



Organochlorine Pesticide Concentrations in Water, Soil and Sediment of the Indian Creek and Huntsville Spring Branch Watersheds



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ABSTRACT

The persistence of pesticides in terrestrial and aquatic ecosystems of the Indian Creek (ICW) and Huntsville Spring Branch (HSBW) watersheds is a major concern for North Alabama. This particular study entailed the collection of 54 soil and sediment samples from upland, bank and in-stream depositional areas within these two watersheds. Concentrations of 22 pesticides were determined through dual-column analysis using GC-ECD. The most predominant occurrences were observed for DDT (dichlorodiphenyltrichloroethane), DDE, DDD, heptachlor and various endrin compounds. OCP concentrations ranged from undetectable to 5080 µg/kg-dw. An obvious trend was observed for DDT and its metabolites. DDT-DDE-DDD, respectively. OCP concentrations tended to be higher at the upland positions and in the HSBW, especially at site 9. Overall, ICW showed more consistent detections for many of the compounds. Many of the OCPs also exceeded established water and soil quality criteria. These findings were attributed to variations in absorption, volatilization, plant uptake, microbial degradation, land use and other processes affecting the degradation and retention of these pesticides at specified locations.

INTRODUCTION

Organochlorine Pesticides
Numerous studies have shown that organochlorine pesticides (OCPs) pose significant health and environmental risks (Wagener et al., 2008). Nonetheless, they have been used extensively worldwide in agriculture and to control soil dwelling and vector carrying insects (Table 1).

Biomagnification, environmental persistence, and chronic impacts on aquatic and terrestrial organisms are among the disadvantages associated with the use of OCPs. Most OCPs have been shown to be toxic to fish, invertebrates, mollusks, birds, and humans due to bioaccumulation in the food chain (Hellwell, 1988; ILO, 1996).

They usually reach aquatic ecosystems through erosion and runoff from agricultural and contaminated land, atmospheric deposition, and discharging of effluents from factories and sewage (Beitz et al., 1994). Their lipophilic nature causes them to concentrate in the tissue of exposed organisms (Smith and Gangoli, 2002). Equally important, factors like low solubility and high soil adsorption coefficients cause OCPs to persist in the environment for years after their initial entry (Barbush et al., 1996; PAN, 2008).

According to a study by Gilliom (2007), pesticides were detected 90% of the year in NAWQA streams that had developed watersheds. They were found in the fish and sediment of most of the streams investigated. It was concluded that despite bans, most of the nation's rivers and streams are contaminated with pesticides.



Figure 1a) DDT being sprayed to prevent insect bites (b) DDT (c) Eggs damaged by OCPs.

Relevance of Historical Pollution

For years, DDT was manufactured on Redstone Arsenal by the Olin Chemical Company. Manufacturing, handling, and disposal practices eventually led to the discharge of DDT residues throughout the arsenal's drainage system into the nearby HSB-IC tributary system. It is estimated that 4.32 x 10⁵ to 8.0 x 10⁶ kg of DDT residues were discharged into the ICW and HSBW, resulting in contamination of nearby waterways and more than 1400 acres of the Wheeler National Wildlife Refuge (WNNR) (Figure 2) (Rebitzke, 2003; Reich et al., 1985). Disturbance and redistribution of these compounds as well as other historical OCPs are a major concern for surface water quality in these areas.

Objectives

- To assess the occurrence and spatial distributions of OCPs in the surface water, surrounding alluvial sediment, and soils of selected areas within these watersheds.
- To assess the potential for sediment toxicity within the ecosystems.

FOCUS OF RESEARCH

This research examines the occurrence and spatial distribution of organochlorine pesticides in water, soil and sediment of the Indian Creek and Huntsville Spring Branch watersheds of North Alabama.



Site 1: Dry Creek @ Kelly Springs Rd



Site 6: (Big Spring @ Dismoreaux Rd)



Site 2: (IC @ Hwy 72)



Site 9: (HSB @ Johnson Rd)



Site 5: (IC @ Tennessee River)



Site 5: (HSB @ Passes Road)



Figure 2 a) HSB & IC Watersheds & Sampling Sites by the HSB-IC Tributary System in the Wheeler Lake Basin

Table 2. Sediment Quality Criteria for OCPs used to Screen Sediment for Protection of Aquatic Life (µg/kg).

