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DERIVATION OF A SITE-SPECIFIC SOIL CRITERION FOR DIOXINS AND FURANS IN MIDLAND MICHIGAN

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Introduction

Surface soils in Midland, Michigan have been analyzed for polychlorinated dibenzodioxins and furans (PCDD/Fs). Concentrations range from not detectable to 0.45 parts per billion TEQ (ppb, or micrograms per kilogram [µg/kg]). This study was initiated to identify a concentration of PCDD/Fs in soils that would not pose an unacceptable health risk to residents (i.e., a site-specific soil criterion).

A stochastic analysis using probability density functions for various site-specific exposure parameters was used. In addition, the results of a site-specific *in vitro* study of bioaccessibility of PCDD/Fs in local soils were incorporated into the analysis. This analysis is consistent with regulatory risk assessment guidance issued by U.S. EPA and the Michigan Department of Environmental Quality.[1,2,3,4,5,6,7,8,9,10]

Methods and Materials

Toxicity Criteria

The MDEQ slope factor is based on the Pathology Working Group's re-evaluation of the animal liver tumor data,[11,12] and a revised body-weight scaling factor to extrapolate the dose in animals to humans.[13] The World Health Organization's latest toxicity equivalency factors (TEFs) were also used in this assessment.[14]

Exposure Assessment

Potentially exposed populations were identified based on current land use in the affected areas and included industrial and commercial workers, recreators, school students, and residents. In practice, the residential scenario is generally considered to yield the lowest, most health-protective soil criterion; therefore, the residential exposure scenario was used in this analysis to derive the soil criterion. Potential exposures to both children and adults were evaluated. The routes of potential exposure to soil are incidental soil ingestion and dermal contact. The migration of surface soil particles to ambient air, and subsequent inhalation exposure, was not evaluated, because this pathway was unlikely to contribute more than 1% to the total dose when compared to the direct-contact pathways.[15] Consumption of homegrown vegetables was not addressed, because PCDD/Fs are not significantly translocated into plant material by the root system.[7] Finally, because there are no beef, dairy, or poultry farms in or near the affected areas; exposure via ingestion of meat and dairy products was not evaluated.

Exposure Parameters: Probability Density Functions (PDFs) and Point Estimates

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PDFs were used for body weight, exposure duration, soil ingestion rate for children, total skin surface area, and soil-to-skin adherence factor. All remaining exposure parameters (adult soil ingestion rate, percent skin surface area exposed, oral and dermal bioavailability, and averaging time) were input as single values (point estimates), because there are insufficient data available to describe the distribution of inherent variability. All PDFs and point estimates used in this analysis are presented in Table 1 (following references).

Derivation of Soil Criteria Distributions

A quantitative stochastic analysis was performed using Latin Hypercube (LHC) statistics. A commercially available software program, Crystal Ball™,[16,17] was used to simulate a full distribution frequency for each parameter. A total of 5,000 iterations were performed to ensure that a "point of convergence" was reached (i.e., a point at which additional iterations would not significantly alter the results).[18,19,20] Per MDEQ guidance, an acceptable increased cancer risk of 10^{-5} was used. The output was a distribution of site-specific soil criteria and associated probabilities.

Results and Discussion

The calculated 50th and 5th percentile soil criteria are 4.1 and 1.48 ppb, respectively. Most EPA assessments are designed to be protective at the 95th percentile of exposure, which in this assessment, would correspond to the 5th percentile soil criterion.[5] Thus, the soil criterion identified for Midland, Michigan is 1.48 μg/kg (ppb) TCDD TEQ.

Neither the U.S. EPA nor state environmental regulators/toxicologists have set non-cancer toxicity criteria (e.g., reference doses [RfDs]) for PCDD/Fs, because cancer is generally considered to be the more sensitive endpoint (e.g., the effect that occurs at the lowest dose level). However, a TCDD RfD has been proposed recently in the peer-reviewed scientific literature.[21] These researchers performed a detailed review of the non-cancer health effects literature and used standard EPA methods to develop an RfD for TCDD of 5 pg/kg-day. This value is 25 times higher than the dose associated with the site-specific criterion for Midland soils (0.2 pg/kg-day based on a soil criterion of 1.48 μg/kg). Hence, the site-specific standard of 1.48 μg/kg is protective of cancer and any non-cancer health effects associated with PCDD/F exposure in Midland.

