SPORT FISH CONSUMPTION BY THE GENERAL POPULATION FROM A WATERWAY CONTAMINED WITH PCDDS AND PCDFS

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Introduction

The University of Michigan Dioxin Exposure Study (UMDES) was designed to determine whether residents living on contaminated soils and participating in activities in a contaminated region have higher serum concentrations of polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) than residents of Michigan in areas with no unusual source of dioxin-like compounds. The study included a multi-stage, probability sample of the population who were interviewed in person and donated 80 mL blood, household dust and residential soil samples. The serum, household dust and soil samples were analyzed for the 29 PCDD, PCDF and polychlorinated biphenyl (PCB) congeners recognized by the World Health Organization as having dioxin-like activity.[1]

This short paper focuses specifically on sport fish consumption from the waterways immediately downstream of the local Dow Chemical Facility: the Tittabawassee River, Saginaw River, and Saginaw Bay. Monitoring of fish caught from the area over the past five years indicate that the fish are measurably accumulating PCDDs and PCDFs in their tissues with certain benthic, non-migratory species such as carp or catfish being more contaminated (3 - 40 ppt $TEQ_{DF\text{-}2005}$, wet weight) while more migratory species such as walleye are less contaminated (1.5 - 5 ppt $TEQ_{DF\text{-}2005}$, wet weight).[2,3] Additionally, though indeterminate in source, the TEQ due to coplanar-PCBs often equals or exceeds the TEQ due to PCDDs and PCDFs within fish tissues from the Saginaw River and Saginaw Bay.

Previous modeling of recent (past five years) fish consumption data from the UMDES has indicated a stable, significant *positive* relationship between consumption of walleye and/or perch from any waterbody, store, or restaurant and serum levels of 2,3,4,7,8-pentaCDF.[4,5,6] However there were no significant, positive associations between consumption of fish from the Tittabawassee River, Saginaw River or Saginaw Bay and serum levels of TCDD, 2,3,4,7,8-pentaCDF, PCB126 or the total TEQ. New variables were created collapsing the individual fish consumption variables from the Tittabawassee River and the Saginaw River/Saginaw Bay into one new variable ('TRSRSB') to mimic the PCDD and PCDF contamination in the fish. This paper presents the population data on recent fish consumption from the combined TRSRSB waterway and the results of multivariate linear regression modeling for recent sport fish consumption and serum levels of TCDD, 2,3,4,7,8-pentaCDF, PCB126 and total TEQ.

Materials and Methods

Data used has been taken from the University of Michigan Dioxin Exposure Study dataset; the entire protocol has been published elsewhere.[7] Briefly, a stratified, probability sample of the population living in three counties surrounding a Dow Chemical Facility in Midland, Michigan, USA, as well as a distant referent population was eligible. The sampled communities were limited to adults, age 18 years and older, who had lived in their current home for five or more years. For this analysis, data from the referent population was omitted, leaving the interview and serum data from 695 individuals – a population sample of residents in Midland, Saginaw and southwestern Bay Counties, Michigan, USA.

All independent variables are taken from the UMDES questionnaire results. Previous variables for Tittabawassee River fish consumption and Saginaw River/Bay fish consumption were combined into one new continuous variable (TRSRSB) by species category (walleye, perch; catfish, bullhead, carp, suckers; steelhead, trout, salmon; panfish; pike, pickerel, muskellunge; other). Stepwise linear regression methods were then used to test the significance of the new fish consumption variables with the previously tested study variables (i.e. age,

BMI, smoking, breastfeeding, occupation, game consumption, etc.).[4,5,6] Population weighting was incorporated in all regression modeling. A threshold of $p < 0.05$ was set for selection and retention of variables in the stepwise regression.

Serum analyses were performed by Vista Analytical Laboratories for the 29 PCDDs, PCDF and PCBs that make up the WHO TEQ. Observations below the limit of detection were substituted with LOD/√2. All serum results were lipid adjusted and population weighted; total dioxin concentration (TEQ) was calculated using the World Health Organization's 2005 toxic equivalency factor (TEF) weighting system.[1] Serum concentrations were first $\log_{10}$ normalized before use in models.

