

ACCUMULATION OF DIOXINS AND FURANS IN TREE SWALLOWS (*TACHYGINETA BICOLOR*) NESTING NEAR CENTREDALE MANOR RESTORATION PROJECT SUPERFUND SITE, RHODE ISLAND

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Introduction

From at least 1921 to 1940, the area that is now the Centredale Manor Restoration Project Superfund Site, North Providence, RI was the location of textile manufacturing activities. Between 1952 and 1971, the site was used for chemical manufacturing and drum recycling. An estimated 219,869 square feet of contaminated fill is present at the Site; the main contaminant of concern is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD).

The U.S. Environmental Protection Agency (EPA) is conducting an ecological risk assessment at the Site. The tree swallow (*Tachycineta bicolor*) was one ecological receptor chosen for study. Tree swallows are widely used to quantify bioavailability, distribution, and effects of local sediment contamination¹⁻⁵. Tree swallows readily use nest boxes, so study sites can be established at specific locations of interest. They feed within 400 m⁶ of their nest box on emergent aquatic insects⁷. Residues in their tissues thus reflect local sediment contamination for chemicals that transfer into the biota⁸. Swallows will nest at high densities so adequate sample sizes can be obtained. Finally, data are available on dioxin and furan concentrations in tree swallows at a number of locations across North America^{1-5,9}.

Because tree swallows are migratory birds, concentrations found in eggs could have been acquired elsewhere. Calculation of accumulation rate in nestlings can be used to quantify local exposure because nestlings are only fed from the local area and the contaminant mass contributed from the egg is factored out.

The objective of this study was to determine if tree swallows were accumulating dioxins and furans at the Centredale Manor Restoration Project Superfund Site.

Methods

Fifty-nine swallow nest boxes were attached to posts during early spring 2000 along the shoreline of Allendale Mill Pond (29 boxes), hereafter called Allendale, and Greystone Mill Pond (30 boxes), hereafter called Greystone. An additional 30 boxes were put up on Lyman Mill Pond, hereafter called Lyman, in 2001. Allendale (4636109 Northing, 293847 Easting) is an impounded area on the Woonasquatucket River and is just downstream of the intersection of highways 44 and 15, Centerdale, RI. This is the location where the contamination is thought to have originated. Lyman (4635133N, 294172E) is the first pond downstream of Allendale, and Greystone (4636109N, 293867E) is the first pond upstream of the Superfund Site.

Nest boxes were visited approximately once per week beginning in early May until late June each year. A sample of 2 - 3 eggs per clutch (5 clutches/site) was collected at approximately mid-incubation in 2000 and as each clutch started to hatch in 2001. An 11 - 13 day-old nestling was also collected from each nest box where sibling eggs were previously collected. All samples were collected under appropriate state and federal collecting permits.

Eggs and nestlings were removed from the nest box and weighed. Contents of eggs from an individual nest box were emptied into a chemically clean jar; eggshells were discarded. Nestlings were decapitated with a sharp pair of scissors¹⁰. Contents of the upper gastrointestinal tract were removed, as was a small (<0.2 g) piece of the liver (data not reported here). The carcass remainder (including the head and the rest of the liver) was placed in a chemically-clean jar. The eggs and carcass remainders were frozen until shipped to Battelle, Columbus, Ohio for chemical analysis.

Dioxins (7 congeners) and furans (10 congeners) were analyzed in tree swallow eggs and carcass remainders. Chemicals analyzed were 2,3,7,8-TCDD; 1,2,3,7,8-PeCDD; 1,2,3,4,7,8-HxCDD; 1,2,3,6,7,8-HxCDD; 1,2,3,7,8,9-HxCDD; 1,2,3,4,6,7,8-HpCDD; OCDD; 2,3,7,8-TCDF; 1,2,3,7,8-PeCDF; 2,3,4,7,8-PeCDF; 1,2,3,4,7,8-HxCDF; 1,2,3,6,7,8-HxCDF; 1,2,3,7,8,9-HxCDF; 2,3,4,6,7,8-HxCDF; 1,2,3,4,6,7,8-HpCDF; 1,2,3,4,7,8,9-HpCDF and OCDF. See Battelle¹¹ for details of the chemical analyses.

Accumulation rates (pg/day)² were calculated for each egg/nestling pair and compared among year/sites using analysis of variance (ANOVA) followed by Bonferroni mean separation tests. Data were rank transformed to satisfy the homogeneity of variance assumption of ANOVA. Normality was preserved with this transformation. Contaminant mass (pg) in eggs and nestlings was calculated by multiplying the concentration (pg/g) in the sample by the sample mass (g). The accumulation rate was calculated by subtracting the contaminant mass in the egg from the contaminant mass in the nestling and dividing by the age of the nestling. Accumulation rate was calculated and statistically analyzed only for congeners present in >50% of samples.

Results

All 7 dioxin and 8 of 10 furan congeners were detected in >50% of samples and were statistically analyzed. The 2 furans not detected in >50% of samples were 1,2,3,7,8,9-HxCDF and 1,2,3,4,7,8,9-HpCDF. Accumulation rates were positive for TCDD at all locations in both years (Table 1). The magnitude of accumulation rate per day was higher for TCDD (> 900 pg/day) at both Allendale and Lyman in 2000 and 2001 than at the upstream reference site (Greystone, <15 pg/day).

