ENVIRONMENTAL FACTORS THAT EXPLAIN VARIATION IN SERUM DIOXIN CONCENTRATIONS IN A COMMUNITY IN MICHIGAN, USA

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Introduction and Study Goals

The University of Michigan Dioxin Exposure Study (UMDES) is designed to assess exposures to dioxins (PCDDs), furans (PCDFs) and coplanar polychlorinated biphenyls (PCBs) to the adult population of Midland and Saginaw Counties, Michigan, USA. The study was undertaken in response to concerns among the population of Midland and Saginaw Counties that dioxin-like compounds from the Dow Chemical Company facilities in Midland have contaminated areas of the City of Midland and sediments in the Tittabawassee River flood plain.[1] There is concern that residents' body burdens of dioxins may be elevated because of environmental contamination. A central goal of the study is to determine which factors explain variation in serum congener levels, and to quantify how much variation each factor explains. Random samples of five geographically-defined populations were studied:

- Residents of Midland and Saginaw counties who reside in the flood plain of the Tittabawassee river in areas where soil is believed to be contaminated with dioxins.
- Residents of Midland, Saginaw, and Bay counties who reside in areas adjacent to the flood plain of the Tittabawassee River, where contamination is believed to exist with a lower probability than in the floodplain.
- Residents of Midland, Saginaw and Bay counties who do not reside in the flood plain.
- Residents of Midland who live downwind from the Dow Chemical Company where there is believed to have been aerosol deposition of dioxins.
- Residents of Jackson and Calhoun counties in Michigan, which represent a referent county with no appreciable industrial sources of dioxins.

Each participant was interviewed to assess their potential exposure to dioxins through various environmental pathways and gave a blood sample. Samples of house dust and soil were collected from participants' homes. Blood serum, house dust, and soil were analyzed for the WHO 29 list of PCDDs, PCDFs, and PCBs using high precision GC/MS. [2,3,4,5]

Regression analyses were performed to identify factors that predicted the serum TEQ and each of the seven congeners that were the most important contributors to the TEQ (2,3,7,8 TCDD; 1,2,3,7,8 PeCDD; 2,3,4,7,8 PeCDF; 1,2,3,6,7,8 HexCDD; PCB 126; PCB 156; and PCB 118).

The explanatory factors studied included:

- Residential history over the previous 20 years (addresses were geocoded and then soils were assigned PCDD, PCDF, and PCB concentrations based on a kriged map of concentrations from soils that were sampled)
- Property use, including trash burning, pets that entered the home, wearing shoes in the home, gardening activities, fireplaces and wood burning stoves, fire damage to the home, and flooding (in contaminated areas).
- Dietary history over the past 20 years, focusing on consumption of fish and game from the contaminated areas, home raised meat and poultry, and store bought meat, fish, poultry, and dairy products.
- Pregnancy and breast feeding history
- Work history (focused on jobs with likely exposure to PCDDs, PCDFs, and PCBs) and military service during the Vietnam era.

- Recreational activities in the contaminated areas (fishing, hunting, water sports).
- Demographic factors
- Smoking history
- Concentrations of PCDDs, PCDFs, and PCBs in soil samples from the participant's property.
- Concentrations of PCDDs, PCDFs, and PCBs in house dust samples from the participant's home.

Survey weights that reflected selection probabilities, clusters, and strata were used in the regression analyses to insure that inferences from the regression models were applicable to the population from which participants were selected. Multiple imputation procedures were used to impute missing values for explanatory variables.[6,7]

Many of the explanatory variables were in a form in which the distribution of the variable was skewed or had a small number of extreme values (such as the duration of eating a food item or the total number of meals eaten). These variables were analyzed as continuous variables and also as categorical variables to assess the effect of extreme values. Because there were many potential explanatory variables, a model-building strategy was employed:

- A baseline model that included age, age^2, and BMI was selected after examination of transformations of these variables, choosing the model that had the highest adjusted r^2. Age, age^2, and BMI were forced into all subsequent models.
- Each group of variables was examined separately (such as diet, residential history, work history, soil dioxin concentration, house dust concentration, etc.) using backwards selection to identify significant predictors ($p \leq 0.1$) of the outcome variable. Significant predictors from this step were then chosen for further analyses in overall models.
- The significant predictors from all groups of variables were entered into overall models to identify the combination of variables that had the greatest value of the adjusted r^2.
- All variables that were not selected for the overall model were then re-examined to see if any entered the overall model, using backwards selection. Variables that had a p-value ≤ 0.05 were retained in the final overall model.

