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PCDD/Fs and dioxin-like PCBs in fish species from Lake Victoria, East Africa

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HIGHLIGHTS

- Fish species collected from Lake Victoria were extracted for PCDD/Fs and dl-PCBs.
- Concentrations of the ∑PCDD/Fs in the muscles ranged from 0.06 to 0.59 pg g^{-1} fw.
- The ∑dl-PCBs in the fish muscles and livers ranged from 0.2 to 19.0 pg g^{-1} fw.
- The WHO_{2005}-TEQs varied from 0.001 to 0.74 pg TEQ g^{-1} for PCDD/Fs and dl-PCBs.
- Based on the calculated WHO-TEQs, the fish was fit for human consumption.

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ABSTRACT

Two commercially important fish species, Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*) belonging to different trophic levels were collected from the Napoleon Gulf and Thurston Bay in Lake Victoria. Polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and dioxin-like polychlorinated biphenyls (dl-PCBs) were extracted from the fish muscles and livers using the ^{13}C isotope dilution method, followed by multiple column chromatography clean-up. Analysis was achieved by a high resolution gas chromatography coupled with a high resolution mass spectrometer. The concentrations of analytes ranged from 0.07 to 0.59 pg g^{-1} fresh weight (fw) and 0.3–19.0 pg g^{-1} in *L. niloticus* and 0.06–0.18 and 0.2–15.7 pg g^{-1} in *O. niloticus*, for ∑PCDD/Fs and ∑dl-PCBs, respectively. Differences in congener concentrations were observed between the two fish species and study sites, and this was attributed to differences in feeding habits and trophic levels. World Health Organization-toxic equivalents (WHO-TEQs) were in the range 0.01–0.16 pg TEQ g^{-1} for the PCDD/Fs and 0.001–0.74 pg TEQ g^{-1} for the dl-PCBs. The TEQ values in the present study were lower compared to those of most fish samples reported in literature and were within permissible levels recommended by the European Union, implying that the fish was fit for human consumption.

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1. Introduction

Lake Victoria has the largest fresh water fishery in East Africa with annual yields exceeding 800 000 metric tons (Odongkara et al., 2009). By 2008, increasing industrialization had been noted in the watershed together with a large human population of more than 30 million people that depend on the fish as a primary source of fats and proteins (Johnson, 2009). In spite of the importance of fish to the diet of the local population, as well as it being an important export commodity, a survey of literature shows no available data concerning the profiles of PCDD/Fs and dl-PCBs in the aquatic environment of Lake Victoria. Globally, these organic pollutants are widely spread in the environment and of concern especially because they are highly hydrophobic and, resistant to biotic and abiotic degradation (Laisi et al., 2008). The congeners of PCDD/Fs with chlorine substitution in the 2, 3, 7, 8 positions are thought to pose a risk to human health due to their toxicity, carcinogenic potency and potential effects on animal immunological and reproductive systems (Kumar et al., 2001). They tend to accumulate in top predators (Braune and Simon, 2003), and are thought to damage natural hormones (Minh et al., 2004).

Elsewhere in the World, concern about the health implications of PCDD/Fs and dl-PCBs has led to numerous surveys to determine their levels in fish products among other foods in order to assess human exposure (Zhang et al., 2008; Moon and Choi, 2009). The

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fish tend to accumulate amounts of such non-ionic organic chemicals at thousands of times their concentration in the surrounding medium through consumption of phytoplankton, insects, suspended particles and contaminated sediments (Bush and Kadlec, 1995). Consequently, human dietary intake of these chemicals is considered one of the major pathways, especially through consumption of fish (Bayarri et al., 2001). This study was aimed at obtaining preliminary information on the occurrence of PCDD/Fs and dl-PCBs in fish species from Lake Victoria. The generated data will be used as a benchmark to compare the levels of the pollutants over time.

2. Materials and methods

2.1. Study area and sampling

Two sampling areas namely, the Napoleon Gulf and Thurston Bay in Jinja Municipality were selected for this study. Jinja Municipality has dense urban development and industrialization, and these land use activities could be sources of pollutants into Lake Victoria via runoff. The Napoleon Gulf is adjacent to Jinja Municipality on the northern shoreline of Lake Victoria, where River Nile (the only outlet of the lake) begins its journey to the Mediterranean Sea, while the Thurston Bay which is also located on the same shoreline is rather far from Jinja town (Fig. 1). A total of 64 fish of different species (*Lates niloticus* and *Oreochromis niloticus*) and ages 1–3 years were collected in March, 2011. The weights of *L. niloticus* varied from 1522.6 to 2876.9 g (mean 2262.9 g) while those of *O. niloticus* ranged from 274.8 to 552.4 g (mean 406.3 g). The mean length (±standard deviation) of the latter species was 27.6 ± 2.6 cm, whereas that for the former was 65.2 ± 4.7 cm. Specimens were individually rinsed with distilled water to remove any impurities. Subsequently, the muscles and livers of 4–5 fish of the same species and location were separately excised, pooled and macerated to obtain homogenized samples. The samples were transferred into clean glass bottles and sealed using aluminum caps. The bottles were kept in cooling boxes containing ice packs and transferred to the German Research Center for Environmental Health for laboratory chemical analysis, and frozen at −28 °C until analysis.

