LINEAR REGRESSION MODELING TO PREDICT HOUSEHOLD DUST PCB CONGENER CONCENTRATIONS

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Abstract
Household dust samples were obtained from the residences of eligible participants in the University of Michigan Dioxin Exposure Study (UMDES). Linear regression models were used to determine which factors explained the variations in polychlorinated biphenyl (PCB) congener concentrations in household dust measured from the participants in the UMDES and to quantify how much of the variation each factor explained. Potential dust predictor variables were derived from the UMDES questionnaire, dust sampling field data notes and results from the household dust and soil sampling laboratory analyses. Household dust samples were obtained from 764 study participants over the course of three sample seasons. For all congeners, older floor surfaces, higher PCB congener concentrations in soil and remediation for dioxins were associated with higher PCB congener concentrations in household dust. In general, Jackson and Calhoun Counties had higher congener concentrations in household dust than areas in Midland and Saginaw counties. Dust loading and dogs at the residence were associated with lower PCB concentrations for most congeners and working at Dow (ever in a lifetime) was linked to lower PCB77 concentrations. PCB congener concentrations in the soil samples and the age of floor surface provided the greatest explanation of the variance in the models.

Introduction
The University of Michigan Dioxin Exposure Study (UMDES) was conducted to explain the variation in serum levels of polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs) and to quantify how much of the variation each factor explained. The study was undertaken in response to concerns of environmental contamination in the Tittabawassee River floodplain in Midland and Saginaw Counties in Michigan and in areas within the City of Midland, Michigan. Household dust was determined to be one of many potential explanatory factors for the variation in serum levels of PCDDs, PCDFs and PCBs and household dust samples were obtained from eligible UMDES study participants. The purpose of the present study is to describe which factors explained the variations in PCB congener concentrations in household dust measured from participants in the UMDES and to quantify how much of the variation each factor explained.

Materials and Methods
UMDES study participants were recruited from five populations, described elsewhere[1], from areas in Midland, Saginaw, Bay, Jackson and Calhoun Counties in Michigan using a two-stage area probability household sample design. In order to be eligible for household dust sampling, a participant had to be eligible to provide a serum sample, had to be the owner of their residence and had to have lived in their residence for at least five years. Detailed methods for sample selection, recruitment, eligibility and consent are described elsewhere.[2]

The household dust sampling protocol was based on the American Society for Testing and Materials (ASTM) method "Standard Practice for Collection of Floor Dust for Chemical Analysis".[3] A High Volume Small Surface Sampler (HVS3), capable of capturing 99.95% of particles above 0.3µm aerodynamic mean diameter, was used to collect each household dust sample. Sample locations were selected by the samplers after entering a residence and were generally taken from one or two locations with a high potential for human exposure. Bulk dust and filter samples were combined and a single household dust sample from each residence was analyzed by Vista

Analytical Laboratory, Inc. (El Dorado Hills, California, USA) for the WHO designated 29 PCDD, PCDF, and PCB congeners[4] using US EPA methods 1668[5] and 8290[6]. The full UMDES protocol, including the household dust sampling protocol[7], is available online at www.umdioxin.org.

Congener concentration is the outcome of interest presented in this report. Congener concentration is the amount of a PCDD, PCDF or PCB congener per gram of dust, measured in pg/g or parts per trillion (ppt). Household dust levels can also be measured in terms of congener loading. Congener loading is the amount of a PCDD, PCDF or PCB congener per square meter of floor surface, measure in pg/m^2. Congener loading was also calculated and analyzed and the results of those analyses will be presented in future reports.

Potential household dust predictor variables were derived from the UMDES questionnaire (i.e., work history, property use and remediation variables), household dust sampling field data notes (i.e., sampling season and floor surface variables) and results from the household dust and soil sampling laboratory analyses. Continuous variables were reported in years or days to account for a participant's total cumulative exposure to a potential source of contamination while living in their current residence. Based on the data available, several potential predictor variables were also created to group participants into different exposure categories. Categorical variables were created to explain sample season, floor surface sampled and floor replacement after a flood. Sample season was determined based on the month the household dust was sampled. Each floor surface sampled was classified as a high pile carpet (i.e., velvet carpet), low pile carpet (i.e., berber carpets) or a hard floor surface. A variable was also created for residences that had been affected by river flooding to differentiate between floor surfaces that had been replaced after the flooding and floor surfaces that had not been replaced after the flooding.

SAS version 9.1 statistical software was utilized to complete all analyses.[8] The PCB congener concentration outcome variables were transformed to a log base10 scale. Histograms confirmed that the distributions of the outcome variables were extremely skewed in the original scale and were normalized after transformation. Descriptive statistics were calculated using both unweighted data and survey sample weighted data. Graphs were also created to explain important relationships between household dust and soil PCB congener concentrations. Tables and boxplots, available on the UMDES website, www.umdioxin.org, provide descriptive statistics and distributions by region for the TEQ and 29 dioxin congeners. [Note: TEQ values presented were based on the World Health Organization 2005 TEFs].[4]

Linear regression modeling used data from five imputed data sets and survey sample weights generated based on the 764 subjects who had household dust measurements taken. Final variable selection was based on forward and backward selection techniques after testing for interactions and collinearity. For example, sampling time was not included in the regression models because sampling time was directly related to dust loading or how much dust there was on a floor surface per square meter of floor surface. The final variable list only included a soil concentration variable and other statistically significant variables.

