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Organochlorine pesticides and heavy metals in fish from Lake Awassa, Ethiopia: Insights from stable isotope analysis

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HIGHLIGHTS

- OCPs and heavy metals bioaccumulation examined in fish species from Lake Awassa – Ethiopia.
- Levels of DDTs and heavy metals varied among the studied fish species.
- *p,p′*-DDE, predominate congener, showed significant relationship with $\delta^{15}N$.
- Most of the heavy metals showed negative correlation with $\delta^{15}N$.

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ABSTRACT

The levels and bioaccumulation of organochlorine pesticides (OCPs) and heavy metals were studied in muscle and liver of three fish species, with two trophic levels, from Lake Awassa, Ethiopia. DDTs were the predominant organic pollutant in all species with a maximum level of 73.28 ng g^{-1} wet weight (ww). *p,p′*-DDE was the predominate congener and showed a significant ($p < 0.001$) relationship with $\delta^{15}N$, which indicates that DDTs could biomagnified in the food web of the lake. Generally, high levels of heavy metals (Cd, Co, Cr, Cu, Ni, Pb, Zn and Hg) were found in liver samples as compared to muscles. The levels of Cd, Co, Cu, Ni, and Pb in liver samples showed negative correlation with $\delta^{15}N$. They were found markedly higher in the lower trophic level fish species ($p < 0.05$) that indicates biodilution whereas; Zn level showed positive correlation with $\delta^{15}N$.

1. Introduction

Organochlorine pesticides (OCPs) and heavy metals are among biosphere pollutants of global concern due to their environmental persistence, ability to bioaccumulate and magnify in the food chain and chronic toxicity to wildlife and humans (Jones and de Voogt, 1999; Papagiannis et al., 2004). In aquatic systems, fish are exposed to these environmental pollutants either from water via gills or/and from the diet. Henceforth, fish are the most suitable indicators for the burden of aquatic pollution monitoring since they concentrate pollutants in their tissues and enabling the assessment of transfer of pollutants through the trophic web (Fisk et al., 2001; Boon et al., 2002). Thus, bioaccumulation of pollutants can be considered as an index of environmental pollutants in the aquatic bodies. It is therefore useful to link a pollution load to the trophic position of fish species. Stable isotope analysis (SIA) has been widely employed, using stable nitrogen ratio ($\delta^{15}N$) to characterize an organism's trophic position while stable carbon ratio ($\delta^{13}C$) signatures have been used to determine the source and flow of carbon in a food web (Cabana and Rasmussen, 1994; Hecky and Hesslein, 1995).

The Ethiopian Rift Valley region that encompasses seven principal lakes namely Lake Ziway, Abijata, Langano, Shalla, Awassa, Abaya and Chamo is a densely populated area confined with agro industry enterprises and various agricultural farms especially floriculture and horticulture industry (Jansen et al., 2007). Lake Awassa, the smallest of the Rift Valley lakes (90 km^2 in area), lies to the west of Awassa town and about 275 km south of Addis Ababa, capital of Ethiopia. The lake is an endorheic basin and eutrophic lake with agricultural and industrial activities in its catchment. Four public factories operate within the catchment of lake

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discharge their wastes directly to River Tikur Wuha and eventually to the lake (Desta, 2003). These activities as well as population growth have substantially increased the burden of contamination. Recent studies on fish fillets have revealed high levels of mercury (Hg) in *Barbus* fish species from the lake (Desta et al., 2006, 2008). Wastes from urban areas, agricultural fields and the regional hospital in Awassa drain to the lake (Desta, 2003), but the levels of pollutants especially pesticides reaching the lake have never been studied. As to the best of our knowledge, this is the first study on the bioaccumulation of organochlorine pollutants in individual fishes and species in Lake Awassa, Ethiopia.

The objective of this study is, therefore; (i) to investigate the levels of OCPs and heavy metals in three fish species and as well as to study their bioaccumulation profiles, which reflect the state of pollution, from the insights of stable isotope analysis (ii) to estimate an indication of public health risk levels due to the pollutants associated with fish consumption.

