Identifying a Soil Clean-up Criteria for Dioxin in Residential Soils: How Has 20 Years of Research and Risk Assessment Experience Impacted The Analysis?

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Introduction

Over the past 20 years, numerous scientists have conducted risk assessments to identify the concentrations of polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) in soils which are sufficiently low to not pose a health hazard to humans [1-5]. Identification of the proper methodology, exposure factors and toxicity criteria to use has been topics of vigorous debate for the past two decades. Although a great deal of new information on the dioxins has been collected over the past decade, no one has attempted to bring all this information together to recommend a new soil guidance value (sometimes called “clean-up values”) for dioxin in residential or industrial site soils; especially one which attempts to account for the uncertainty in the toxicology data and exposure factors.

In the following sections we provide a methodology and scientific basis for selected parameters used to develop probability-based ranges for risk-based soil cleanup criteria applicable to PCDD/Fs in urban residential settings. Since our last paper [3] addressing soil cleanup levels for TCDD, a considerable amount of new information has become available on the key parameters that drive the risk calculations for identifying acceptable concentrations of dioxin in contaminated soil. Thus, we have incorporated new information on child soil ingestion rates, dermal uptake parameters, bioavailability, residential exposure duration and others. These different assumptions are incorporated using probabilistic techniques. Distributions of health risk-based dioxin soil clean-up levels consistent with USEPA guidance were developed.

Materials and Methods

This risk assessment was conducted in a manner consistent with the National Academy of Science [6] and USEPA guidance for human health risk assessment [7-9]. To characterize the full range of potential exposures that could occur, a quantitative stochastic analysis was performed, using Latin Hypercube (LHC) statistics, to quantify the uncertainty and variability associated with the exposure parameters used to calculate the urban residential soil criterion. Commercially available software programs (e.g., @Risk^{TM}, Crystal Ball^{TM}) were used simulate a full distribution frequency for the input values.

Both cancer and noncarcinogenic health risks were evaluated and a variety of exposure pathways considered. Although there is no current reference dose for dioxins that is endorsed by USEPA [10], we have utilized an assumed RfD of 5 pg/kg-day as proposed by others [11] . Cancer potency factors ranging from 9,600 to 156,000 $(mg/kg\text{-}day)^{-1}$ were utilized based on various analyses of the Kociba et al. (1978) rat cancer bioassay data [12-14] . For this analysis, an acceptable cancer risk of 1 in 100,000 was selected and for noncancer risks, a hazard index of 1 was utilized.

Results

The probabilistic analysis showed that assumptions about childhood soil ingestion had the largest effect on the soil criteria, and that the cancer risk at a 1 per 100,000 target risk level predicted lower soil guidelines than did noncancer risks. Table 1 summarizes the exposure assumptions for the childhood soil ingestion exposure pathway. Potential soil TCDD guidelines identified in this analysis ranged from 0.6 to 2.9 ppb for cancer (see Figure 1) and from 1.9 to 7 ppb for noncancer endpoints.

Table 1. Exposure parameters for the child scenario: Incidental soil ingestion

Parameter	Type	Value	Units

Soil ingestion rate	Probabilistic	Empirical Distribution 25%ile = 11; 50%ile = 24; 90%ile = 73; 95%ile = 88; Max = 137	mg/day
Exposure frequency	Deterministic	350	days/year
Exposure duration	Probabilistic	Empirical Distribution 25%ile = 3; 50%ile = 9; 90%ile = 26; 95%ile = 33; Max = 70	years
Oral bioavailability	Deterministic	0.25	unitless
Meteorological factor	Deterministic	0.667	unitless
Body weight	Probabilistic	Lognormal Distribution $\mu = 14.9$; $\sigma = 4.0$	kg
Averaging time	Deterministic	25,550	days

The results of the sensitivity analysis indicate that the distribution of soil criteria is highly sensitive to the exposure duration and child soil ingestion rate PDFs, with all other parameters being of lesser importance.

Conclusions

This analysis attempted to integrate all the relevant information that has been developed over the past 20 years since the derivation of the 1 ppb guideline. The only exception was that the US EPA's proposed cancer potency factor of 1,000,000 $(mg/kg\text{-}day)^{-1}$ was not quantitatively considered in the analysis . For numerous reasons, we believe such a CPF is unlikely to be an appropriate estimator of the cancer risk[15]. However, if it were adopted, it would identify soil concentrations of about 50-90 ppt TEQ (a concentration close to background in urban areas).

We incorporated a detailed probabilistic assessment to allow risk managers to examine the degree of conservatism associated with varied margins of safety at different percentiles and under a wide variety of plausible scientific assumptions and parameters that define exposure and risk.

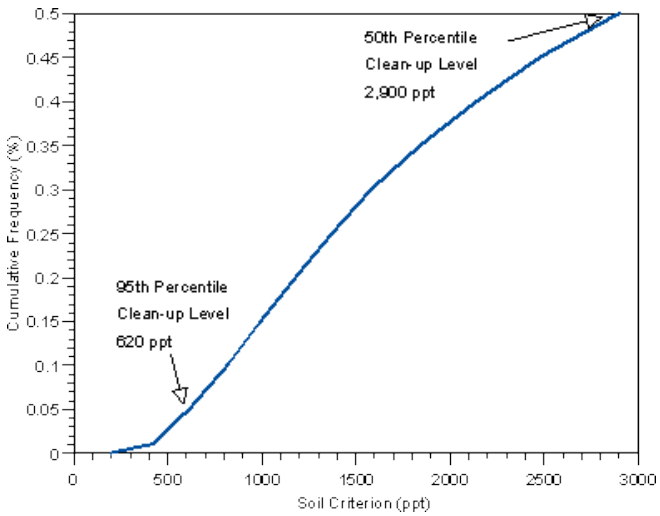

Figure 1: Distribution of TCDD soil criterion utilizing a uniform distribution of cancer potency factors ranging from 9,600 to 156,000 $(mg/kg\text{-}day)^{-1}$ and exposure factors identified in Table 1 - child soil ingestion exposure scenario.

Our analysis supports the historical position of the USEPA and ATSDR that a 1 ppb dioxin soil cleanup criterion is almost certainly protective for both cancer and non-cancer health effects associated with exposure to PCDD/Fs [5, 16-18]. However, our work clearly shows that depending on the weight of evidence regarding the carcinogenic potency or developmental hazard, dioxin concentrations in the range of 620 ppt to 1900 ppt could also be considered acceptable.

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