Pesticide	Aquatic Invertebrates		Terrestrial Invertebrates		Aquatic Fish		Terrestrial Birds		Marine & Estuarine Fishes		Terrestrial Mammals	
	LC50	NOEC	LC50	NOEC	LC50	NOEC	LC50	NOEC	LC50	NOEC	LC50	NOEC
Aldrin	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
β-BHC	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
γ-BHC	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
Chlordane	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
DDT	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
DDE	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
DDD	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
Endrin	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
Endrin ketone	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
Endrin aldehyde	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
Heptachlor	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
Heptachlor epoxide	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
Methoxychlor	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1

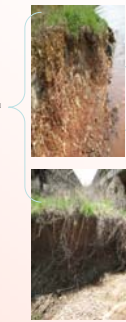


Figure 3: Upland, bank and in-stream locations.



Figure 4: Land use/land cover for the ICW and HSB Watershed.

REFERENCES

1. Beitz H., H. Schmidt, F. Herzel. 1994. Occurrence, toxicological and ecotoxicological significance of pesticides in groundwater and surface water. Chem Plant Protection. 8:3-53.
2. Gilliom R.J. 2007. Pesticides in U.S. Streams and Groundwater. Environmental Science and Technology. U.S. Geological Survey Pesticide National Synthesis Project. National Water Quality Assessment Program (NAWQA). 41(10): 3409-3414.
3. Greenberg, A.F., L.S. Clesceri, & A.D. Eaton. 2000. Standard Methods for the Examination of Water and Wastewater. 18th Ed. Am. Public Health Assoc., Washington, DC.
4. Rebitzke J. 2003. Environmental Justice Case Study: DDT Contamination. Triana, AL. Environmental Justice Case Studies. University of Michigan, School of Natural Resources and Environment. Pp. 1-6.
5. Reich A.R., J.L. Perkins, G. Cutter. 1986. DDT Contamination of North Alabama Aquatic Ecosystem. Environmental Toxicology and Chemistry. 5:873-735.
6. Wagener L.P., A.T. Lemley, F.J. Wagener. 2008. A review of physical-chemical parameters related to the soil and groundwater fate of selected pesticides used New York State. Cornell University Press. Internet Online Source.
7. Webber E.C., D.R. Bayne, and W.C. Seacock. 1988. DDT contamination of benthic macroinvertebrates and sediments from tributaries of Wheeler Reservoir, Alabama. Archives of Environmental Contamination and Toxicology. 18(5): 728-733.

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Other References Available Upon Request.

RESULTS & DISCUSSION

Pesticides in Soil and Sediment

Results for the soil/sediment showed that the watersheds are still polluted with a variety of promulgated OCPs. As indicated in Figure 5, OCP occurrences in soil/sediment were widespread in both watersheds. They were detected in all of the sites and in upland, bank and in-stream positions. Concentrations ranged from undetectable to 5080 µg/kg-dw.

Sixteen of the OCPs investigated were found and they were detected in 46 of the 54 samples analyzed; only 4 samples from each of the watersheds showed undetectable levels of OCPs. Additionally, the number of OCPs detected in the HSBW (14) almost doubled those of the ICW (8). Many of the concentrations were also substantially higher in the HSBW. Aldrin, α-BHC, γ-BHC, δ-BHC, endosulfan sulfate and methoxychlor were not detected in any of the soil/sediment samples, even though aldrin and γ-BHC were observed in the water samples.

The ICW showed detections for DDD (Σ = 401.10), DDE (Σ = 414.33), DDT (Σ = 543.83), endrin (Σ = 5.39), endrin aldehyde (Σ = 7.43) and endrin ketone (Σ = 12.03) µg/kg-dw. The highest ΣOCP concentrations observed for HSBW were toxaphene (Σ = 5080), DDT (Σ = 2039), and DDE (Σ = 870.73) µg/kg-dw. The lowest ΣOCP concentrations were observed for the endosulfan isomers. Many of the OCP concentrations exceeded the EPA Region IV, NOAA, Canadian and OSWER sediment quality benchmarks shown in Table 2.