2. Materials and methods

2.1. Study area and sample collection

Lake Awassa (surface area: 90 km^2; mean depth: 11 m) is a fresh closed lake, without an out flow situated in the Ethiopian rift valley (Fig. 1). The littoral area is covered with emergent and sub-mergent macrophytes and inhabited by diverse species of benthic and bird fauna (Kibret and Harrison, 1989; Tilahun et al., 1996). The lake is highly productive. It has a rich phytoplankton and zooplankton that support large populations of six fish species: *Oreochromis niloticus*, *Clarias gariepinus*, *Barbus intermedius*, *Barbus paludinosus*, *Garra quadrimaculata* and *Aplocheilichthyes antinorii*; the first three of which are commercially and economically important (Golubtsov et al., 2002).

A total of 49 representative fish samples from three fish species, *O. niloticus* (n = 20), *C. gariepinus* (n = 18) and *B. intermedius* (n = 11) were bought from local fishermen at shore in January 2011. Information about the samples by species is given in Table 1. The freshly collected adult fish individuals were thawed

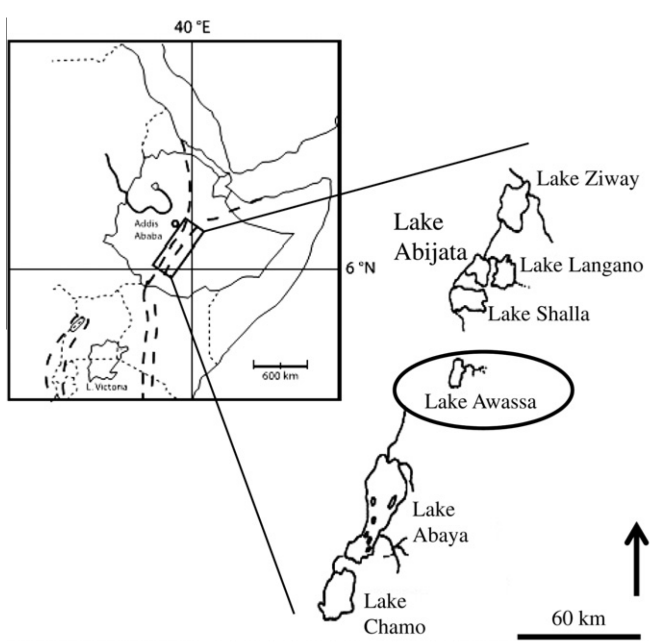

Fig. 1. Geographical map of Ethiopia showing the location of Lake Awassa in the Ethiopian Rift Valley.

Table 1
Biometric data and lipid content (median and range); stable isotope ratio values and concentration of DDTs (ng g^{-1} wet weight) in muscle of three fish species from Lake Awassa, Ethiopia.

Species (common name)	n		Standard length (cm)	Weight (g)	Lipid (%)	$\delta^{15}N$ (‰) Mean ± SD (Range)	$\delta^{13}C$ (‰) Mean ± SD (Range)	Σ-DDT Mean ± SD (Range)
O. niloticus (Tilapia)	20	Median range	22 (19–26)	311 (200–436)	0.49 (0.03–1.23)	8.45 ± 0.4[b] (7.96–9.58)	−21.1 ± 0.3[a] (−21.46–20.14)	1.80 ± 1.25 (0.63–5.19)
C. gariepinus (Catfish)	18	Median range	36 (26–44)	426 (152–731)	0.32 (0.07–2.45)	9.49 ± 1.4[a] (7.45–11.81)	−20.9 ± 1.2[a] (−22.41–19.43)	9.35 ± 7.64 (2.26–30.84)
B. intermedius (Barbus)	11	Median range	27 (21–32)	309 (150–548)	0.68 (0.26–1.71)	10.39 ± 1.5[a] (8.46–12.26)	−20.4 ± 0.7[a] (−21.59–19.44)	21.34 ± 23.17 (6.82–73.28)

n = Number of fishes sampled.
Mean values ± standard deviation (range values).
Values with different letters (a, b) within a column are significantly different at $p < 0.05$ level (Tukey test is applied).