2.2. Chemical analysis

The tissues were allowed to thaw and a known mass was spiked with ^{13}C-labelled PCDD/F and dl-PCB surrogate standards. The spiked tissues were then mixed with hydromatrix™ (Varian) to remove any moisture. Extraction was carried out using an accelerated solvent extractor (Dionex 200, Sunnyvatem CA, USA) at a temperature of 120 °C and pressure of 120 bar, using a 3:1 v/v of *n*-hexane/acetone as extraction solvent. The resulting organic extract was passed through a drying funnel of anhydrous sodium sulfate and eluted with 100 mL of *n*-hexane. The extraction volume was concentrated to 2 mL on a rotary evaporator and kept for purification to remove interferences by two sequential liquid chromatography steps.

The first purification step was performed by adsorption chromatography using a multilayered sandwich glass column (packed successively from bottom to top with 2 g silica gel, 5 g 33% silica gel-sodium hydroxide, 2 g silica gel, 5 g 44% silica gel-sulfuric acid, 10 g 22% silica gel-sulfuric acid and 5 g sodium sulfate). The column was washed with 60 mL *n*-hexane before being connected to a reversible carbon column (Carboxen 1016, Supelco) that had been rinsed by an equivalent volume (25 mL) of toluene and *n*-hexane, respectively. The concentrated extract was then applied to the column and eluted with 100 mL of *n*-hexane. PCDD/Fs and non-*ortho* PCBs were retained in the carbon column, while the mono-*ortho* PCBs passed through both columns. The sandwich column was removed and the carbon column was further eluted with

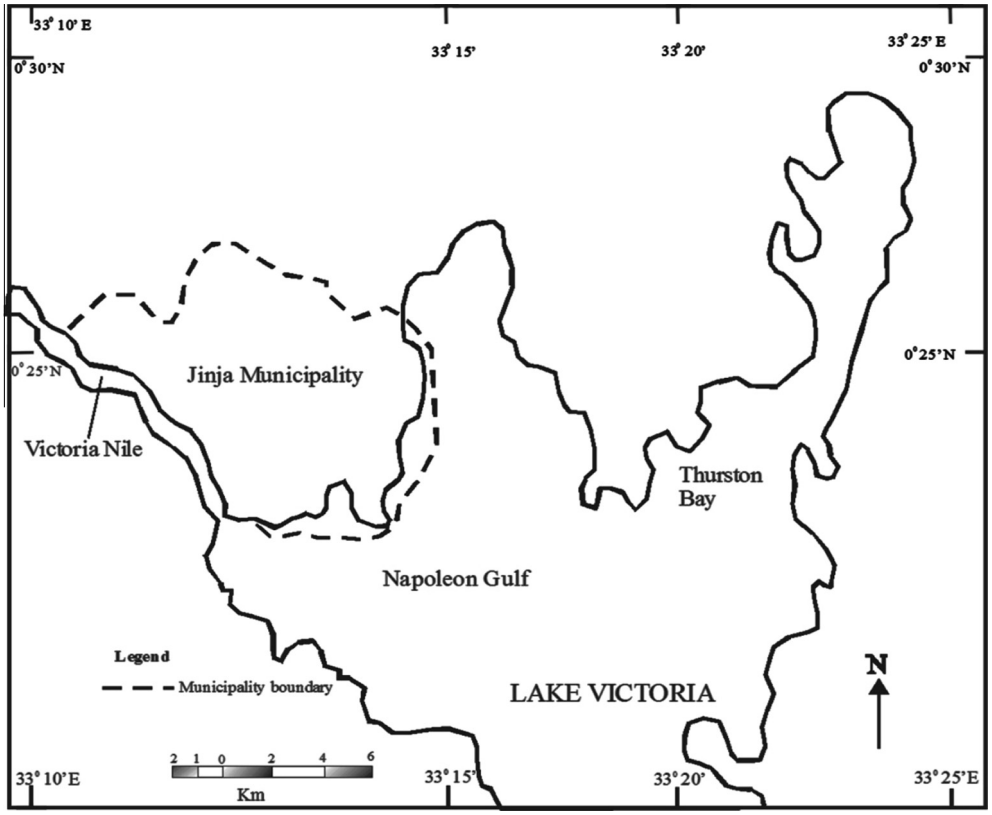

Fig. 1. Map showing the study areas (adopted from Ssebugere et al. (in press).

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