vanadium

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		0	a
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	b
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	c
MW	Molecular weight (g/mol)		50.94	SCDM
Transfer Factors				
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables leafy vegetables forage/silage	variable variable variable	See Appendix G See Appendix G See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		0.0025	Baes et al., 1984
Ba_{milk}	Biotransfer factor for milk (d/kg)		0.002	Baes et al., 1984
BCF	Fish bioconcentration factor (L/kg)		NA	
BAF	Fish bioaccumulation factor (L/kg)		NA	
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	U.S. EPA, 1997a
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		0.007	U.S. EPA, 1997b
URF	Unit risk factor (per µg/m^3)		NA	
RfC	Reference concentration (mg/m^3)		NA	

NA = Not applicable.

[a] Constituent is a nonvolatile metal; therefore, it is assumed to be 100 percent in the particulate phase and 0 percent in the vapor phase.

[b] Set equal to K_ds. For organics, the K_d values for soil and suspended sediments differ due to differing levels of organic carbon in soil versus suspended sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[c] Set equal to K_ds. For organics, the K_d values for soil and bottom sediments differ due to differing levels of organic carbon in soil versus bottom sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

Table K-12. Chemical-Specific Inputs for Zinc

Parameter	Definition		Value	Reference
Chemical/Physical Properties				
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)		0	a
K_ds	Soil-water partition coefficient (mL/g or L/kg)		variable	See Appendix D
$K_{d,sw}$	Suspended sediment-surface water partition coefficient (L/kg)		variable	b
$K_{d,bs}$	Bottom sediment-sediment pore water partition coefficient (L/kg)		variable	c
MW	Molecular weight (g/mol)		65.38	SCDM
Transfer Factors				
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	root vegetables leafy vegetables forage/silage	variable variable variable	See Appendix G See Appendix G See Appendix G
Ba_{beef}	Biotransfer factor for beef (d/kg)		1.2E-4	Baes et al., 1984
Ba_{milk}	Biotransfer factor for milk (d/kg)		3.0E-5	Baes et al., 1984
BCF	Fish bioconcentration factor (L/kg)		4.4	Stephen, 1993
BAF	Fish bioaccumulation factor (L/kg)		NA	
Other Parameters				
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)		0.6	U.S. EPA, 1997a
Health Benchmarks				
CSF	Cancer slope factor (per mg/kg/d)		NA	
RfD	Reference dose (mg/kg/d)		0.3	U.S. EPA, 1998
URF	Unit risk factor (per µg/m^3)		NA	
RfC	Reference concentration (mg/m^3)		9.0E-4	CalEPA, 1997

NA = Not applicable.

[a] Constituent is a nonvolatile metal; therefore, it is assumed to be 100 percent in the particulate phase and 0 percent in the vapor phase.

[b] Set equal to K_ds. For organics, the K_d values for soil and suspended sediments differ due to differing levels of organic carbon in soil versus suspended sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

[c] Set equal to K_ds. For organics, the K_d values for soil and bottom sediments differ due to differing levels of organic carbon in soil versus bottom sediments. Metals, however, are not thought to be affected by organic carbon; therefore, the K_d values are the same.

Table K-13. Chemical-Specific Inputs for 2,3,7,8-TCDD

Parameter	Definition	Value	Ref
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	5.5E-1	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	2.7E+6	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	4.4E+6	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	9.7E-13	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	1.9E-5	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	322	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	1.6E-5	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.7E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	6.1E+4	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	3.9E+3	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	5.6E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	5.4E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.0E-2	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	1.11	d
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	1.27	d
BAF_{worms}	Bioconcentration factor for TCDD-TEQ in worms (unitless)	9.1	Sample et al., 1998a
$BAF_{invertebrates}$	Bioaccumulation factor for TCDD-TEQ in invertebrates (unitless)	1.3	Sample et al., 1998b
$BAF_{vertebrates}$	Bioaccumulation factor for TCDD-TEQ in vertebrates (unitless)	7.2	Sample et al., 1997
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.76	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
CSF	Cancer slope factor (per mg/kg/d)	156,000	U.S. EPA, 1994a

Table K-13. (continued)

Parameter	Definition	Value	Ref
RfD	Reference dose (mg/kg/d)	NA	

(continued)

Parameter	Definition	Value	Ref
URF	Unit risk factor (per µg/m^3)	3.3E-8	U.S. EPA, 1998
RfC	Reference concentration (mg/m^3)	NA	
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	1	e
TEF_B	Toxicity equivalency factor for birds	1	e

NA = Not applicable.

