PCDDs and PCDFs in Small Mammals Foraging in the Tittabawassee River Floodplain, Michigan

S.J. Coefield[1], M.J. Zwiernik[1], R.M. Seston[1], T.B. Fredricks[1], J.N. Moore[1], D.L. Tazelaar[1], D.P. Kay[2], P.D. Jones[1], P.W. Bradley[1], and J.P. Giesy[1]

[1]Michigan State University, East Lansing, MI and [2]ENTRIX, Inc., East Lansing, MI

National Food Safety and Toxicology Center
Zoology Department
MICHIGAN STATE UNIVERSITY

ENTRIX

ABSTRACT

The Tittabawassee River located in central Michigan is known to contain elevated concentrations of polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in sediments, floodplain soils, and fish downstream of Midland, MI. The Aquatic Toxicology Laboratory at Michigan State University is investigating the impact of this contamination on the terrestrial ecosystem, using the Great Horned Owl (GHO) and insectivorous shrews as indicator species. Mammals, including herbivorous small mammals (chipmunks, mice, voles, and flying squirrels) and insectivorous shrews were sampled at two locations upstream and four locations downstream of Midland from 2003-2004. The results from the mammal data will be used in part to extrapolate GHO dietary exposure to PCDF/Ds. Total concentrations of seventeen 2,3,7,8 PCDF/PCDD congeners, expressed as avian TEQs, ranged from 0.228-4.61 ng/kg, ww, for herbivorous small mammals and 0.38-25.3 ng/kg, ww, for insectivorous shrews at the reference area. Concentrations of avian TEQs downstream of Midland ranged from 3.48-880 ng/kg, ww, for herbivorous small mammals and 22.9-8790, ww, ng/kg for shrews. The significant difference between the shrew and concentrations in other small mammals is due to their different diets and underlines the importance of dietary composition in determining contaminant exposure.

INTRODUCTION

The elevated PCDF/D levels in the Tittabawassee River floodplain soils and sediments has prompted an examination of its impact on the terrestrial ecosystem.

This study was designed specifically to measure PHAH concentrations in terrestrial small mammals that typically comprise the diet of great horned owls. Small mammals are good indicators of the presence of chemicals in terrestrial ecosystems for several reasons: (a) they integrate their exposures over a broad area and yet their entire home range is much smaller than the area to be studied; (b) they occupy a major prey position in trophic food webs; (c) they ingest materials with direct exposure to soil (e.g, plants, terrestrial invertebrates, etc.).

METHODS AND MATERIALS

- Small mammals were collected from six sites (2 references, 4 target) from May-July 2004
- The mammals were trapped in 30 x 30m grids of alternating Sherman and pitfall traps (Figures 1 and 2).
- Prior to homogenization, mammals were identified to species and GI tract content was removed.
- Chemical extraction followed EPA method 3540C and 3541.
- Congener-specific PCDF/D analysis was conducted with GC/high resolution MS following EPA method 8290 at AgriQuality Limited (Lower Hutt, New Zealand).
- Great horned owl food intake rate based on literature values.
- Great horned owl average potential daily dose estimated based on avian-specific World Health Organization (WHO_{Avian}) TCDD equivalency factors.
- Small mammal body burdens were calculated based on mammalian-specific World Health Organization ($WHO_{Mammalian}$) TCDD equivalency factors.

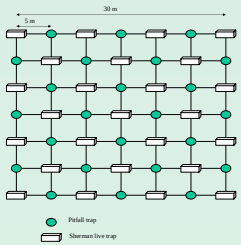


Figure 1. Small mammal trapping grid.

Figure 2. Small mammal capture.

Representative Great Horned Owl Diets for Michigan

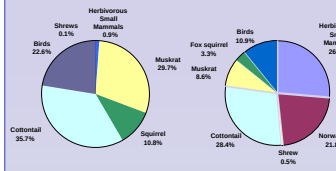


Chart 5. GHO Dietary Composition by Biomass (Strause 2005)

Chart 6. GHO Dietary Composition by Biomass (Craighead and Craighead 1956)

Deer mouse

Great horned owl prey remain analysis

RESULTS AND DISCUSSION

The PCDF/D concentrations in small mammals downstream of The Dow Chemical Co in the target area is significantly higher than PCDF/D concentrations of small mammals in the reference areas. In addition, contaminant concentration differed dramatically between small mammal species with herbivorous vs. insectivorous diets (see Charts 1 and 2). The PCDF/D concentrations in shrews exceeds the body burden TRV for TCDD. In studies with rats, significant decreases in fertility, litter size, gestation survival, neonatal survival and growth were seen in animals with 130 ng/kg TCDD maternal body burden. However, roughly 90% of the TEQs measured in small mammals in the target area are comprised of the furans 2,3,4,7,8-PeCDF and 1,2,3,4,7,8-HxCDF, 1,2,3,7,8-PeCDF, and 2,3,7,8-PeCDF. Differences in pharmacokinetics between the congeners and TCDD lends uncertainty to a TRV based on TCDD-derived values.