RESULTS & DISCUSSION

Pesticides in Surface Water

No OCPs were detected in IC even though 4 out of the 22 OCPs investigated were observed in HSB. Concentrations ranged from undetectable to 0.0712 µg/L, with some unconfirmed (*) concentrations.

Dieldrin and heptachlor epoxide exceeded EPA fresh water quality criterion continuous concentration (CCC) standards, (0.0712 > 0.056 µg/L) and (0.0321 > 0.0038 µg/L), respectively. Other OCPs observed were aldrin (0.0133* µg/L) and γ-BHC (0.0257* µg/L). As shown in Table 3, most of the concentrations in the water exceeded human health risk standards (USEPA, 2002). Site 6, which is the location of a natural karst spring, was shown to be the most contaminated by OCPs, this indicates some contamination of groundwater. The exceedances suggest that some concentrations might cause potential health problems to human and aquatic organisms.

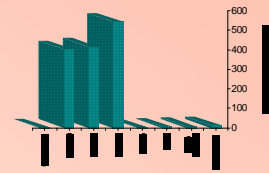
Table 3. U.S. National Recommended Water Quality Criteria and OCP concentrations in water (µg/L).

Pesticide	Concentration	Human Health Risk	CCC
Aldrin	0.0133	0.0133	0.0038
β-BHC	0.00	0.00	0.00
γ-BHC	0.00	0.00	0.00
δ-BHC	0.00	0.00	0.00
Chlordane	0.00	0.00	0.00
DDT	0.00	0.00	0.00
DDE	0.00	0.00	0.00
DDD	0.00	0.00	0.00
Endrin	0.00	0.00	0.00
Endrin ketone	0.00	0.00	0.00
Endrin aldehyde	0.00	0.00	0.00
Heptachlor	0.00	0.00	0.00
Heptachlor epoxide	0.0257	0.0257	0.0038
Methoxychlor	0.00	0.00	0.00

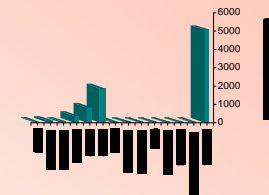
Note: * = Not Detected, ** = unconfirmed.

There were no DDTRs detected in any of the surface water samples. The fate of DDT in an aquatic ecosystem entails volatilization and sorption to biota and sediment. The results obtained could also be attributed to the small sample size. It is expected that more intensive sampling would provide a better indication of the status of OCPs in surface water for IC and HSB. Overall, the occurrences or lack thereof could be attributed to natural environmental conditions, land use (Figure 4), migration, transformation of these compounds, and the amount of suspended particles present in the surface water (Yang et al., 2007).

Indian Creek Watershed



Huntsville Spring Branch



Organochlorines

Figure 5. ΣOCP Concentrations for Soil/Sediment in the Indian Creek (ICW) and Huntsville Spring Branch (HSBW) Watersheds.

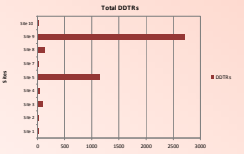


Figure 6. ΣDDTR Concentrations in Soil/Sediment in ICW and HSBW as affected by site.

Table 4. DDTR Residue Concentrations in Soil/Sediment of the ICW and HSBW.

Site	Location	Aldrin	β-BHC	γ-BHC	δ-BHC	Chlordane	DDT	DDE	DDD	Endrin	Endrin ketone	Endrin aldehyde	Heptachlor	Heptachlor epoxide	Methoxychlor
1	Upland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	In-stream	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Upland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	In-stream	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Upland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	In-stream	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Upland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: ND= Not Detected, * = unconfirmed.

CONCLUSIONS

The watersheds showed widespread contamination by OCPs, especially the DDTRs. We are in agreement with Graham and Campbell (2002) in that, we can reasonably conclude that DDTRs may still be present in water and wildlife of these areas.

This work supports a number of studies that attribute fish and macroinvertebrate impairments in Indian Creek and Huntsville Spring Branch to elevated levels of organochlorine compounds in the soil and sediment of these watersheds.

It is very important that specific measures be implemented to ensure that these compounds remain intact and are not transported into the water column.