ASSESSING THE DISTRIBUTION AND ENVIRONMENTAL RELEVANCE OF DDT CONTAMINATION IN LAKE APOPKA AND THE OCKLAWAHA RIVER CHAIN-OF-LAKES, FLORIDA

Gregory Durell[1] and Aisa Ceric[2]

1 Battelle, 397 Washington Street, Duxbury, MA 02332, USA
2 St. Johns River Water Management District, 4049 Reid Street, Palatka, FL 32177, USA

Introduction

The St. Johns River Water Management District (SJRWMD), which covers all or parts of 18 counties in an area of around 12,400 square miles in northeast and east-central Florida, is one of five water management districts in Florida. The SJRWMD is responsible for managing ground and surface water and is dedicated to the preservation and management of the water resources throughout its jurisdictional area. Growth in the SJRWMD's population in recent decades and projected future growth are placing increasing demands on these water resources.

The importance of sediments in overall aquatic ecosystem health and environmental management has become widely recognized, and sediment assessment has in recent years become an important part of the SJRWMD's work. In 1996, the SJRWMD initiated a regional baseline sediment quality assessment of lakes, streams, and estuaries in its area (Figure 1). The primary focus was on contamination by organic compounds and metals that may bioaccumulate and/or be toxic to aquatic life. This baseline assessment provided new insight into the status of the freshwater sediments in the SJRWMD and identified a few areas of potential concern for more detailed assessment.

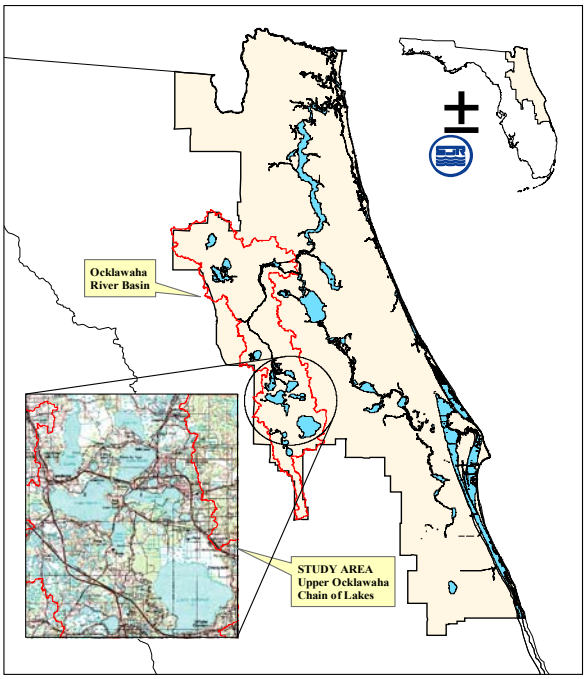


Figure 1: The St. Johns River Water Management District and the upper Ocklawaha River chain-of-lakes

The upper Ocklawaha River chain-of-lakes was identified as having pesticide concentrations that warranted additional study. An investigation was conducted to more thoroughly assess the concentration, distribution, potential origin, and possible ecological implications of the chlorinated pesticide concentrations in the sediments from Lake Apopka downstream to Lakes Beauclair, Dora, Eustis, and Griffin. The study also included Lake Harris, which discharges to Lake Eustis. The primary focus was on DDT, which had been identified as the pesticide and contaminant of greatest potential concern in the Ocklawaha River chain-of-lakes[1].

Methods and Materials

The initial regional baseline survey included sampling and measuring trace organic and metal contaminants in surface sediments from 170 representative sites. More than 100 new locations were sampled in the detailed assessment that followed, and about 50 of those were collected in the upper Ocklawaha River chain-of-lakes. Surface sediments were collected from the top 10 cm using a Ponar or Eckman dredge, and rigorous protocols were used to ensure sample integrity.

To meet the objectives of this program, analytical methods were used that could provide trace-level data for highly relevant toxic and/or persistent compounds. The carefully selected analytes included more than 100 organic compounds (e.g., PAH, pesticides, and PCB) and 15 metals (e.g., mercury, arsenic, and lead). Optimized versions of the National Oceanic and Atmospheric Administration National Status and Trends analytical methods were employed for the analysis[2]. The focus of the upper Ocklawaha River chain-of-lakes investigation was on the chlorinated pesticide DDT and its degradation products DDD, DDE, DDMU, and dichlorobenzophenone.

In order to analyze for chlorinated pesticides, sediment samples were fortified with surrogate compounds, serially solvent extracted, and then purified using alumina, high-performance gel permeation chromatography, and activated copper. The extract was analyzed using high-resolution gas chromatography/electron capture detection (HRGC/ECD), which had dual-column analysis on DB-5 and DB-1701 columns; both of which were 60 m long with a 0.25 mm ID, and 0.25 µm film thickness. Pesticide detection limits of 0.05–0.1 µg/kg, dry weight, were achieved.

