USING CONGENER RATIOS AND TOXICITY EQUIVALENCY FACTORS IN EVALUATING EXPOSURES TO DIOXIN: A PROPOSED RISK ASSESSMENT APPROACH

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Introduction

Dioxins are found in all media and in all parts of the world, and are therefore considered to be ubiquitous organic chemicals[1]. Sources of dioxins include forest and brush fires and various combustion and chemical processes, including automobile exhaust and charcoal-fired barbecues. A database of background concentrations in various environmental media has been compiled by the USEPA for use in risk assessment and other scientific applications[1].

The presence of dioxins in environmental media, *i.e.*, air, soil, water, is routinely evaluated using risk assessment according to the USEPA paradigm[2]. The objective of a risk assessment is to identify the need for remedial action of site-related chemicals. Inclusion in the baseline risk assessment of chemicals that are not site-related is inappropriate, as these chemicals will be excluded from remedial action decisions.

Two modifications of the typical risk assessment approach to evaluating dioxins are proposed. These are the use of (1) the use of congener ratios versus analytical detection limit approach in determining sample concentrations and (2) a toxicity equivalency (TEQ)-based versus measured concentration approach for background comparisons.

Method

The first proposed approach addresses the limitation of using a function of the analytical detection limit to estimate the concentrations of non-detected dioxin congeners in a sample. In a typical approach, non-detected dioxin congeners may be assumed to be present in the sample at one-half of the reported analytical detection limit. This method may result in overestimating the concentrations of non-detected congeners in samples. An alternative approach is to use the ratios of dioxin congeners from samples where all congeners are detected and apply these ratios to samples with some non-detected congeners.

Eleven soil samples containing dioxins associated either with background (7 samples) or fuel burn-off pits (4 samples) were selected for this evaluation. The fuel burn-off pits were selected because these had been used to burn off excess fuel hydrocarbons and had dioxin congeners similar to background samples. All samples had consistent congener patterns according to the following scheme: octa-substituted>hepta-substituted>hexa-substituted>penta-substituted>tetra-substituted. For each of the eleven samples, the ratio of each congener to octa-chlorinated dibenzo-p-dioxin (OCDD) was calculated. OCDD was selected because it was present in all samples including background. For those congeners that were non-detect in a given sample, the congener was assumed to be present at one-half the detection limit to set a ratio. Note that this assumption results in OCDD:congener ratios that are lower than if the actual concentration (assumed to be below one-half the detection limit) were used.

The second proposed approach evaluates background dioxin concentrations as a total using a TEQ-adjusted total sample concentration versus evaluating each individual congener. The toxicity equivalence factors are numerical estimates of relative congener toxicity to 2,3,7,8-TCDD[3]. This approach consists first of determining the concentration of each 2,3,7,8-substituted congener in each sample. For those congeners detected in a sample, the reported concentration is used. For those congeners non-detect in a sample, the OCDD-congener ratio, as described above, was used to set the sample congener concentration. Each congener concentration was then multiplied by the appropriate toxicity equivalency factor (TEF) to generate a toxicity-weighted concentration. These weighted concentrations are then summed to calculate the total dioxin concentration for that sample. In this approach, the concentrations of all dioxin congeners in the sample are represented in the single toxicity-weighted value.

Results and Discussion

The mean and range of OCDD:congener ratios were calculated from the eleven samples. For example, the range of OCDD:1,2,3,4,7,8-HxCDD was 166 to 640 with a mean of 360. The OCDD:1,2,3,4,7,8-HxCDD the proposed ratio is 360, the mean of eleven ratios. The OCDD:congener ratios are presented in Table 1.

