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DDT Contamination at Wheeler National Wildlife Refuge

Abstract. *Disposal of industrial waste resulted in massive DDT contamination at Wheeler National Wildlife Refuge, Alabama. Nearly a decade after the cessation of DDT manufacturing at the facility responsible, concentrations of DDT residues in the local fauna are still high enough to suggest avian reproductive impairment and mortality. Populations of fish-eating birds are low, endangered species are being exposed, and muscle lipids of game birds contain up to 6900 parts of DDT (isomers and metabolites) per million.*

The impact of toxic waste on the environment is often difficult to assess (*1*). However, the effects of DDT pollution are well known and have helped spur the environmental movement. In particular, data on DDT residues have been experimentally tied to harmful effects in various wildlife species. In this report we document the effects of massive contamination of an important national resource with industrial DDT.

From 1947 to 1970, DDT was manufactured on a site leased from the U.S. Army at Redstone Arsenal, Alabama. Production reached approximately 10^6 kg per year in 1963 (*2*); more than 6×10^5 kg were produced in 1970 prior to June of that year, when manufacture ceased. A ditch carrying effluent from the factory ran directly into Wheeler National Wildlife Refuge, where it joined Huntsville Spring Branch, a tributary to the Tennessee River, about 1 km from the plant site. The refuge, a 140-km^2 area administered by the U.S. Fish and Wildlife Service, is the major waterfowl refuge in Alabama, with winter populations recently estimated at 80,000 ducks and geese; in the past, population peaks of 150,000 were recorded (*3*).

In the 1960's, attempts were made to contain the effluent by dumping it in holding ponds or hauling it to landfills. Even so, the amount of DDTR (the simple sum of DDT isomers and metabolites) currently present in the sediments of Huntsville Spring Branch within the boundaries of the wildlife refuge has been estimated to be as high as 4×10^6 kg (*4*). Gross contamination is not limited to the aquatic system; in February 1979 we collected fist-sized chunks of crystalline material lying on the ground near the plant site; this material was 21 percent DDT.

Table 1. Concentrations of DDTR in selected fauna collected in February 1979 at Wheeler National Wildlife Refuge and the adjacent Redstone Arsenal. Abbreviations: Max, maximum; GM, geometric mean; and CI, 95 percent confidence interval.

Species and tissue	DDTR (ppm)	
	Wet weight basis	Lipid weight basis
Mallard ducks (N = 27)		
Carcass		
Max	480	6730
GM	4.0	38.0
CI	1.6–9.9	15–49
Muscle		
Max	150	6900
GM	0.67	11.5
CI	0.31–1.4	2.1–49
Crows (N = 14)		
Muscle		
Max	49	1470
GM	4.0	123
CI	1.4–11.2	42–355
Cottontail rabbits (N = 4)		
Muscle		
Max	0.52	79
GM	0.27	21.7
CI	0.12–0.62	0–626
Swamp rabbits (N = 5)		
Muscle		
Max	0.58	79
GM	0.25	18.0
CI	0.10–0.50	1.1–170

Birds, rabbits, and earthworms were collected for residue analysis in February 1979 (*5*), nearly 9 years after the manufacture of DDT at the Redstone site was halted. Mallard ducks (*Anas platyrhynchos*) were collected from flocks entering an evening roosting area on Huntsville Spring Branch approximately 0.5 km downstream from its confluence with the drainage ditch. Crows (*Corvus brachyrhynchos*), cottontail rabbits (*Sylvilagus floridanus*), and swamp rabbits (*Sylvilagus aquaticus*) were collected 0.4 to 0.5 km from the plant site. Composite samples of earthworms (*Bimastos, Dendrobaena,* and *Diplocardia*) were obtained about 0.1, 0.3, and 1.0 km from the factory.

Concentrations of DDTR in these fauna are high (Table 1). On a lipid weight basis, concentrations of residue in the muscle of the rabbits and birds exceeded established tolerances for human consumption of domestic animals in 37 of 50 samples (*6*). The concentration of DDTR in whole carcasses of female mallards was as high as 480 parts per million (ppm) (wet weight), and the geometric mean for DDE (1,1-dichloro-2,2-bis(*p*-chlorophenyl)-ethylene) in these females was 3.8 ppm (6.1 ppm DDTR) (*7*). In an experimental study, females of the closely related black duck (*Anas rubripes*), with whole-carcass DDE residues averaging 3.4 ppm, produced eggs with shells nearly 10 percent thinner than those of control eggs (*8*). Also, the overall productivity of these females was found to be significantly lower than that of controls ($P < .05$, χ^2 test). In captive mallard ducks reproductive effects due to DDE occur for periods of at least 11 months after cessation of exposure (*9*) and in captive black ducks for at least 2 years after exposure (*8*).

Waterfowl wintering at Wheeler National Wildlife Refuge migrate from as far north as Ontario (*10*). Our data and those of Longcore and Stendell (*8*) and Haegele and Hudson (*9*) indicate that impaired reproduction on breeding grounds far removed from the refuge is highly likely. In addition, contamination from this one source has had a strong influence on the interpretation of DDT residue data for the entire waterfowl population of Alabama. Nationwide monitoring of pesticides in waterfowl wings since the mid-1960's has shown that DDT and DDE concentrations in Alabama waterfowl are among the highest in the United States. Up to 50 percent of all ducks killed by Alabama hunters come from a tricounty area surrounding the refuge; and the residues found in these animals, high enough to indicate im-

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paired breeding, inflate state averages to abnormal levels (*11*).

