BACKGROUND LEVELS OF PCDDs, PCDFs, AND PCBs IN BLOOD, SOIL, AND HOUSEHOLD DUST IN THE GENERAL POPULATION OF MICHIGAN, USA

Garabrant D[1], Franzblau A[1], Lepkowski J[2], Adriaens P[3], Demond A[3], Hedgeman E[1], Knutson K[1], Zwica L[1], Chen Q[4], Olson K[2], Ward B[2], Towey T[3], Ladronka K[2], Sinibaldi J[2], Chang S-C[3], Lee S-Y[4], Gwinn D[5], Sima C[4], Swan S[5], Gillespie BW[4]

[1]Department of Environmental Health Sciences, University of Michigan School of Public Health, 109 S Observatory, Ann Arbor, MI 48109; [2]Survey Research Center, Institute for Social Research, University of Michigan, 426 Thompson Street, Ann Arbor, Michigan 48104; [3]Department of Civil and Environmental Engineering, University of Michigan College of Engineering, 1351 Beal, Ann Arbor, MI 48109; [4]Department of Biostatistics, University of Michigan School of Public Health, 109 S Observatory, Ann Arbor, MI 48109; [5]Center for Statistical Consultation and Research, Horace Rackham School of Graduate Studies, Ann Arbor, Michigan 48109

Introduction and Study Goals

This paper describes the pattern of blood dioxin concentration and the factors that explain variation in blood dioxin concentrations in an area of Michigan (Jackson and Calhoun counties) that is believed to be representative of the general population.

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. (1) The study includes a population-based survey in Jackson and Calhoun Counties, Michigan to serve as a referent population for Midland and Saginaw Counties. Jackson and Calhoun counties were chosen as referent areas because they are demographically similar to Midland and Saginaw counties and were felt to be representative of the general population of Michigan with respect to sources of dioxins. In contrast to Midland and Saginaw, there is no known industrial source of dioxins in these counties. There are other potential, low level sources of dioxins in Jackson and Calhoun that are believed to be typical for Michigan. These include: a small number of industrial incinerators registered with the Michigan Department of Environmental Quality, a functioning municipal incinerator in Jackson, a hospital incinerator in Jackson that was shut down approximately 5 years ago, and a river contaminated with PCBs in a neighboring county approximately 10 miles from the border of Calhoun County. Consumption of fish from the contaminated area is believed to be minimal among the residents of Calhoun County.

These counties provide an opportunity to characterize the distribution of serum dioxins in the blood, house dust, and soils in an area that is typical of the Midwest USA, having a mixture of agriculture, manufacturing, and service industries. The goal of the present study is to determine which factors explain variation in serum congener levels, and to quantify how much variation each factor explains in this population.

Each participant in the study 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. (2-5) 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 large and complex and it 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 previous studies have included information on dietary habits, occupations, recreational activities, measured house dust contamination, and measured soil dioxin contamination in a population that was chosen because it has no unusual source of dioxin exposure. Previous studies have typically been performed where there was excessive exposure [8-10], have been based on convenience samples of the general population [11, 12], or have studied only blood dioxins [13]. Thus, there is a need for study among a representative sample of the general population that characterize the relationships between blood dioxins and soil dioxins, while controlling for other exposure pathways.

The present study will assess how much variation of the serum dioxin level is explained by each of the factors listed above, 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. Understanding the proportion of the total variation in the TEQ explained by the models allows inferences on the relative importance of various exposure sources and pathways, and may offer insights into how public health resources should be prioritized to reduce future exposures.

The results will address the following concerns:

- The pattern of congeners in the soil and serum will be examined to determine whether specific serum congener levels are correlated.
- The relationship between house dust contamination and 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 Michigan and the contamination of these food sources. 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.
- There is also concern that contamination of the Kalamazoo River in an area 10 miles from Calhoun County and the municipal incinerator in the city of Jackson may contribute to serum dioxin levels in this population. These factors will be examined to determine whether eating locally caught fish and living in proximity to the incinerator predict 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. [14] Thus, the survey methods insure that the results are applicable to the general population, which may allow population-based strategies to be developed to reduce future exposures.

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. [15] 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.