Accumulation rates of 2 dioxin congeners (1,2,3,4,6,7,8-HpCDD and OCDD) and 2 furan congeners (1,2,3,4,6,7,8-HpCDF and OCDF) did not differ among sites ($P > 0.05$). The remaining 4 dioxins and 6 furans had positive average accumulation rates that varied among sites (Table 1). In most of these instances (13 of 20 possible comparisons), Greystone did not differ from Allendale. Additionally, the magnitude of accumulation rate differences among sites for these other congeners was small compared to TCDD. For example, the average accumulation rate of TCDD at Allendale was 147 times greater than that at Greystone in 2000 and 122 times greater in 2001. The difference in accumulation rate for the other dioxin and furan congeners, between Allendale and Greystone or Lyman and Greystone was less than a factor of 4.

Discussion

The very high and positive accumulation rates of TCDD in nestlings at Allendale in 2000 and 2001 and Lyman in 2001 indicated local contamination at these sites. Average accumulation rates for

TCDD at Allendale were 988 and 1736 pg/day; at Lyman the rate was 1686 pg/day. Upstream of the Centredale Manor Restoration Project Superfund Site TCDD contamination was much less. Accumulation rates were positive at Greystone, but only averaged 7 pg/day in 2000 and 14 pg/g in 2001.

These accumulations rates are high compared to other locations. In other studies, TCDD was detected in too few egg or nestling samples for an accumulation rate to even be calculated. For example only 12% of eggs contained detectable concentrations of TCDD along the Housatonic River, western Massachusetts⁴ where dioxins and furans were probably a contaminant of the PCBs in that system. Along the Wisconsin River, Wisconsin, at sites down stream of historic pulp and paper mills, only 13% of swallow eggs contained TCDD⁵. If TCDD is not detected then accumulation rates will be negligible.

The highly positive accumulation rates of TCDD at both Allendale and Lyman compared to the upstream reference site (Greystone) indicated that TCDD contamination of tree swallows nesting at the Centredale Manor Restoration Project Superfund Site or in the first pond downstream of the Superfund Site is bioavailable and originated from the sediments in those two ponds. Concentrations of TCDD in excess of 4000 pg/g have been detected in those sediments¹². The remaining dioxins and furans were present at more similar concentrations in nestlings throughout the system than when compared to TCDD. The accumulation rates for other dioxin and furan congeners either did not differ among any of the sites (4 congeners), did not differ between Greystone and Allendale (13 of 20 comparisons) or Greystone and Lyman (6 of 10 comparisons), or the magnitude of the differences was small between the upstream reference and the downstream sites.

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Table 1. Mean accumulation rates (pg/day) for dioxin and furan congeners in tree swallows nesting near Centredale Manor Restoration Project Superfund Site, Rhode Island in 2000 and 2001.

Analyte	Year	Location	Mean		SE
2,3,7,8-TCDD <i>P</i> < 0.001	2000	Greystone	6.70	B ¹	1.03
		Allendale	987.7	A	236.8
	2001	Greystone	14.18	B	6.19
		Allendale	1736.4	A	250.4
		Lyman	1685.9	A	421.4
1,2,3,7,8-PeCDD <i>P</i> = 0.011	2000	Greystone	1.78	B	0.19
		Allendale	3.18	AB	0.67
	2001	Greystone	3.72	B	2.96
		Allendale	5.15	AB	0.43
		Lyman	6.01	A	0.55
1,2,3,4,7,8-HxCDD <i>P</i> < 0.001	2000	Greystone	1.57	B	0.22
		Allendale	2.97	AB	0.78
	2001	Greystone	2.42	B	0.36
		Allendale	5.24	A	0.42
		Lyman	5.69	A	0.67
1,2,3,6,7,8-HxCDD <i>P</i> < 0.001	2000	Greystone	3.15	C	0.91
		Allendale	6.10	BC	1.91
	2001	Greystone	5.55	ABC	1.42
		Allendale	15.3	A	2.88
		Lyman	14.1	AB	2.90
1,2,3,7,8,9-HxCDD <i>P</i> < 0.001	2000	Greystone	1.00	C	0.08
		Allendale	1.36	BC	0.47
	2001	Greystone	1.13	C	0.34
		Allendale	4.23	A	0.74
		Lyman	2.59	AB	0.34

Analyte	Year	Location	Mean		SE
2,3,7,8-TCDF <i>P</i> = 0.003	2000	Greystone	5.44	B	0.47
		Allendale	6.67	AB	1.77
	2001	Greystone	7.10	AB	1.29
		Allendale	11.41	A	0.98
1,2,3,7,8-PeCDF <i>P</i> = 0.001	2000	Greystone	1.02	B	0.10
		Allendale	1.35	AB	0.36
	2001	Greystone	1.40	AB	0.18
		Allendale	2.29	A	0.21
2,3,4,7,8-PeCDF <i>P</i> = 0.001	2000	Greystone	1.03	B	0.11
		Allendale	1.61	B	0.44
	2001	Greystone	1.67	B	0.25
		Allendale	5.18	A	1.42
1,2,3,4,7,8-HxCDF <i>P</i> < 0.001	2000	Greystone	1.09	C	0.09
		Allendale	1.46	BC	0.41
	2001	Greystone	1.47	BC	0.39
		Allendale	3.52	A	0.51
1,2,3,6,7,8-HxCDF <i>P</i> < 0.001	2000	Greystone	1.11	C	0.09
		Allendale	1.72	BC	0.47
	2001	Greystone	1.15	C	0.25
		Allendale	3.28	A	0.23
2,3,4,6,7,8-HxCDF <i>P</i> < 0.001	2000	Greystone	0.30	C	0.05
		Allendale	1.09	AB	0.20
	2001	Greystone	0.57	BC	0.14
		Allendale	1.59	A	0.19
		Lyman	1.09	AB	0.15

¹ Means sharing same letter are not significantly different. *df*=4,20. *N* = 5 nestlings per year/site.