Results

The UMDES data set is a large and complex data sets that explores the relationship between serum dioxin levels and numerous environmental exposure pathways. The results provide insight into the sources of variation in adult serum dioxin levels, adjusting for the contributions of multiple sources. Few, if any, previous studies have included information on dietary habits, occupations, recreational activities, measured house dust contamination, and measured soil dioxin contamination. Thus, the present study will assess how much variation of the serum dioxin level is explained by each of these factors, and will estimate the proportion of the total variation in serum dioxin levels that is explained by the factors under study.

Similarly, the models for each PCDD, PCDF, and PCB congener will identify the important predictors of each congener and will assess how much variation of the serum congener level is explained by each of these factors. It is anticipated that the models will explain a high proportion of the total variation in the TEQ and of some of the important congeners.

The results will address the following concerns:

- Contaminated soil is a principal concern of this population because of the possibility that living on contaminated soil may contribute to serum dioxin levels. The pattern of congeners in the soil and serum will be examined to determine whether specific serum congener levels are correlated.
- Contamination of homes by dioxins is a concern. The contribution of house dust contamination to the serum dioxin levels will be examined.
- The dietary factors that are associated with higher serum TEQ levels and with higher levels of each serum congener are of concern because these factors may represent important exposure pathways. Sport caught fish and game are of particular concern because of the commonality of fishing and hunting in this region of Michigan and the contamination of the local rivers and Saginaw Bay. Store bought and home raised meat, poultry, dairy, and fish will also be examined to determine whether the contributions to serum dioxins from these sources are different than the contributions from sport caught sources.
- Root vegetables raised in the contaminated areas are of concern because of the possibility that contaminated soil will be incorporated into the diet of consumers.

- Recreational activities in the contaminated areas, including public parks and land in the flood plain of the Tittabawassee and Saginaw rivers, are a public health concern. The population needs to know whether activities in these areas are associated with higher levels of serum dioxins.
- The relationships between serum dioxin levels and the exposure variables may differ for specific congeners, and in different regions of Michigan. It is anticipated that the predictors of serum dioxin levels may be different among residents of the Tittabawassee River flood plain than among residents of Jackson and Calhoun counties because the pattern of environmental contamination is different in these regions. These differences will be examined.
- There is also concern that Jackson County has dioxin contamination due to a municipal incinerator and that this may be an important predictor of serum dioxin levels in this population. This factor will be examined to determine whether living in proximity to this source is a predictor of serum dioxin levels and whether the pattern of dioxin contamination in soils from this region correlates with the pattern of serum dioxins.

Discussion

This study makes important contributions to the methods by which environmental sources of dioxin exposure and their relationships to adult serum dioxin levels are studied. First, the study relies on a multi-stage random sample of the population, which allows inferences from the data analyses to be applied to the general population from which the sample was drawn.[6] There are few such population-based studies of dioxin contamination. Second, the study includes multiple imputation methods to minimize the effects of missing data and to avoid biases that result from missing data.[7] Third, the study achieved high participation rates and included a non-response survey which allowed assessment of and adjustment for non-response bias.[8]Thus, the survey methods insure that the results are applicable to the general population, which allows effective, population-based strategies to be developed to manage the contamination.

More importantly, the study provides insight into the environmental factors that explain variation in adult serum dioxin levels and the magnitude of their relative contributions. It is widely held that diet is the predominant source of the human body burden of dioxins. This study allows examination of the relative contribution of various dietary sources and, because sport fishing and hunting are prevalent in Michigan, allows examination of the relative contributions of sport caught meat and store bought meat.[9] It also answers important questions about the consequences of consuming home raised produce and meat from contaminated areas. Dioxin contamination of soils is not uncommon in industrialized areas and there is a need to understand the extent to which living on and using these soils contributes to the body burden of dioxins. This has implications for soil cleanup criteria and for public health recommendations for the future uses of contaminated properties.

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