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Levels of Total Mercury in Different Fish Species and Sediments from the Upper Volta Basin at Yeji in Ghana

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Abstract In this study, total mercury concentrations were determined in sediments and seven different fish species from the Upper Volta Basin area of Yeji in Ghana. Mercury concentrations found ranged from 44.17 to 85.88 ng/g wet weight for *Synodontis gambiesis*, from 11.25 to 79.73 ng/g wet weight for *Synodontis membranaceus*, from 13.11 to 38.64 ng/g wet weight for *Synodontis ocellifer*, from 16.39 to 25.82 ng/g wet weight for *Distishodus rotratus*, from 40.80 to 90.30 ng/g wet weight for *Bagrus docmac*, from 10.48 to 61.90 ng/g wet weight for *Chrysichthys nigrodigitatus* and from 12.33 to 24.18 ng/g wet weight for *Gnathoneus senegalensis*. These values are below the 500 ng/g guideline recommended by the WHO/FAO, implying that fish from the Upper Volta Basin area of Yeji are safe for human consumption. Good correlation was observed between mercury concentration and fresh weight ($R^2 = 0.6067$) and total length ($R^2 = 0.8754$) for *Gnathonemus senegalensis*. However, poor correlations were observed between mercury concentration and fresh weight and total length for the other six species. Mercury in sediments ranged from 11.87 to 70.25 ng/g dry weights with a mean of 41.60 ng/g dry weight being below the IAEA threshold of 810 ng/g.. These values show that sections of the Upper Volta River remain relatively clean in spite of substantial loadings of mercury into the river's basin from gold mining activities.

Keywords Mercury · Upper Volta Basin · Yeji · Automatic mercury analyzer · Fish muscle · Sediments · Ghana

Mercury is one of the most serious and scientifically challenging contaminant in aquatic resources throughout the world. Although mercury occurs in different forms in the environment, most of the attention has been focused on methylmercury in fish to which humans are widely exposed (Ercal et al. 2001). Although extensive surveys have been carried out in many countries to evaluate the presence of mercury in the aquatic biota including fish (Love et al. 2003; Storelli et al. 2003), information on mercury contamination of fish and sediments in freshwaters of Ghana remains lacking and this research is aimed at filling this gap. The Volta River is the main fresh water fish source for Ghana of which Yeji is one of the main landing sites. The Volta Lake is formed by the confluence of the Black Volta and the White Volta rivers at Yeji in the central part of the country. The river flows in a southerly course through Lake Volta to Ada on the Gulf of Guinea. The total length, including the Black Volta where it rises from Burkina Faso is about 1,500 km (930 miles). Fishing has been more successful, although only about 20% of the country's fish consumption comes from Lake Volta. Artisanal mining based on the use of mercury for the recovery of gold is common and widespread in the Upper Volta basin at Yeji in the Brong-Ahafo Region of Ghana (Fig. 1).

In this study, total mercury concentrations are determined in different species of fish and sediments in order to generate data needed for the assessment of mercury intake from fish and for the development of consumption advisories for the general public. It represents a baseline reference for future works.

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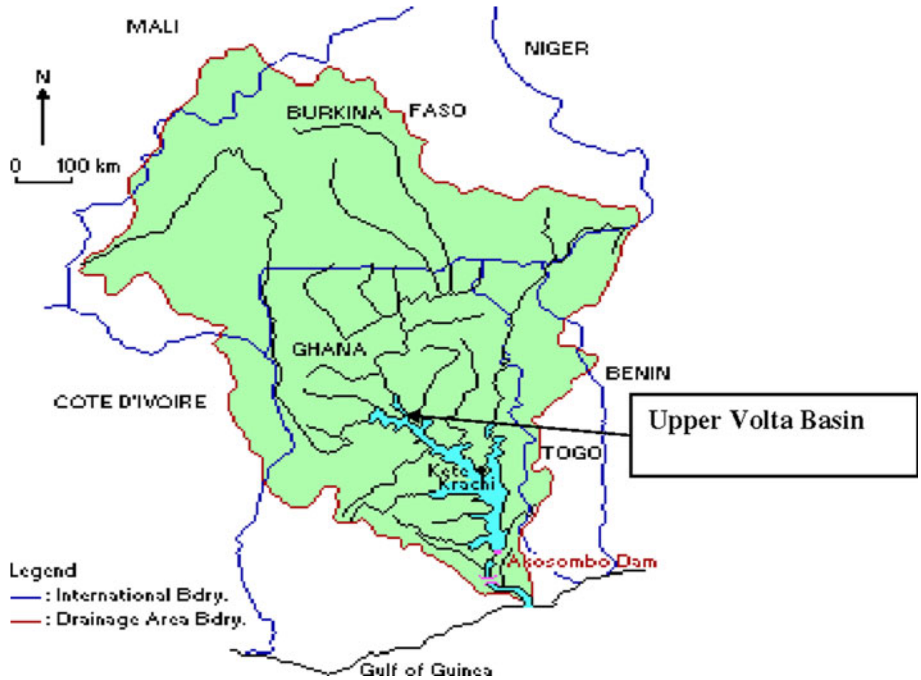