[a] Calculated from an equation in Travis and Arms, 1988.
[b] Pork biotransfer factor set equal to beef biotransfer factor.
[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).
[d] No BCFs for these chemicals are presented due to the low concentration of these isomers. Values for these chemicals are taken from the most structurally similar isomer listed in Stephens et al. (1992).
[e] Van den Berg et al., 1998.

Table K-14. Chemical-Specific Inputs for 2,3,7,8-TCDF

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	7.1E-1	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	2.1E+6	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	3.4E+6	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	1.2E-11	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	4.2E-4	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	306	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	8.6E-6	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm2/s)	4.8E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	8.1E+4	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	3.2E+3	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	6.5E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	1.6E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	3.0E-3	Lorber and Rice, 1993
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.92	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	0.46	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.23	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.1	d
TEF_B	Toxicity equivalency factor for birds	1	d

NA = Not applicable.

[a] Calculated from an equation in Travis and Arms, 1988.
[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-15. Chemical-Specific Inputs for 1,2,3,7,8-PeCDD

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	2.6E-1	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	2.7E+6	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	4.4E+6	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	1.2E-12	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	1.2E-4	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	356.4	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	2.6E-6	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.5E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.2E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	3.9E+3	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	5.6E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	5.4E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	1E-2	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	1.11	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	1.27	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.57	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	1.0	d
TEF_B	Toxicity equivalency factor for birds	1.0	d

NA = Not applicable.

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-16. Chemical-Specific Inputs for 1,2,3,7,8-PeCDF

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	4.2E-1	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	3.8E+6	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	6.2E+6	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	3.6E-12	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	2.4E-4	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	340.4	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	6.2E-6	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.6E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	4.6E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	5.1E+3	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	4.6E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	1.1E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	2.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	1.20	d
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	2.50	d
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.26	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.05	e
TEF_B	Toxicity equivalency factor for birds	0.1	e

[a] Calculated from an equation in Travis and Arms, 1988.
[b] Pork biotransfer factor set equal to beef biotransfer factor.
[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).
[d] No BCFs for these chemicals are presented due to the low concentration of these isomers. Values for these chemicals are taken from the most structurally similar isomer listed in Stephens et al. (1992).
[e] Van den Berg et al., 1998.

Table K-17. Chemical-Specific Inputs for 2,3,4,7,8-PeCDF

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	3.0E-1	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	5.1E+6	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	8.3E+6	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	4.3E-12	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	2.4E-4	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	340.4	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	6.2E-6	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.6E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	4.6E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	6.4E+3	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	3.9E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	4.9E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	9.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	1.20	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	2.50	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.39	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.5	d
TEF_B	Toxicity equivalency factor for birds	1.0	d

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-18. Chemical-Specific Inputs for 1,2,3,4,7,8-HxCDD

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	7E-2	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	3.8E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	6.2E+7	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	1.3E-13	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	4.4E-6	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	390.9	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	1.2E-5	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.3E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	4.5E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	3.0E+4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	1.2E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	3.2E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	6.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.85	U.S. EPA, 1994a, b
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	1.46	U.S. EPA, 1994a, b
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.16	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.1	d
TEF_B	Toxicity equivalency factor for birds	0.05	d

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-19. Chemical-Specific Inputs for 1,2,3,6,7,8-HxCDD