Results and Discussion

The population of Midland, Saginaw and Bay County, Michigan residents over the age of 18 yrs and with 5+ years at their current residence is 91% white, 53% female, has a median age of 52 years and a median BMI of 28 kg/m^2 (data not shown). The median serum $TEQ_{DFP\text{-}2005}$ for the population is 20.7 ppt with a range from 3.8 – 211 ppt (Table 1).

Within this population, 70% have consumed sport-caught fish from any waterbody within the past five years (not shown); 20% of the population has consumed sport-caught fish from the Tittabawassee River, Saginaw River, and/or Saginaw Bay within the past five years (Table 2). Fish species consumed vary, with walleye and/or perch being the dominant sport species from the contaminated area whereas walleye and/or perch, panfish (e.g. bluegill, crappie, pumpkinseed/sunfish), and steelhead, trout and/or salmon being equally preferred from other areas.

Median sport fish meal consumption from the Tittabawassee River, Saginaw River and/or Saginaw Bay among sports fish consumers within the general population is 25 meals over five years, or an average of five meals per year. Sport fish consumption ranges from only one meal of sport-caught fish over the past five years to an average of 4 meals per week from the contaminated waterway or 6 - 7 meals per week from any other waterbody, every week for the past five years. However, the 90^{th} percentile estimates indicate that, within the general population, weekly meals of sport-caught fish from TRSRSB or elsewhere are no more than one meal per week (see Table 2).

Stepwise linear regression models were run to test the association of the new fish variables with serum concentrations of 2,3,7,8-TCDD, 2,3,4,7,8-pentaCDF, PCB126 and the total TEQ (after adjustment for other significant covariates). The models explained from 60.9% of the population variance for serum TCDD concentration to 70.1% of the variance for serum 2,3,4,7,8-pentaCDF concentration to 72.0% of the population variance for serum TEQ. Of the four serum models run with the new fish variables, there were only significant, stable associations within the 2,3,4,7,8-pentaCDF and the TEQ model: walleye/perch consumption from the Tittabawassee River, Saginaw River, and/or Saginaw Bay was inversely associated with serum 2,3,4,7,8-pentaCDF concentration ($\beta = -0.0005$). Sport fish consumption from any other location was positively associated with serum 2,3,4,7,8-pentaCDF concentration ($\beta = 0.0001$), and 'other' fish consumption from the TRSRSB was inversely associated with total serum TEQ ($\beta = -0.0022$) (coefficients reflect increases/decreases in *lognormal* serum concentration for every sport fish meal consumed).

The primary hypothesis behind this analysis was that fish caught from a contaminated waterbody would lead to an increase in the contaminant levels of the population consuming them. Combining the waterways based on PCDD and PCDF contaminant levels in the fish and sediment did not significantly improve the analysis of sport fish consumption from the original study model.[4,5,6] Our data indicate that, despite the contamination known to be present in the local fish, there is little or no association of human serum levels with past five years sport fish consumption within the general population of these counties. This result is consistent with the overall findings from another United States, population-based study of adults living near industrial contamination with dioxin-like compounds and consuming locally caught fish.[9]

The University of Michigan Dioxin Exposure Study was designed to determine whether residence in a contaminated area and contact with contaminated soils increased body burden of dioxin-like compounds, hence we oversampled the population in areas where there was known soil and sediment contamination. Likewise, studies designed with the express purpose of identifying associations between human serum levels and sport fish consumption have oversampled populations believed to be frequent sport fish consumers. Within these studies, 'frequent fish consumers' consumed ≥ 26 pounds of sport-caught fish in the preceding year or an average of 49 meals per year over multiple decades.[10,11] Our study found that sport fish consumption from the Tittabawassee River, Saginaw River and Saginaw Bay in the study population was common (~20% of the population), but the majority of the general population from Midland and Saginaw Counties did not report frequent consumption (i.e., more than one meal per week) of these fish, particularly of the more contaminated benthic species. Further assessment of the impact of fish consumption from these waterways will require either more specific analysis with the available population data, such as further collapsing of sport fish consumption based on species congener patterns (which still may not be adequate) or specific oversampling of consumers of sport fish from the Tittabawassee River, Saginaw River and Saginaw Bay.