Overall adjusted r-square values were calculated for each PCB congener concentration regression model to describe how well each model explained the total variation. Additionally, the change in the adjusted r-square (ΔR^2) was calculated after removing each significant variable one at a time to determine which predictor variables provided the greatest explanation of the variance in each model.

Results and Discussion

Household dust samples were obtained from 764 study participants over the course of three sample seasons. 205 of those samples were from the Floodplain region, 161 from the Near Floodplain region, 168 from other parts of Midland/Saginaw not in the floodplain, 32 from the Midland Plume and 198 from the Jackson and Calhoun region. 224 household dust samples were taken in Fall 2004, 432 samples were taken in Summer 2005 and 108 samples were taken in Spring 2005. The mean age of the floor surfaces sampled was 12.2 years. Prior to sampling, five residences had been remediated as a result of dioxin contamination.

For all congeners, scatterplots showed a positive correlation between the soil PCB concentrations and the household dust PCB concentrations. As the soil PCB concentrations increased, the household dust PCB concentrations also increased. Scatterplots are not included in this report.

Regression models, using both forward and backward selection methods, produced similar results and therefore, only the backward selection method is presented. The parameter estimates, overall adjusted r-square values and change in adjusted r-square values are reported in Table 1. For all congeners, higher maximum soil PCB concentrations on properties or PCB concentrations around the house, older floor surfaces and household remediation for dioxins were associated with higher PCB concentrations in household dust. Across all congeners, except PCB 77 and PCB 123, Jackson and Calhoun counties had higher congener concentrations in household dust than areas in Midland and Saginaw counties. Owning vegetable and flower gardens (PCB77, PCB126, and PCB169), fire damage (PCB169), high pile carpet (PCB77, PCB81, PCB126 and PCB169) and floors that had not been replaced after flooding were other variables associated with higher PCB concentrations for some congeners. Dust loading and dogs at the residence were associated with lower PCB concentrations for most congeners and working at Dow (ever in a lifetime) was linked to lower PCB 77 concentrations. Unlike the PCDDs and PCDFs, sampling season was not associated with PCB concentrations in household dust.

In this study, the backward selection model explained about 26% to 37% of dust PCB congener concentrations variations. Based on the change in the adjusted r-square values, the PCB concentrations in the soil samples and the age of floor surface provided the greatest explanation of the variance in the models. The change in the adjusted r-square (ΔR^2) values will be described in a future report. Congener concentration and congener loading are both important outcomes for household dust studies and in future reports, congener loading will also be reported.[9]

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Table 1: Significant Parameter Estimates and Overall Adjusted R-square Values for PCB Congener Concentrations in Household Dust**
(Shaded estimates: var. associated with higher levels, Non-shaded estimates: var. associated with lower levels)

	PCB 77	PCB 81	PCB 126	PCB 169	PCB 105	PCB 114	PCB 118	PCB 123	PCB 156	PCB 157	PCB 167	PCB 189
Soil (log ppt)												
Soil dioxin conc. around house	0.371	0.376						0.496				
Max soil dioxin conc. on property			0.648	0.626	0.341	0.309	0.327		0.493	0.542	0.533	0.469
Region												
M/S floodplain vs. J/C			-0.331	-0.269	-0.287	-0.311	-0.266		-0.240	-0.311	-0.240	-0.251
M/S near floodplain vs. J/C		-0.183				-0.206	-0.186					
M/S out of floodplain vs. J/C												
Midland plume vs. J/C			-0.237			-0.229						
Property Use												
Indoor/Outdoor Pets (yrs*)			-0.004	-0.004								
Vegetable/flower/other garden (yrs*)	0.006		0.005	0.004								
Fire damage (yrs*)				0.108								
Indoor Conditions												
R worked at Dow (yrs*)	-0.008											
Any dogs at the residence	-0.165	-0.144			-0.216	-0.216	-0.220			-0.169	-0.182	
Floor Surface												
Age of floor surface (yrs*)	0.014	0.013	0.008	0.006	0.010	0.010	0.010	0.010	0.010	0.008	0.009	0.012
Some velvet carpet (high pile) vs. hard surface	0.383	0.399	0.324	0.313								
Floor not replaced after flooding vs. not flooded			0.345									
Dust Load (log g/m^2)				-0.145	-0.167	-0.180	-0.179	-0.201	-0.136	-0.157	-0.154	
Remediation												
House remediated for dioxins	0.380	0.301	0.744	0.380	0.819	0.742	0.813	0.534	0.839	0.871	0.883	0.959
Overall Adjusted R-square (%)	**30.34**	**29.17**	**35.40**	**26.63**	**36.87**	**34.68**	**36.84**	**34.68**	**28.13**	**34.70**	**35.17**	**28.93**

* Years/days in which subjects lived at the sampled residence
** All parameter estimates are significant at alpha=0.05 level