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	4.0E-2	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	1.2E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	2.0E+7	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	4.7E-14	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	4.4E-6	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	390.9	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	1.2E-5	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.3E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	4.5E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.3E+4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.3E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	2.7E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	5.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.99	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	1.62	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.17	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.1	d
TEF_B	Toxicity equivalency factor for birds	0.01	d

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-20. Chemical-Specific Inputs for 1,2,3,7,8,9-HxCDD

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	2E-2	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	1.2E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	2.0E+7	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	6.4E-14	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	4.4E-6	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	390.9	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	1.2E-5	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.3E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	4.5E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.3E+4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.3E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	3E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	6E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.50	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	1.05	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.045	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.1	d
TEF_B	Toxicity equivalency factor for birds	0.1	d

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-21. Chemical-Specific Inputs for 1,2,3,4,7,8-HxCDF

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	6.0E-2	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	1.2E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	2.0E+7	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	3.2E-13	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	8.3E-6	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	374.9	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	1.4E-5	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.4E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.5E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.3E+4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.3E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	3.8E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	7.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.86	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	1.89	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.056	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.1	d
TEF_B	Toxicity equivalency factor for birds	0.1	d

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-22. Chemical-Specific Inputs for 1,2,3,6,7,8-HxCDF

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	6.0E-2	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	1.2E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	2.0E+7	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	2.9E-13	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	1.8E-5	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	374.9	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	6.1E-6	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.4E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.5E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.3E+4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.3E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	3.2E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	6.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.73	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	1.68	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.093	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.1	d
TEF_B	Toxicity equivalency factor for birds	0.1	d

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-23. Chemical-Specific Inputs for 1,2,3,7,8,9-HxCDF

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	1.1E-1	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	1.2E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	2.0E+7	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	3.7E-13	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	1.3E-5	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	374.9	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	1.0E-5	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.4E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.5E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.3E+4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.3E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	3.2E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	6.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.73	d
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	1.68	d
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.15	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.1	e
TEF_B	Toxicity equivalency factor for birds	0.1	e

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] No BCFs for these chemicals are presented due to the low concentration of these isomers. Values for these chemicals are taken from the most structurally similar isomer listed in Stephens et al. (1992).

[e] Van den Berg et al., 1998.

Table K-24. Chemical-Specific Inputs for 2,3,4,6,7,8-HxCDF

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	7.0E-2	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	1.2E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	2.0E+7	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	2.6E-13	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	1.3E-5	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	374.9	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	1.0E-5	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.4E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.5E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.3E4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	2.3E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	2.7E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	5.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.39	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	0.54	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.18	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.1	d
TEF_B	Toxicity equivalency factor for birds	0.1	d

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-25. Chemical-Specific Inputs for 1,2,3,4,6,7,8-HpCDD

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	2E-2	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	9.8E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	1.6E+8	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	4.2E-14	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	2.4E-6	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	425.3	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	7.5E-6	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.1E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	3.5E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	6.2E+4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	7.1E-4	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	5.4E-3	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	1E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.22	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	0.98	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.033	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.01	d
TEF_B	Toxicity equivalency factor for birds	0.001	d

[a] Calculated from an equation in Travis and Arms, 1988.
[b] Pork biotransfer factor set equal to beef biotransfer factor.
[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).
[d] Van den Berg et al., 1998.

Table K-26. Chemical-Specific Inputs for 1,2,3,4,6,7,8-HpCDF

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	4.0E-2	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	4.9E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	7.9E+7	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	1.8E-13	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	1.4E-6	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	409.3	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	5.3E-5	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.2E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	4.4E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	3.7E+4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	1.1E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	5.4E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.18	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	0.68	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.011	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.01	d
TEF_B	Toxicity equivalency factor for birds	0.01	d

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-27. Chemical-Specific Inputs for 1,2,3,4,7,8,9-HpCDF