Wintering mallard ducks occupy a relatively low trophic level compared to that of other avian species. In addition, seasonal migrations were under way at the time collections were made, and individuals in transit from less contaminated locations were undoubtedly included in our sample. Consequently, the presence of high concentrations of residue in the mallards underscores the seriousness of the contamination problem at Wheeler. The elevated mean DDTR concentration in muscle of wintering crows (Table 1) shows the potential for greater effects higher in the food web of the refuge. Piscivorous birds would be expected to suffer the most, and the depauperate state of this component of the local fauna is notable. According to refuge personnel (*3*), thousands of double-crested cormorants (*Phalacrocorax auritus*) used to winter at Wheeler but are now rarely seen; bald eagles (*Haliaeetus leucocephalus*) have not bred in the refuge since the late 1940's; and a mixed-species heron rookery (250 to 300 nests) showed a precipitous population decline in 1950–1951, and all reproductive activity there has since ceased (*12*). Several endangered species inhabit the refuge, including gray bats (*Myotis grisecens*), Indiana bats (*Myotis sodalis*), and transient bald eagles, but the impact of the DDT on these animals is not known.

In addition to the reproductive effects implied by the DDT residue data, direct avian mortality due to DDT poisoning also seems possible. Earthworms collected from beneath the litter of a bottomland hardwood forest 70 m northwest of the confluence of the drainage ditch and Huntsville Spring Branch had a dry weight DDTR concentration of 326 ppm (including 224 ppm DDT), which approaches or exceeds concentrations in earthworms that have been associated with lethality in wild populations of birds of the genus *Turdus* (*13*). The samples of earthworms collected in different habitats 0.1 and 0.3 km from the plant site contained DDTR at 74.2 and 5.2 ppm (dry weight), respectively. These concentrations do not imply lethality, but approach or exceed dietary levels that were shown to impair reproduction in experimental studies of several bird species (*14*).

To our knowledge, these data constitute the first documentation of gross pollution with industrial DDT in terrestrial and freshwater ecosystems. Past studies have reported extensive contamination of marine life off Southern California by DDT that was discharged directly into the ocean by a Los Angeles pesticide manufacturer (*15*). Very little was known about the effects of DDT on ecosystems at the time these disposal practices were initiated. Just as little is known about many chemicals in wastes currently being discharged into the environment. These examples demonstrate the environmental consequences of inadequate waste disposal practices. The persistence of harmful residues nearly a decade after the cessation of DDT manufacture near Wheeler emphasizes the need for safeguards and well-planned programs for disposing of all toxic chemical wastes.

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4. "DDT residues in sediments and fish in the vicinity of Redstone Arsenal, Alabama" (unpublished report, Tennessee Valley Authority, Chattanooga, 1978). Residues in fish are also reported to be very high by the Tennessee Valley Authority, and there is concern for the health of local residents engaged in subsistence fishing [*Morb. Mortal. Wkly. Rep.* **28**, 123 (1979)].
5. We analyzed a 10-g portion of the homogenized sample for organochlorine pesticides and polychlorinated biphenyl compounds by gas-liquid chromatography with a 1.5 percent OV-17 and 1.95 percent QF-1 column. The lower limit of reportable residues was 0.10 ppm for pesticides and 0.25 ppm for polychlorinated biphenyls. The analytical procedures were described by E. Cromartie *et al.* [*Pestic. Monit. J.* **9**, 11 (1975)], except that the organochlorines were separated into four fractions rather than three (T. E. Kaiser *et al.*, *ibid*, in press).
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Calcium Regulation During Stimulus-Secretion Coupling: Continuous Measurement of Intracellular Calcium Activities

Abstract. *Accurate measurements of intracellular calcium activities in salivary gland epithelial cells of the insect* Phormia regina *were obtained with microelectrodes in which* N,N′-*di(11-ethoxycarbonyl)undecyl*-N,N′-*4,5-tetramethyl-3,6-dioxaoctane diacid diamide was incorporated in a liquid membrane system. When calibrated in solutions approximating the ionic concentration of the cell interior, these microelectrodes gave rapid stable responses that were linear functions of the logarithm of calcium activities and were not affected by potassium, sodium, and magnesium. Continuous monitoring of calcium activities during serotonin-induced saliva release provided direct evidence of hormonal influence on transmembrane calcium movement and spontaneous regulation of intracellular calcium by stimulated cells.*

Sensitive intracellular measurements of ionized Ca^{2+} are essential for understanding the mechanisms of Ca^{2+} regulation in cells and for the elucidation of cellular events such as contraction, excitation, secretion, and hormone action. The most successful procedures currently employed for measuring Ca^{2+} in biological systems make use of the photoluminescent protein aequorin and metallochrome absorbance indicators (*1*). Although these methods are extremely sensitive and can be used to measure the Ca^{2+} content of subcellular fractions as well as of intact cells, satisfactory calibration of the indicator signal over a wide range of Ca^{2+} concentrations is difficult because of changes in nonspecific absorption. This difficulty can be offset to some extent by using different

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