Fig. 1 Map of Ghana showing the geographical layout of the Volta River

Materials and Methods

The fish species were collected from random commercial catches from Yeji depending on the species available for sale between October 2006 and March 2007. Samples obtained were therefore reflective of species meant for consumption. Sediments were also collected during the same period. A total of one hundred and nine (109) fishes covering six (6) species were obtained. The fish samples were sorted by species, placed in clean plastic bags and stored on ice in an ice chest. Ten (10) sediments samples were collected from the top five (5) centimeters from ten (10) different spots at an interval of about 100 meters with the help of a truncated plastic container in the midstream of the lake. The sediments were then placed in polyethylene bags and labeled. The samples were then transported to the laboratory where the fish were identified and the stored in a freezer at −2°C. Subsequently, the fish samples were washed with distilled water, dried on tissue paper and the length and body weight of each was taken after defrosting in the laboratory. A portion of the edible muscle tissue was removed from the dorsal part of each fish, homogenized and stored in clean-dapped glass vials and kept in a freezer until analysis. Sediment samples were air dried for three days and sieved with 2 mm mesh. The samples were then transferred into labeled polyethylene bags for analysis.

All reagents used were of analytical reagent grade (BDH Chemicals Ltd, Poole, England) unless otherwise stated. Double distilled water was used for the preparation of all solutions. The fish and sediment samples were digested for total mercury determination by an open flask procedure developed at the National Institute for Minamata Disease (NIMD) in Japan by Akagi and Nishimura (1991). The accuracy of this method has been verified at NIMD through interlaboratory comparison exercise and by participating in the analyses of Certified Reference Materials (CRMs) supplied by the International Atomic Energy Agency (IAEA). In the procedure, about 0.5 g of sample was weighed into 50 mL volumetric digestion flask and a mixture of 1 mL H_2O, 2 mL $HNO_3{-}HClO_4$ (1:1) and 5 mL H_2SO_4 was added. The mixture was then heated at a temperature of 250 ± 5°C until the solution was clear. The sample solution was then cooled and diluted to 50 mL with double distilled water. A blank and standard solution digest using 25, 50, and 100 µl of 1µg mL^{-1} standard Hg solution were subjected to the same treatment. The concentrations of the standard solution digest obtained were 25, 50 and 100 ng/L.

Quality assurance samples analyzed included blanks, replicate samples and pre-digestion spikes. Accuracy of the analytical procedure was evaluated by analysis of certified reference materials (Dogfish muscle, DORM-2) from the National Research Council of Canada (NRC).

Results and Discussion

The accuracy of the technique used in this study was determined by analyzing certified reference materials and recovery studies. The detection limit of the analytical technique used in this study was 0.5 ng g^{-1}. The validity of the method has been proved by the agreement between the measured (4.65–4.72 $\mu g g^{-1}$) and the certified (4.15–4.79 $\mu g g^{-1}$) concentrations in dogfish muscle of the certified reference material (DORM-2). Pre-digestion recovery studies were performed by spiking samples with 25 and 50 µl of 1 µg mL^{-1} standard Hg solution. Recovery studies yielded results (97–102%), within the 95% confidence limit.

Total mercury (Hg) concentrations were determined in the edible muscles of fish and sediments from the Upper Volta basin at Yeji in the Brong-Ahafo Region of Ghana where widespread. A total of one hundred and ninety fish samples of six species of fish and ten sediments were analyzed for total mercury.

Results for total length of fish, fresh weight and total mercury concentration in 190 samples made up of six fish species are presented in Table 1. All the fish species analyzed in this study are consumed by the local population.

