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Organochlorine pesticide residues in sediments from the Uganda side of Lake Victoria

John Wasswa [a,*], Bernard T. Kiremire [a], Peter Nkedi-Kizza [b], Jolocam Mbabazi [a], Patrick Ssebugere [a]

[a] *Department of Chemistry, Makerere University, P.O. Box 7062, Kampala, Uganda*
[b] *Soil and Water Science Department, University of Florida, Gainesville, FL 32611, United States*

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A B S T R A C T

Organochlorine (OC) residues were analysed in 117 sediment samples collected from four bays of the Uganda side of Lake Victoria. The sediments were collected with a corer at a depth of 0–20 cm, and extracted for OC residues using a solid dispersion method. The extracts were cleaned using gel permeation chromatography and analysed for pesticide residues using a gas chromatograph (GC) equipped with an electron capture detector. The results were confirmed using a GC equipped with a mass spectrometer (MS). A total of 16 OC residues, most of them persistent organic pollutants (POPs) were identified and quantified. The OC residue levels were expressed on an oven dry weight (*d.w.*) basis. Endosulphan sulphate, in the range of 0.82–5.62 $\mu g\ kg^{-1}$ *d.w.*, was the most frequently detected residue. Aldrin and dieldrin were in the ranges of 0.22–15.96 and 0.94–7.18 $\mu g\ kg^{-1}$ *d.w.*, respectively. DDT and its metabolites lay between 0.11–3.59 for *p,p′*-DDE, 0.38–4.02 for *p,p′*-DDD, 0.04–1.46 for *p,p′*-DDT, 0.07–2.72 for *o,p′*-DDE and 0.01–1.63 $\mu g\ kg^{-1}$ *d.w.* for *o,p′*-DDT. The levels of γ-HCH varied from 0.05 to 5.48 $\mu g\ kg^{-1}$ *d.w.* Heptachlor was detected only once at a level of 0.81 $\mu g\ kg^{-1}$ *d.w.*, while its photo-oxidation product, heptachlor epoxide, ranged between non-detectable (ND) to 3.19 $\mu g\ kg^{-1}$ *d.w.* Chlordane ranged from ND to 0.76 $\mu g\ kg^{-1}$ *d.w.* Based on the threshold effect concentration (TEC) for fresh water ecosystems, aldrin and dieldrin were the only OCs that seemed to be a threat to the lake environment.

1. Introduction

Organochlorine pesticides in the environment are characterised by high chemical stability, poor water solubility and low vapour pressures (Bouwman, 2004). Consequently they are commonly referred to as persistent organic pollutants (Darko et al., 2008). In East Africa, OC pesticides have been in use since the 1940s and have tended to accumulate in soil (Madadi et al., 2006; Ssebugere, 2010) and sediment (Werimo et al., 2009). Owing to ingestion of sediment, OC pesticides and their residues find their way into edible fish (Licata et al., 2003; Ogwok et al., 2009; Ssebugere et al., 2009). Health risks associated with OC metabolites are well established (Engel et al., 2000; Garry, 2004). As such, out of the 21 POPs that have been ear-marked for phase-out and elimination, fourteen are OC pesticides; dichlorodiphenyltrichloroethane (DDT), aldrin, endrin, dieldrin, chlordane, heptachlor, hexachlorobenzene (HCB), mirex, toxaphene, alpha hexachlorocyclohexane, beta hexachlorocyclohexane, chlordecone, lindane and pentachlorobenzene (Stockholm Convention, 2001, 2009).

In Uganda, the use of pesticides especially in ensuring the sustainability of large quantities of high quality agricultural produce has been steadily increasing over the past half century (Kasozi et al., 2006). Lake Victoria basin has been particularly singled out as the region with the greatest number of activities involving the use of pesticides (NEMA, 2000). The lake, the second largest freshwater body in the world, has an area of 68 800 km^2, a mean depth of 40 m and an irregular shoreline of about 3440 km in length lying in catchments of about 184 000 km^2 (Payne, 1986; Wikipedia, 2009). The Victoria Nile at Jinja in Uganda is the lake's only single outlet. The lake basin experiences an equatorial climate, supporting extensive subsistence and commercial farming. In addition to being a source of domestic and industrial water, the lake is believed to contain 350 different fish species (Kwetegyeka et al., 2008) and provides an estimated 220 000 metric tonnes of fish annually for Uganda alone (Ogwok et al., 2009). In the past few decades, however, the lake's productivity has been severely compromised by increased industrial and agricultural activity in its basin, resulting in increased polluted urban runoffs, nutrient and pesticide load, and wetland encroachment (Nyenje et al., 2010). As a result, nearly half of the lake floor currently experiences prolonged anoxia for several months of the year, compared to the 1960s when such anoxia was sporadic and localised (Hecky et al.,

* Corresponding author. Tel.: +256 772 504657; fax: +256 41 531061.
E-mail address: jnwasswa@chemistry.mak.ac.ug (J. Wasswa).