References

[1] Franzblau A, Garabrant D, Adriaens P, Gillespie BW, Demond A, Olson K, Ward B, Hedgeman E, Knutson K, Zwica L, Towey T, Chen Q, Ladronka K, Sinibaldi J, Chang S-C, Lee S-Y, Gwinn D, Sima C, Swan S, Lepkowski J. The University of Michigan Dioxin Exposure Study: Project Overview. *Organohalogen Comp 2006* (Forthcoming).
[2] Zwica L, Knutson K, Towey T, Hedgeman E, Franzblau A, Chen Q, Lee S-Y, Sima C, Gillespie BW, Adriaens P, Demond A, Lepkowski J, Ward B, Ladronka K, Olson K, Sinibaldi J, Chang S-C, Gwinn D, Swan S, Garabrant D. Measurements of Household Dust Concentrations of PCDD s, PCDFs, and PCBs From a Community In Michigan, USA. *Organohalogen Comp 2006* (Forthcoming).
[3] Hedgeman E, Chen Q, Gillespie BW, Franzblau A, Knutson K, Zwica L, Sima C, Lee S-Y, Lepkowski J, Ward B, Ladronka K, Olson K, Sinibaldi J, Towey T, Adriaens P, Demond A, Chang S-C, Gwinn D, Swan S, Garabrant D. Measurements of Serum Concentrations of PCDD s, PCDFs, And PCBs From A Community in Michigan, USA. *Organohalogen Comp 2006* (Forthcoming).
[4] Adriaens P, Demond A, Towey T, Chang S-C, Chen Q, Franzblau A, Gillespie BW, Gwinn D, Hedgeman E, Knutson K, Ladronka K, Lee S-Y, Lepkowski J, Olson K, Sima C, Sinibaldi J, Swan S, Ward B, Zwica L, Garabrant D. Measurements of Soil Concentrations of PCDDs, PCDFs, and PCBs From a Community In Michigan, USA. *Organohalogen Comp 2006* (Forthcoming).
[5] Hedgeman E, Luksemburg W, Patterson D, Knutson K, Franzblau A, Garabrant D. Methods For Processing And Analyzing Serum PCDD , PCDF, and PCB Levels For The University of Michigan Dioxin Exposure Study. *Organohalogen Comp 2006* (Forthcoming).
[6] I. Lepkowski J, Olson K, Ward B, Ladronka K, Sinibaldi J, Franzblau A, Adriaens P, Gillespie BW, Chang S-C, Chen Q, Demond A, Gwinn D, Hedgeman E, Knutson K, Lee S-Y, Sima C, Swan S, Towey T, Zwica L, Garabrant D. Survey Methodology In An Environmental Exposure Study: Methods To Assure Sound Inference. *Organohalogen Comp 2006* (Forthcoming).
[7] Olson K, Sinibaldi J, Lepkowski J, Ward B, Ladronka K, Towey T, Wright D, Gillespie BW. Missing Data In An Environmental Exposure Study: Imputation To Improve Survey Estimation. *Organohalogen Comp 2006* (Forthcoming).
[8] Eskenazi B et al. Relationship of serum TCDD concentrations and age at exposure of female residents of Seveso, Italy. Environ Health Perspect. 2004;112:22-7.
[9] Millette MD. An investigation of blood dioxin levels among persons in Calcasieu Parish, Louisiana. i-22. 2000. Lake Charles, Louisiana, ATSDR.
[10] Gibbs J, Hansen M, Ferrario J. Ambient air sampling for dioxins, furans and coplanar PCBs in an urban industrialized corridor in Calcasieu Parish, Louisiana. Organohalogen Compounds 2003;60-65.
[11] Grassman J et al. Survey of Serum concentrations of dioxins, furans, and coplanar polychlorinaed biphenyls in a small non-random sample of U.S. residents. Organohalogen Compounds 2004;66:2872-6.
[12] Patterson DGJr et al. Age specific dioxin TEQ reference range. 2004.
[13] Wingfors H et al. Multivariate data evaluation of PCB and dioxin profiles in the general population in Sweden and Spain. Chemosphere 40[40], 1083-1088. 2002. Pergamon.
[14] Olson K, Sinibaldi J, Lepkowski J, Ward B, Ladronka K. Examination of Non-Response Bias In The University of Michigan Dioxin Exposure Study. *Organohalogen Comp 2006* (Forthcoming).
[15] Olson K, Lepkowski J, Ward B, Ladronka K, Sinibaldi J, Franzblau A, Adriaens P, Gillespie BW, Bandyk J, Chang S-C, Chen Q, Demond A, Gwinn D, Hedgeman E, Knutson K, Lee S-Y, Sima C, Swan S, Towey T, Zwica L, Garabrant D. Prevalence of Exposure Routes In The University of Michigan Dioxin Exposure Study: Food Consumption, Recreational and Household Activities, Occupations And Demographics. *Organohalogen Comp 2006* (Forthcoming).