Comparison of the site-specific soil criterion to measured concentrations from affected areas indicates that no sample exceeds the site-specific criterion of 1.48 μg/kg. Therefore, it can be concluded that PCDD/Fs in Midland soils do not pose a significant health risk to the community.

References

1. U.S. EPA. 1989a. Risk assessment guidance for Superfund Volume I, Human health evaluation manual (Part A). U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. Washington, DC. December. EPA/540/1-89/002.
2. U.S. EPA. 1989b. Risk assessment guidance for Superfund. Human health risk assessment. U.S. Environmental Protection Agency, Region IX recommendations. December.
3. U.S. EPA. 1997a. Guiding principles for Monte Carlo analysis. Risk assessment forum. U.S. Environmental Protection Agency, Washington, DC. EPA/630/R-97/001.
4. U.S. EPA. 1997b. Memorandum from Deputy Administrator Fred Hansen on the Use of Probabilistic Techniques (including Monte Carlo Analysis) in Risk Assessment, and Guiding 40 Principles for Monte Carlo Analysis. Office of Research and Development, Washington, DC. 41 EPA/630/R-97/001. May. 42
5. U.S. EPA. 1999a. Risk assessment guidance for Superfund: Volume 3 – (Part A, Process for

conducting probabilistic risk assessment). U.S. Environmental Protection Agency, Solid Waste and Emergency and Remedial Response. December.

6. U.S. EPA. 1997. Exposure factors handbook (EFH). U.S. Environmental Protection Agency, Office of Research and Development. Washington, DC. February. EPA/600/P-95/000Fa-c.

7. U.S. EPA. 2000a. Draft exposure and human health risk assessment of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and related compounds, Parts I, II, and III. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Exposure Assessment and Risk Characterization Group, Washington, DC. September. EPA/600/P-00/001Bg.

8. U.S. EPA. 2000b. Child-specific exposure factors handbook. U.S. Environmental Protection Agency, National Center for Environmental Assessment. June. NCEA-W-0853.

9. MDEQ. 2001a. Part 201 generic soil direct contact criteria technical support document. Environmental Response Division Operational Memorandum #18, Attachment B, Toxicological and Chemical-Physical Data for Part 201 Cleanup Criteria. September 21.

10. MDEQ. 2001b. Part 201 generic soil direct contact criteria technical support document. Michigan Department of Environmental Quality, Environmental Response Division. January 5.

11. Pathology Working Group (PWG). 1990a. Pathology Working Group report on 2,3,7,8-tetrachlorodibenzo-p-dioxin chronic toxicity/carcinogenicity study in Sprague Dawley rats. Prepared by R.M. Saure, PWG Chairperson, PATHCO, Inc. and submitted to R.A. Michaels, Chairperson, Maine Scientific Advisory Panel. March 13

12. Pathology Working Group (PWG). 1990b. Hepatotoxicity in female Sprague Dawley rats treated with 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Prepared by R.M. Saure, PWG Chairperson, PATHCO, Inc. and submitted to R.A. Michaels, Chairperson, Maine Scientific Advisory Panel. April 27.

13. MacKenzie-Taylor, D. 2001. Personal communication with K. Fehling of Exponent regarding basis of 2,3,7,8-TCDD MDEQ slope factor. Michigan Department of Environmental Quality.

14. Van den Berg, M., L. Birnbaum, A.T.C. Bosveld, et al. 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ. Health Perspect. 106(12):775–792.

15. Sheehan, P.J., D.M. Meyer, M.M. Sauer, and D.J. Paustenbach. 1991. Assessment of the human health risks posed by exposure to chromium-contaminated soils. J. Toxicol. Environ. Health. 32:161-201.