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	3.0E-2	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	4.9E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	7.9E+7	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	1.4E-13	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	1.4E-6	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	409.3	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	5.3E-5	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.2E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	4.4E+5	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	3.7E+4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	1.1E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	1.6E-2	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	3.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.16	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	0.49	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.027	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.01	d
TEF_B	Toxicity equivalency factor for birds	0.01	d

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

Table K-28. Chemical-Specific Inputs for 1,2,3,4,5,7,8,9-OCDD

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	2.0E-4	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	2.4E+7	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	3.9E+7	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	1.1E-15	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	7.4E-8	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	460.8	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	7.0E-9	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	3.9E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	8.6E+6	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	2.1E+4	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	1.6E-3	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	5.4E-3	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	1.0E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.04	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	0.47	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.034	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.0001	d
TEF_B	Toxicity equivalency factor for birds	0.0001	e

[a] Calculated from an equation in Travis and Arms, 1988.
[b] Pork biotransfer factor set equal to beef biotransfer factor.
[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).
[d] Van den Berg et al., 1998.
[e] Defaults to mammalian value due to lack of bird data.

Table K-29. Chemical-Specific Inputs for 1,2,3,4,6,7,8,9-OCDF

Parameter	Definition	Value	Reference
Chemical/Physical Properties			
F_v	Fraction of pollutant air concentration present in the vapor phase (dimensionless)	2E-3	U.S. EPA, 1994a, b
K_{oc}	Soil adsorption coefficient (mL/g)	3.9E+8	U.S. EPA, 1994a, b
K_{ow}	Octanol-water partition coefficient (unitless)	6.3E+8	U.S. EPA, 1994a, b
VP	Vapor pressure (atm)	4.9E-15	U.S. EPA, 1994a, b
S	Water solubility (mL/g)	1.2E-6	U.S. EPA, 1994a, b
MW	Molecular weight (g/mol)	444.8	U.S. EPA, 1994a, b
H	Henry's law constant (atm-m^3/mol)	1.9E-6	U.S. EPA, 1994a, b
D_a	Diffusivity in air (cm^2/s)	4.0E-2	U.S. EPA, 1994a, b
D_w	Diffusivity in water (cm^2/s)	8.0E-6	U.S. EPA, 1994c
Transfer Factors			
Bv	Air-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g air])	1.3E+6	Lorber, 1995
RCF	Root concentration factor ([µg pollutant/g plant tissue FW]/[µg pollutant/g soil water])	1.8E+5	U.S. EPA, 1994a, b
Br	Soil-to-plant biotransfer factor ([µg pollutant/g plant tissue DW]/[µg pollutant/g soil])	3.2E-4	a
Ba_{beef}/Ba_{pork}	Biotransfer factor for beef or pork (d/kg)[b]	5.4E-3	c
Ba_{milk}	Biotransfer factor for milk (d/kg)	1E-3	Lorber and Rice, 1995
BCF_{chick}	Bioconcentration factor for TCDD-TEQ in poultry (unitless)	0.07	Stephens et al., 1992
BCF_{eggs}	Bioconcentration factor for TCDD-TEQ in eggs (unitless)	0.30	Stephens et al., 1992
BSAF	Fish biota-to-sediment accumulation factor (unitless)	0.0033	Bauer, 1992
Other Parameters			
F_w	Fraction of wet deposition that adheres to plant surfaces (dimensionless)	6.0E-1	Lorber and Rice, 1995
Health Benchmarks			
$TEF_{H,M}$	Toxicity equivalency factor for humans and mammals	0.0001	d
TEF_B	Toxicity equivalency factor for birds	0.0001	d

[a] Calculated from an equation in Travis and Arms, 1988.

[b] Pork biotransfer factor set equal to beef biotransfer factor.

[c] The Ba_{beef} for dioxin congeners was calculated from the Ba_{milk} and the ratio of the percentage of beef fat to the percentage of milk fat. Therefore, the biotransfer factor for beef is 5.4 times higher than for milk. The Ba_{pork} was assumed to be the same as the Ba_{beef} (Lorber and Rice, 1995).

[d] Van den Berg et al., 1998.

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