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2010). Concerns over increased pollution as a result of the above activities have led to efforts being made to address the root causes in order to mitigate this environmental impact. Emphasis has been laid on microbiological, eutrophicational, inorganic chemical and suspended solid causes of pollution due to enhanced effluent discharge (Odada et al., 2004). Little, however, has been done to assess the pesticide residue input to the lake's current state of pollution.

The present paper reports and assesses the levels of OC pesticide residues in sediments from Lake Victoria, Uganda. The results might prompt the relevant authorities to put in place appropriate deterrent measures to safeguard the sustainability of the lake.

2. Materials and methods

2.1. Study area

The area of study was the Uganda side of Lake Victoria (Fig. 1). The lake stretches across the equator at 00° 30′N–03° 00′S and 31° 39′W–34° 53′E. This area has undergone rapid ecological changes resulting from agricultural practices that have led to massive deforestation within the vicinity of Lake Victoria. The lake shores, which were historically fringed by extensive papyrus (*Cyperus papyrus*)-dominated wetlands, have been degraded by a rapidly rising human population (Rusongoza, 2003), putting mounting pressure on the lake in terms of sedimentation, water pollution (Mbabazi et al., 2010), algal blooming (Nyakairu et al., 2010) and overfishing. Four bays of the lake, namely, Murchison, Napoleon, Thurston and Waiya (Fig. 1) were selected as suitable sites for the study because of the large human settlements, industrial and agricultural activities within their immediate vicinities. The sampling points were referenced using a geographical positioning system (GPS).

2.2. Sample collection and preservation

A total of 117 sediment samples were collected at quarterly intervals from 2003 to 2007 inclusive. Sediments were collected in triplicate at 0–20 cm depths per sampling site, because sediments at this level are expected to be the most contaminated, and have the greatest potential for exchange with the water column (Nowell et al., 1999). Sediment composition was not uniform for the four bays. In the Napoleon Gulf and Thurston bay, the sediment was dark and rich in organic matter, whereas in Waiya bay it contained a lot of sand. At Murchison bay, much of the sediment was clay. The samples were taken using a sediment corer, wrapped in aluminium foil and placed in labelled, air-tight bags. They were kept in ice-coolers and transported to the laboratory where they were kept at −20 °C before extraction.

2.3. Sediment extraction procedure

Sediment samples were extracted for pesticides residues using a dispersion method (Åkerblom, 1995). Gravel was removed from

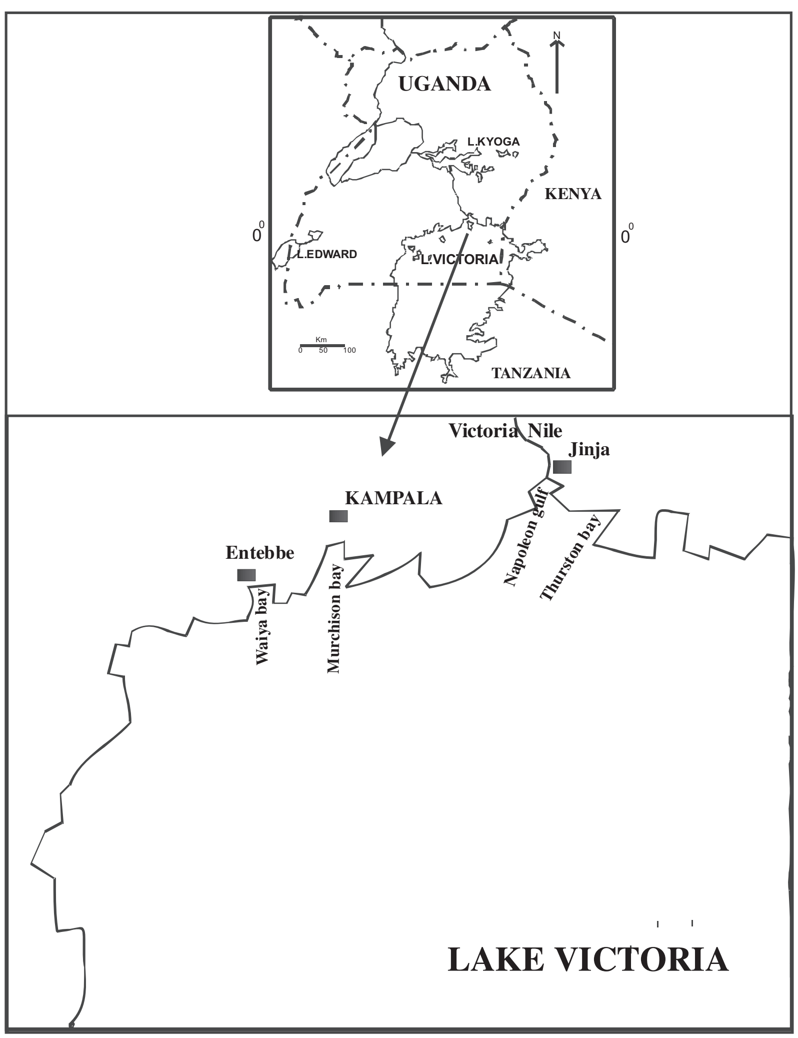

Fig. 1. Schematic map of Uganda showing location of study sites.