16. Palisade Corporation. 1990. @ Risk. Risk analysis and simulation add-in for Lotus 1-2-3. Version 1.55. Newfield, NY.

17. Decisioneering. 1993. Crystal ball. Forecasting and risk analysis for spreadsheet users, Version 4.0. Denver, Colorado.

18. McKone, T.E., and K.T. Bogen. 1991. Predicting the uncertainties in risk assessment. Environ. Sci. Technol. 25(10):1674–1681.

19. Finley, B.L., and D.J. Paustenbach. 1994a. The benefits of probabilistic exposure assessment: Three case studies involving contaminated air, water, and soil. Risk Anal. 14(1):53-73.

20. Finley, B.L., D.M. Proctor, P.K. Scott, N. Harrington, and D.J. Paustenbach. 1994. Recommended distributions for exposure factors frequently used in health risk assessment. Risk Analysis 14(4):533–553.

21. Greene, J.F., S.M. Hays, and D.J. Paustenbach. 2002. Basis for a proposed reference dose (RfD) for dixoin of 5–10 pg/kg-day: A weight-of-evidence evaluation of the human and animal studies. J. Toxicol. Environ. Health (in press).

22. Stanek, E.J., E.J. Calabrese, and M. Zorn. 2001. Soil ingestion distributions for Monte Carlo risk assessment in children. Human and Ecological Risk Assessment 7(2):357-368.

23. Costeff, H. 1966. A simple empirical formula to estimate the approximate surface area in children. Arch. Dis. Child. 41:681–683.

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24. Holmes, K.K., Shirai, J.H., Richter, K.Y., and Kissel, J.C. 1999. Field measurement of dermal soil loadings in occupational and recreational activities. Env. Res. 80(2, Part 1):148–157.
25. U.S. EPA. 1991a. Human health evaluation manual, supplemental guidance: Standard default exposure factors. Interim final. Directive 9285.6-03. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Toxics Integration Branch, Washington, DC.
26. Johnson, T., and Capel, J. 1992. A Monte Carlo approach to simulating residential occupancy periods and its application to the general U.S. population. Prepared for the U.S. EPA. December.

Table 1. Exposure Parameters

Exposure Parameter	Child Value	Adult Value
Soil ingestion rate (mg/day)	Cumulative distribution:[22] μ= 31, ó=31	Point estimate:[6] 50
Skin surface area (cm^2)	Correlated to body weight[23]	Correlated to body weight[23]
Fraction of skin attributable to body parts (unitless)	Point estimate:[8] 0.0561, hands 0.1338, forearms 0.1526, face 0.243, lower legs 0.06876, feet U.S. EPA 2000	Point estimate:[6] 0.0515, hands 0.059, forearms 0.0745, face U.S. EPA 1997
Soil adherence rate, skin (mg/cm^2)	Lognormal distribution:[24] μ= 0.15, σ=2.1; hands μ= 0.031, σ=1.8; forearms μ= 0.058, σ=1.6; face μ= 0.023, σ=1.2; lower legs μ= 0.13, σ=1.4; feet	Lognormal distribution:[24] μ= 0.2, σ=1.9; hands μ= 0.05, σ=2.1; forearms μ= 0.058, σ=1.6; face
Dermal Bioavailability (unitless)	Point estimate:[10] 0.0175	Point estimate:[10] 0.0175
Exposure Frequency (days/year)	Point estimate:[10,25]: 350	Point estimate:[10,25] 350
Exposure Duration (years)	Cumulative distribution:[26] μ= 12, σ=8	Cumulative distribution:[26] μ= 12, 9, σ=8
Meteorological Factor (unitless)	Pointe estimate:[10] 0.667	Point estimate:[10] 0.667
Body Weight (kg)	Lognormal distribution:[19] μ= 14.9, σ=4	Cumulative distribution:[19] μ= 71, σ=15.9
Averaging Time (days)	Point estimate:[1,10,25] 25,550	Point estimate:[1,10,25] 25,550