The use of the ratios to estimate non-detected congener concentrations is important in background data sets which have a pattern of detectable concentrations of the higher chlorinated congeners (hepta- and octa-substituted) and below detection levels of the lower chlorinated congeners (tetra-, penta-, and hexa-substituted). This is because of the assumed difference in toxic potency (low chlorine congeners >> high chlorine congeners). When a function of the detection limit (*e.g.*, one-half detection limit) is used to estimate the sample concentration of lower-chlorinated congeners, these non-detects can be the largest contributors to toxicity-weighted total concentration. The background samples in this evaluation are characterized as having detectable levels of the less toxic hepta- and octa-substituted congeners with the remaining congeners below detection limits.

The typical procedure is to utilize one-half the reported detection limit as representative of the upper limit of the concentration, which could be present in the sample and remain undetected. However, the detection limit is oftentimes more a function of the analytical procedure than representative of the dioxin concentrations in the sample. For example, the proposed ratio of detected levels of tetra-dioxin to OCDD is 1:300. However, if the OCDD levels are less than 50 parts per trillion (ppt) and the tetra-dioxin detection limit is 1.0 ppt, these numbers would suggest a ratio of 1:100 (one-half detection limit:to 50 ppt). Since the tetra-dioxin (along with the 1,2,3,7,8-penta-dioxin and 2,3,4,7,8-penta-furan) with their TEFs of 1.0 (0.5 and 0.5) can inappropriately contribute to the total *toxicity-weighted concentration* when compared to the hepta- and octa-substituted congeners with TEFs of 0.01 and 0.001 respectively, it is very important to not overestimate the concentrations of the lower-substituted congeners. An example comparing the limit of detection versus the ratio approach is provided in Table 2.

References

1. USEPA, 1994. *Estimating exposure to dioxin-like compounds, Vols I-III.* Office of Research and Development. EPA/600/6-88/005Cb. June.

2. USEPA, 1989. *Risk assessment guidance for Superfund, volume I: Human Health Evaluation Manual* (Part A). Interim Final. Office of Emergency and Remedial Response.

3. USEPA, 1989b. *Interim procedures for estimating risks associated with exposures to mixtures of chlorinated dibenzo-p-dioxins and -dibenzofurans (CDDs and CDFs) and 1989 update.* Risk Assessment Forum. EPA/625/3-89/016. March.

TABLE 1

PROPSED OCDD-CONGENER RATIOS FOR ESTIMATING NON-DETECT CONGENER CONCENTRATIONS

CONGENER	RATIO
2,3,7,8-TCDD	260
1,2,3,7,8-PeCDD	300
1,2,3,4,7,8-HxCDD	360
1,2,3,6,7,8-HxCDD	130
1,2,3,7,8,9-HxCDD	110
1,2,3,4,6,7,8-HpCDD	10
OCDD	1.0
2,3,7,8-TCDF	86
1,2,3,7,8-PeCDF	260
2,3,4,7,8-PeCDF	230
1,2,3,4,7,8-HxCDF	190
1,2,3,6,7,8-HxCDF	130
1,2,3,7,8,9-HxCDF	425
2,3,4,6,7,8-HxCDF	31
1,2,3,4,6,7,8-HpCDF	42
1,2,3,4,7,8,9-HpCDF	170
OCDF	23

TCDD and TCDF = tetrachlorodibenzo-p-dioxin and tetrachlorodibenzofuran
PeCDD and PeCDF = pentachlorodibenzo-p-dioxin and pentachlorodibenzofuran
HxCDD and HxCDF = hexachlorodibenzo-p-dioxin and hexachlorodibenzofuran
HpCDD and HpCDF = heptachlorodibenzo-p-dioxin and heptachlorodibenzofuran
OCDD and OCDF = octachlorodibenzo-p-dioxin and octachlorodibenzofuran

TABLE 2

COMPARISON OF LIMIT OF DETECTION VERSUS RATIO METHODS FOR SETTING SAMPLE DIOXIN CONCENTRATIONS

Sample	Total Concentration Using Half-Detection Limits	Total Concentration Using OCDD:Congener Ratios
Background #1	1.4 ppt	1.1 ppt
Background #2	2.5 ppt	2.1 ppt