Results and Discussion

The sediment data were interpreted using a variety of approaches, including (1) comparisons to general contaminant levels in the SJRWMD using districtwide assessment data, (2) comparison to national sediment contaminant databases and "high" concentration levels established on a national level[3,4], (3) inter-comparisons of the concentration distribution within the upper Ocklawaha River chain-of-lakes study area, and (4) comparison of the measured concentrations to effects-based sediment quality guideline (SQGs) values, with consideration for the unique characteristics of many of these sediments[5,6,7]. The analyses consistently indicated that the DDT compound concentrations were elevated in much of the upper Ocklawaha River chain-of-lakes and that there was a contaminant gradient in the lakes system.

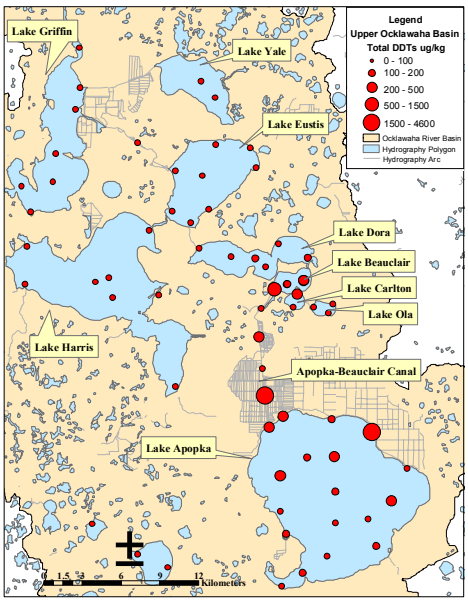
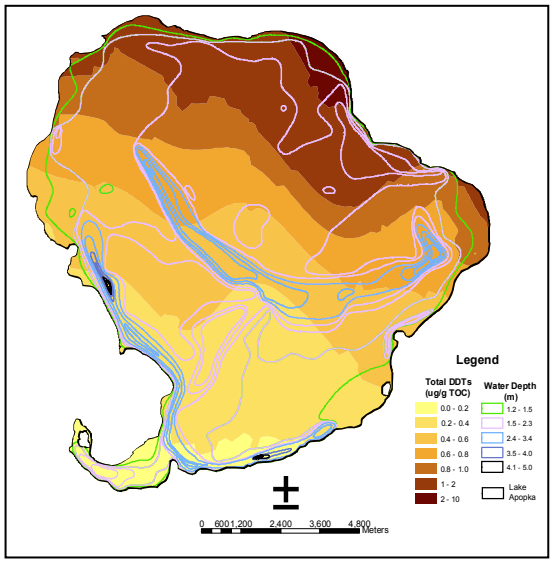


Figure 2: Total DDT concentrations in the upper Ocklawaha River chain-of-lakes surface sediment (µg/kg)

The total DDT concentrations (defined as the sum of the six 2,4- and 4,4-isomers of DDT, DDD, and DDE) at the sampling locations are illustrated in Figure 2. Total DDT concentrations were above 100 µg/kg, dry weight, at most sites sampled in Lake Apopka, the Apopka-Beauclair (AB) Canal, and Lake Beauclair, averaging 384 µg/kg. The concentration exceeded 1,000 µg/kg at two locations. The average total DDT concentrations were about 70, 23, 19, and 17 µg/kg in Lake

Dora, Eustis, Griffin, and Harris, respectively. Lake Apopka is the most upstream lake in the upper Ocklawaha River chain-of-lakes, and it supplies Lakes Beauclair, Dora, Eustis, and Griffin, through the AB Canal. Significant amounts of DDT appeared to have accumulated in the sediments of Lake Apopka, the AB Canal, and Lake Beauclair. However, the DDT concentrations appeared to also be elevated further downstream in this system of inter-connected lakes, compared to similar freshwater systems across the country and relative to SQGs.



Lake Apopka, and its organically rich floodplain that was once part of the lake and converted to farms, appeared to be one source of the DDT in the lakes system. A prediction surface based on TOC-normalized Total DDT concentrations in Lake Apopka sediments (Figure 3) illustrated that the highest levels occurred in the northeastern part and along the northern shore of the lake, where agricultural activities were once centered and where drainage canals from the agricultural lands fed in to the lake. High concentrations were also measured in the AB Canal, which receives flow from Lake Apopka and directly from surrounding lands through smaller canals and runoff. DDT applied to farmlands may have been a primary original source of DDT in the upper Ocklawaha River chain-of-lakes.

Figure 3: Total DDT concentrations in Lake Apopka surface sediment (µg/g TOC)

The original DDT material appears to have been substantially degraded throughout the lakes system. DDD and DDE were the primary DDT degradation products identified in the SJRWMD sediments region wide (as in most sediments nationwide), as well as in the upper Ocklawaha River chain-of-lakes (Figure 4). DDMU and dichlorobenzophenone, both of which are often major DDT degradation products further along the degradation pathway than both DDD and DDE, were included in the Lake Apopka sediment analyses (but not in the analysis of sediments from other locations) and were found to comprise, together, about 40% of the DDT compound concentration in those sediments. Limiting the analysis to merely DDT, DDD, and DDE clearly limits the ability to understand the magnitude and status of the contamination in a DDT investigation.

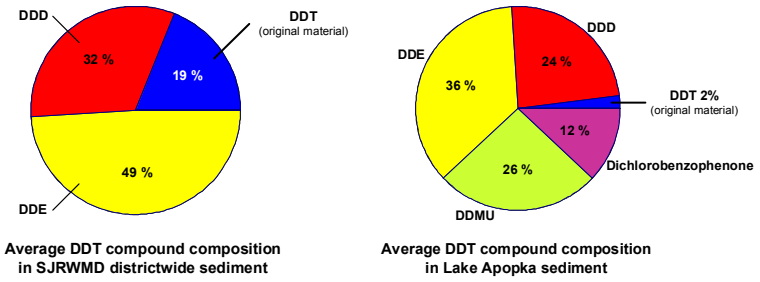


Figure 4: Average DDT compound compositions in surface sediment

The average contaminant concentrations for the SJRWMD district-wide sites were highly comparable to those determined for the 224 NOAA Mussel Watch Program sites[4]. By comparing the sediment total DDT and other contaminant concentrations to effects-based freshwater SQGs, a conservative screening-level potential for ecological harm was assessed. Hazard quotients (HQs)[I] and indices (HIs) were calculated for sites in the upper Ocklawaha River chain-of-lakes system using the published freshwater TEC and PEC values[7] for organic and metal contaminants (Table 1). Reference data are also presented using the NOAA Mussel Watch Program "high" values[4], which represent the 85th percentile contaminant concentration for the Program's coastal US sites.

DDT compounds were responsible for the greatest proportion of elevated HI and HQ values. The results suggest that there is a potential for the sediments in Lake Apopka, the AB Canal, and Lake Beauclair to adversely affect benthic invertebrate community structure. However, many factors impact the bio-availability of sediment-associated contaminants, including the organic content of the sediments[5]. Most sediments in the upper Ocklawaha River chain-of-lakes system had a total organic carbon (TOC) content of 20–35%, compared to an average TOC content near 1% for the sediments used to establish the SQGs (Table 1)[6, 7]. Therefore, it is likely that the calculated HIs and HQs over estimate the potential for adverse effects. The high TOC content could significantly reduce the bioavailability of the contaminants, and further study is needed to determine if the contaminants in these unique sediments could adversely affect the local ecology.

Table 1: Hazard indices and quotients for the upper Ocklawaha River chain-of-lakes surface sediment calculated on all measured contaminants for which SQG values exist [6,7]

Location	HI[a] *(based on TEC)*		HI[a] *(based on PEC)*		Average HQ[a] *(based on PEC)*	
	Average	Range	Average	Range	Average	Range
NOAA "high" value[4]	21.9		5.0		0.42	
SJRWMD-wide	10.3	0.1–88.6	2.0	0.1–15.5	0.16	0.01–1.39
Lake Apopka	47.7	2.4–317	8.4	0.6–53.5	0.75	0.05–4.85
AB Canal/Lake Beauclair	152	0.7–949	26.2	0.4–161	2.35	0.01–14.6
Lake Dora	25.1	0.2–40.1	5.2	0.1–8.1	0.36	0.01–0.56
Lake Eustis	13.1	0.6–28.4	2.8	0.1–5.7	0.18	0.01–0.41
Lake Griffin	11.6	9.1–16.5	2.9	2.1–4.0	0.17	0.13–0.26
Lake Harris	10.1	2.8–17.0	2.5	0.7–3.8	0.15	0.04–0.26

[a] A TEC-based HI >10, a PEC-based HI>1, and an average PEC-based HQ>0.5[7] have been suggested as screening-level guidelines for identifying a *potential* to cause ecological harm.

References

1. Durell, G.S., and J. Seavey Fredriksson, Duxbury, Mass.: Battelle. 1998 and 2001. Final reports to the St. Johns River Water Management District (SJ98-SP5 and SJ2001-SP1).
2. NOAA. 1998. Technical memorandum NOS/ORCA/CMBAD 130. Silver Springs, Md.
3. U.S. EPA. 2001. EPA document 823-R-01-01. Washington, D.C.
4. Daskalakis, K.D., and T.P. O'Connor. 1995. *Mar. Environ. Res.* 40:381.
5. Di Toro, D.M., C.S. Zebra, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, and P.R. Paquin. 1991. *Environ. Tox. Chem.* 10(12):1541.
6. Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. *Environ. Mngt.* 19(1):81.
7. MacDonald, D.D., C.G. Ingersoll, and T.A Berger. 2000. *Arch. Environ. Contam. Tox.* 39:20.

[I] HQ is the ratio of the contaminant concentration to the effects-based SQG (the TEC, in this case). The HI is the sum of the HQs; HQs were calculated for the 8 organic and 9 metal key contaminants for which TEC-based SQG values exist.