Observed mercury concentrations ranged from 44.17 to 85.89 ng/g wet weight for *Synodontis gambiensis* (mean = 69.95 ng/g), 13.11–38.64 ng/g wet weight for *Synodontis ocelleifer* (mean = 24.52 ng/g), 16.39–25.83 ng/g wet weight for *Distichodus rostratus* (mean = 20.52 ng/g), 3.26–79.73 ng/g wet weight for *Synodontis membranaceus* (mean = 43.15 ng/g), 40.80–90.30 ng/g wet weight for *Bagrus docmac* (mean = 67.03 ng/g), 10.48–61.90 ng/g wet weight for *Chrysichthys nigodigitatus* (mean = 25.69 ng/g) and 12.34–24.18 ng/g wet weight for for *Gnathonemus senegalensis* (mean = 19.21 ng/g). The highest mercury concentration (90.30 ng/g wet weight) was recorded for one species of *Bagrus docmac* whereas the lowest mercury concentration (3.26 ng/g wet weight) was recorded for one species of *Synodontis membranaceus*. All the fish samples showed total mercury concentration below the World Health Organization (WHO) threshold of total mercury of 0.5 ng/g wet weight. Total mercury concentration in fish depends on the fish species and varies with factors such as total length (age) of fish and fresh weight of fish.

There was good positive correlation between mercury concentration and fresh weight for *Synodontis gambiensis* ($R^2 = 0.7353$) and *Gnathonemus senegalensis* ($R^2 = 0.6067$). Both species also showed a good positive correlation between mercury concentration and total length (age) with $R^2 = 0.5910$ and $R^2 = 0.8754$, respectively. However, poor correlations were observed between mercury concentration, fresh weight and total length (age) for *Synodontis ocelleifer*, *Distichodus rostratus*, *Synodontis membranaceus*, *Bagrus docmac* and *Chrysichthys nigodigitatus*. It was also observed that some small species of fish (in terms of body weight) had significantly higher T-Hg concentration than large fish.

Good correlations between mercury concentrations and fresh weight of fish and total length have been reported in a number of studies among carnivorous species whereas herbivorous fish species generally show poor correlation (Oppong et al. 2010). The five most significant factors that control mercury accumulation in freshwater fish were reported by Lindqvist et al. (1991) to be organic matter, pH, seasonal changes, regional variations and hydrologic conditions. Growth difference may also influence mercury bioaccumulation. The low levels of total mercury in all the fish species and sediments analyzed compared to the WHO standard showed a relatively clean aquatic environment in spite of the extensive pollution of the river's watershed with mercury from artisanal mining.. The low concentration of mercury in sediments (Table 2) is consistent with the low levels found in the fish species analyzed. The low levels found in fish (range: 3.26–90.30 ng/g wet weight) suggest that there is limited methylation of mercury in the Upper Volta Basin area of Yeji, presumably due to the hydrodynamics of the stretch which prevents the development of anaerobic sediments that promote the production of methylmercury (MeHg). According to WHO environmental health criteria (US Environmental Protection Agency. Mercury Study Report to Congress 1996), Hg concentrations in fresh-water fish from non-polluted areas are commonly in the range of 100–200 ng/g. Comparing the literature data to the the present results shows that the fish analyzed in the this study hadw surprisingly low mercury levels. One significant factor that controls methylation is organic matter content of the aquatic environment. The low levels of mercury found in this study can be

Table 1 Total Hg concentrations (ng/g) in fish muscle samples from the Upper Volta Basin at Yeji

Species name	Sample size (n)	Fresh weight range (g)	Mean weight (g)	Length range (cm)	Mean length (cm)	Hg Conc. range (ng/g)	Mean Hg. conc. (ng/g)
Chrysichthys nigrodigitatus	29	48.0–85.0	65	16.5–20.4	18.8	10.48–61.90	25.69
Bragrus docmac	19	44.0–158.3	64.9	21.1–32.1	24.4	40.80–90.30	67.03
Synodontis membranaceus	9	11.25–79.73	185.1	15.1–33.85	21.4	3.26–79.73	43.15
Synodontis gambiesis	14	70.5–116	91.9	19.1–24.5	21.4	44.17–85.88	69.51
Gnathonemus senegalensis	15	34–52	44.6	15.6–16.8	16.4	12.33–24.18	19.21
Distischodus rostratus	7	23–855	168.9	13.5–41.0	21.2	16.39–25.83	20.52
Synodontis ocellifer	16	18–502.5	183.8	11.5–35.5	22.5	13.11–38.64	24.52

Table 2 Results for mercury in sediments

Sports	1	2	3	4	5	6	7	8	9	10
Mean T-Hg concentration (ng/g)	29.97	26.91	31.36	33.69	61.99	11.87	70.25	68.42	48.91	32.61

attributed to low organic matter content in the particular section of the river (Kwaansa-Ansah and Sekyi-Aidoo 2006, unpublished dissertation, