SITE-SPECIFIC DERMAL RISK ASSESMENT FOR INDUSTRIAL WORKERS EXPOSED TO PCDD/FS AND DIOXIN-LIKE PCBS IN SOIL

Finley Brent L[1]; Shay Erin C[2], Scott Paul K[2]

[1]ChemRisk, Inc.
25 Jessie St, Ste 1800
San Francisco, CA 94105

[2]ChemRisk, Inc.
20 Stanwix St, Ste 505
Pittsburgh, PA 15222

Introduction

Investigations of surface soil and sediment in waste management areas (WMAs) at an operating facility in the U.S. indicate the presence of detectable levels of polychlorinated dibenzodioxins/furans (PCDD/Fs) and polychlorinated biphenyls (PCBs). This analysis presents the results of a site-specific risk assessment conducted to evaluate the potential PCDD/F and dioxin-like PCB risks associated with future dermal contact with site soils. The assessment incorporates site-specific weather conditions and an experimentally-derived dermal adherence factor (DAF).

Materials and Methods

Surface soil and sediment samples from the WMAs were analyzed for the seventeen 2,3,7,8-PCDD/F congeners and the twelve dioxin-like PCBs[1]. The 2,3,7,8 TCDD toxic equivalent (TEQ) concentration was calculated for each of these samples using the toxic equivalency factors (TEF) presented by the World Health Organization[1]. The PCDD/F profile in the site soils was consistent across the various WMAs: 2,3,7,8-TCDD was a minor component, making up less than 0.3% of the TEQ and almost half of the TEQ was comprised of the four hexachlorodibenzofurans. The dioxin-like PCBs contributed little to the total TEQ with an average contribution of 1.7% for the various WMA, ranging from 0.027% for WMA 7 to 7.4% for WMA 1, Approximately 91% of the samples were below the OSWER 20 ppb TEQ value for occupational soils[2]. Exposure point concentrations (EPCs) for each WMA were determined using EPA's ProUCL software version 3.0. The EPCs for each of the WMAs are presented in Table 1.

Absorbed PCDD/F and PCB TEQ doses from dermal contact with soil were calculated using equations 1 and 2 below:

$$Dose = \frac{C_s \times CF \times SA \times DAF \times EVF \times ABS \times EF \times ED \times MET}{BW \times AT} \quad \text{(Equation 1)}$$

where:

Dose	Lifetime average daily dose (LADD) for carcinogens (mg/kg-day)
CS	WMA soil concentration (mg/kg)
CF	Conversion factor (10^{-6} kg/mg)
SA	Skin surface area (cm^2)
DAF	Soil-to-skin dermal adherence factor (mg/cm^2-event)
EVF	Event frequency (events/day)
ABS	Absorption efficiency of chemical through skin (unitless)
EF	Exposure frequency (days/year)
ED	Exposure duration (years)
MET	Correction factor for meteorological conditions that preclude exposure (unitless)
BW	Body weight (kg)
AT	Averaging time (period over which exposure is averaged) (days)

(Equation 2) *Lifetime Excess Cancer Risk = LADD x SF*

Where:

- LADD Lifetime average daily dose (mg/kg-day)
- SF Slope factor $(mg/kg\text{-}day)^{-1}$; the cancer slope factor of 150,000 $(mg/kg\text{-}d)^{-1}$ for dioxin was obtained from HEAST.

Several site-specific exposure parameter refinements were used to evaluate industrial worker PCDD/F and PCB exposures and are discussed below; otherwise, default EPA parameters were used[3-5].

Although facility policy requires the use of full-body protective clothing including gloves and hard hats for physical safety purposes, it was assumed that workers did not wear gloves (i.e. 100% of their hands were exposed), and the 50th percentile exposed skin surface areas for hands and faces of men and women were utilized[3].

The use of a meteorological factor is reasonable for instances where significant precipitation is likely to prevent dermal contact with surface soil[6,7]. As such, a local meteorological factor (MET) of 0.74 was calculated and used in this risk assessment. This MET is based on the number of days that local daily rainfall is at least 0.01 inches and sufficient to preclude the re-suspension of dust due to vehicle traffic[5].

A dermal adherence factor (DAF) for the future worker was experimentally derived based measurements obtained from current workers, using a methodology that that has been published in the literature and validated by the EPA[3,4,8-12]. Hand and face rinse samples were collected after workers performed their daily outdoor duties, and the mass of the soil in the rinse samples were determined using gravimetric analysis. DAFs were calculated by dividing the total mass of soil per sample (mg) by the skin surface area sampled (cm^2).

Additionally, a dermal absorption factor (ABS) was used to describe the degree of transfer of PCDD/Fs and PCBs; the USEPA default ABS value for PCDD/Fs of 3% was used for both PCDD/Fs and PCBs[3]. The default value of 3% is the upper bound of the recommended range of dermal absorption values for TCDD recommended by the USEPA[3,13] These absorption values are based predominantly on in vivo animal studies in which the animals were dermally exposed for 24 to 96 hours to soils containing high concentrations of TCDD that ranged from 0.01 to 17 ppm. These studies indicate that the absorption of TCDD is positively correlated with soil concentration and negatively correlated with organic carbon content. While the default dermal absorption for PCBs as Aroclor mixtures is 14%, it is still appropriate to use the dermal absorption value for TCDD because the dioxin-like PCBs make up a small percentage of the total TEQ for the WMAs on average (1.7%) and the dioxin-like PCBs are a small fraction of the PCB content of the Aroclor mixtures.

Results

The results of the DAF study indicated that the geometric mean DAFs for hands and faces of the workers were 0.05 mg/cm^2 and 0.07 mg/cm^2, respectively, with a combined geometric mean of 0.06 mg/cm^2. The use of geometric means to develop a DAF estimate from the underlying data is consistent with the values that appear in EPA Guidance[3,4]. The potential PCDD/F and PCB carcinogenic risks for the future worker ranged from 5×10^{-7} to 2×10^{-6} at the various WMAs. About 50% of the PCDD/F and PCB risks were due to the contribution of the four hexachlorodibenzofurans to the overall TEQ. On average, 98.9% of the risk was due to the PCDD/Fs versus the PCBs.

Discussion

This dermal assessment of PCDD/F and dioxin-like PCB risks is unique in that it incorporates site-specific information regarding the industrial workers at the facility (i.e. MET and DAF factors). Use of a default DAF can introduce a great amount of uncertainty into a risk assessment, due to a high variability of activity patterns and physical/chemical characteristics of soil. For example, when one consults EPA guidance for a DAF representative of adult hands in an outdoor scenario, values ranging from 0.03 mg/cm^2 to 0.66 mg/cm^2 can be selected[4]. For faces, the range is even greater, at 0.002 mg/cm^2 to 0.23 mg/cm^2. While the EPA-recommended data indicate that dermal adherence to faces can be much less than that of hands in an outdoor adult scenario, our data indicated that the site-specific DAFs for the hands and faces of the industrial workers at this facility were actually quite similar. This is likely due to the fact that the gloves worn by the workers partially precluded the hands from dermal contact while their faces remained uncovered; nonetheless this disparity demonstrates the relevance for using site-specific data. The overall DAF of 0.06 mg/cm^2 calculated here (and used in the risk assessment) fell at the low end of the range of those recommended by the EPA for industrial workers (upper bound - 0.2 mg/cm^2; central tendency - 0.02 mg/cm^2)[3].

The dermal absorption value of 3% used for this assessment is conservative because it is the upper end of the range of values based on animal studies that involved fairly long exposure durations at high concentrations. For facility workers, exposure durations over 24 hours are unlikely because workers are expected within a 24 hour period. While the default dermal absorption for PCBs based on Aroclor mixtures is 14%[3], dioxin-like PCBs make up a small fraction of the total TEQ for these soils and they are a small fraction of the mass of the Aroclor mixtures.

Both a site-specific DAF and MET factor were used to refine the dermal risk assessment and reduce uncertainties associated with the risk estimates for this industrial worker. All industrial worker dermal risks fell within or below the EPA acceptable risk range of 10^{-6} to 10^{-4}.

References

1. Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE (2006) *Toxicol Sci* 93: 223-241.
2. OSWER. 1998. Approach for Addressing Dioxin in Soil at CERCLA and RCRA Sites. OSWER Directive 9200.4-26. April 13, 1998.
3. EPA. 2004. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part E: Supplemental Guidance for Dermal Risk Assessment) – FINAL. OSWER EPA/540/R/99/005. July 2004.
4. EPA. 1997. Exposure Factors Handbook (EFH), Volumes I, II, and III. USEPA. Office of Research and Development. EPA/600/P-95/002Fa.
5. EPA. 2002. Supplemental Guidance for Soil Screening Levels. http://www.epa.gov/superfund/health/conmedia/soil/pdfs/ssg_main.pdf.
6. Paustenbach, D.J., Fehling, K, Scott, P., Harris, M., and B.D Kerger. 2006. *Journal of Toxicology and Environmental Health*, Part B, 9:87–145.
7. van Wijnen, J. H., Clausing, P., and Brunekreef, B. 1990. *Environ. Res*. 51:147–162.
8. Kissel, J.; Richter, K.; Duff, R.; Fenske, R. (1996). *Bull. Environ. Contamin. Toxicol*. 56:722-728.
9. Kissel, J., Richter, K., and Fenske, R. (1996). Risk Analysis 16:115-125.
10. Kissel, J., Shirai, J., Richter, K., and Fenske, R. (1998). J. Soil Contamination 7:737-752.
11. Anderson, E, Browne, N., Duletsky, S., Ramig, J. and Wam, T. (1985) Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments, Office of Health and Environmental Assessment, EPA/600/8-85/010.
12. Holmes, K.K. Jr., Shirai, J., Richter, K., and Kissel, J. (1999). *Environ.Res.*, 80:148-157.
13. EPA. 1992. Dermal ExposureAssessment:Principles and Applications. EPA/600/8-91/011B. January 1992.

Table 1. PCDD/F and PCB TEQ Summary Statistics for the WMAs

WMA	Detected Concentration		95% UCL	EPC
	Min	Max		
WMA 1	0.00025	0.0072	0.0052	0.0052
WMA 2	0.0032	2.26	0.83	0.83
WMA 3	1.92E-06	0.016	0.013	0.013
WMA 4	0.0045	1.38	0.72	0.72
WMA 5	5.18	113.6	72.3	72.3
WMA 6	0.044	21.7	10.9	10.9
WMA 7	6.3	1155	453	453
WMA 8	0.87	0.87	NA	0.87
WMA 9	0.0004	0.558	0.2	0.2
WMA 10	0.87	22.8	6	6

[a]UCL calculation method as recommended by ProUCL unless otherwise noted.
[b]Standard bootstrap UCL used. ProUCL identified distribution as gamma as probability plot indicated that data do not fit normal, lognormal or gamma distributions.

Table 2: Exposure Factors

Parameter	Description/Units	FutureWorker[a]
General		
EF	Exposure Frequency (days per year)	225
ED	Exposure Duration (years)	25
BW	Body Weight (kg)	70
MET	Meteorological Factor (unitless)	***0.74***
ATc	Averaging Time, carcinogen (days)	25550
ATnc	Averaging Time, non-carcinogen (days)	9125
CF	Conversion Factor (kg/mg	1.00E-06
SA	Surface Area of Exposed Skin (cm^2)	3300
ABS	Dermal Absorption Fraction (unitless)	3%
DAF	Dermal Adherence Factor (mg per cm^2 - event)	*0.06*
EvF	Event Frequency (events per day)	1

[a]*Underlined italicized* values indicate site-specific refinements; otherwise values are default EPA parameters (USEPA, 2002).