The marked difference between contaminant concentrations in shrews and other small mammals is a function of their dietary intake. A shrew's energy expenditure surpasses that of any other mammal. Because of its high metabolism, it feeds frequently, both day and night. Some species may consume more than their own weight in food per day, eating mainly invertebrates but also plants, fungi, and other small mammals. In contrast, the remaining small mammal species trapped in this study have lower metabolic rates and largely consume plant matter. The data from this study highlight the importance of dietary composition in understanding and predicting contaminant exposure.

Chart 1. Representative Mean Reference Small Mammal PCDF/D Concentrations from Sanford (Site 1)

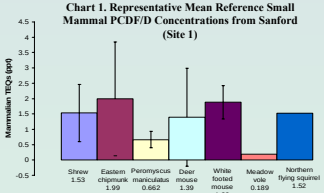


Chart 2. Representative Mean Downstream Small Mammal PCDF/D Concentrations from Smith's Crossing (Site 3)

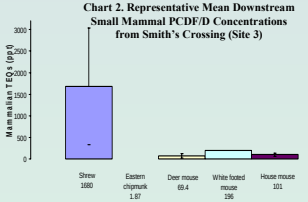


Chart 3. Sanford Mammalian TEQs (1/2 DL)

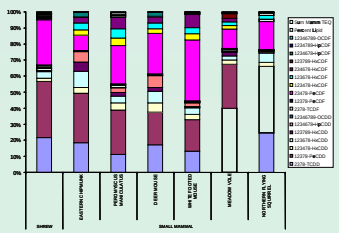
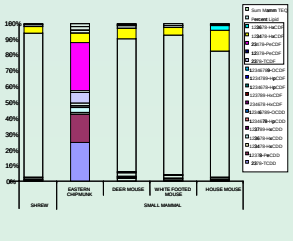


Chart 4. Smith's Crossing Mammalian TEQs (1/2 DL)



GREAT HORNED OWL DIETARY EXPOSURE TO PCDF/ DDs AND FUTURE WORK

Literature based GHO diets attribute a range of herbivorous small mammals of 1 - 25% of the GHO's dietary biomass, and shrew 0.1 - 0.5% of the GHO dietary biomass (see Charts 5 and 6). The actual Tittabawassee River GHO dietary composition is most likely somewhere between these values.

Using literature values for GHO dietary intake (26g/kg/day), and the daily wildlife dose equation for dietary exposure, we can predict the GHO potential daily dietary exposure to PCDD/DF from consumption of small mammals (Table 1).

$$ADD_{pot} = \sum_{k=1}^{m}(C_k \times FR_k \times NIR_k)$$

Table 1. Estimated Daily dietary dose (ng/kg/day) ranges based on WHO_{Avian} TEQs for total TCDDs and literature-based dietary compositions.

Small Mammals	Herbivorous Small Mammals (1.0 to 25% of GHO diet)	Shrews (0.1 to 0.5% of GHO diet)	Total GHO Small Mammal Dietary Exposure Range (1.1 to 25.5% of GHO diet)
ADDpot Reference	$4.36x10^{-4}$ to $1.09x10^{-2}$	$2.70x10^{-4}$ to $1.35x10^{-3}$	**$7.06x10^{-4}$ to $1.23x10^{-2}$**
ADDpot Target	$4.14x10^{-2}$ to 1.04	$5.65x10^{-2}$ to $2.83x10^{-1}$	.

Future work will entail analyzing prey remains collected from the study area and constructing site-specific dietary compositions for the great horned owl to be used to more accurately predict dietary exposure to contaminants.

Great horned owl

CONCLUSIONS

- PCDF/PCD body burdens of small mammals foraging in the contaminated area are greater than those of the reference areas.
- 2,3,4,7,8-PeCDF is the predominant congener in small mammals foraging in the contaminated area.
- PCDF/PCDD concentrations vary depending on small mammal feeding guild.
- The average shrew $TEQ_{mammalian}$ body burden exceeds the lowest body burden known to cause reproductive effects in rats. However, the predominance of furans lends uncertainty to the TCDD-based body burden TRV.
- Great horned owls in the Tittabawassee floodplain may receive a potential average daily intake of 0.09 – 1.32 ng $TEQ_{WHO\ avain}$ /kg/day from small mammal consumption.

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Short tailed shrew

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