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References

1. Van den Berg M., Birnbaum L.S., Denison M., De V.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. *Toxicol Sci* 2006; 93:223.
2. Michigan Department of Environmental Quality. Fish Contaminant Monitoring Program. www.deq.state.mi.us/fcmp/
3. U.S. Department of Health and Human Services. Health Consultation: Evaluation of Saginaw River Dioxin Exposures and Health Risks, 2008.
4. Garabrant D, Hong B, Chen Q, Chang C-W, Jiang X, Franzblau A, Lepkowski J, Adriaens P, Demond A, Hedgeman E, Knutson K,Towey T, Gillespie BW. *Organohalogen Compounds* 2008; submitted.
5. Garabrant D, Hong B, Chen Q, Chang C-W, Jiang X, Franzblau A, Lepkowski J, Adriaens P, Demond A, Hedgeman E, Knutson K,Towey T, Gillespie BW. *Organohalogen Compounds* 2008; submitted.
6. Garabrant D, Hong B, Chen Q, Chang C-W, Jiang X, Franzblau A, Lepkowski J, Adriaens P, Demond A, Hedgeman E, Knutson K,Towey T, Gillespie BW. *Organohalogen Compounds* 2008; submitted.
7. University of Michigan Dioxin Exposure Study Protocol , 2005. www.umdioxin.org
8. Garabrant D, Hong B, Chen Q, Franzblau A, Lepkowski J, Adriaens P, Demond A, Hedgeman E, Knutson K, Zwica L, Chang C-W, Lee S-Y, Olson K, Towey T, Trin H, Wenger Y, Luksemburg W, Maier M, Gillespie BW. Organohalogen Compounds 2007; 69:206.
9. Wong L-Y, Millette MD, Uddin MS, Needham LL, Patterson DG, Turner W, Henderson A. *JESEE* 2008; 18:252.
10. Tee PG, Sweeney AM, Symanski E, Gardiner JC, Gasior DM, Schantz SL. *Environ Health Perspectives* 2003; 111:702.
11. Anderson HA, Falk C, Hanrahan L, Olson J, Burse VW, Needham L, Paschal D, Patterson D Jr, Hill RH Jr, The Great Lakes Consortium. Environmental Health Perspectives 1998; 106: 279.

Table 1: Lipid adjusted serum concentrations for the Midland, Saginaw and Bay County, MI population

	% < LOD	Mean	Median	Minimum	Maximum
$TEQ_{DFP-2005}$, ppt	-	26.5	20.7	3.8	211
2,3,7,8-TCDD, ppt	10.5	3.6	2.0	0.2	65.4
2,3,4,7,8-PentaCDF, ppt	0.9	7.2	6.0	0.3	50
PCB126, ppt	1.0	33.8	18	1.9	378

Table 2: Population percentages of sport-caught fish consumers and median number of sport fish meals consumed

Fish category	Percent of total population who have consumed in past five years		Number of sport fish meals over past five years†, median, 90th %ile, maximum	
	Tittabawassee and Saginaw Rivers, Saginaw Bay	Elsewhere	Tittabawassee and Saginaw Rivers, Saginaw Bay	Elsewhere
Any fish	19.7	68.3	25, 140, 1040	28, 260, 1691
Walleye, Perch	17.2	41.2	15, 60, 1040	15, 211, 780
Catfish, Bullhead, Carp, Suckers	5.8	14.0	10, 25, 145	6, 60, 523
Pike, Pickerel, Muskellunge	1.7	8.9	25, 360, 360	10, 120, 260
Bass	1.3	18.3	20, 20, 20	10, 50, 360
Panfish	3.0	34.4	15, 25, 660	10, 100, 520
Steelhead, Trout, Salmon	2.7	37.3	15, 60, 200	10, 60, 978
Other	0.5	10.3	5, 5, 150	5, 30, 520

†Limited to the population who consumes the specified fish category.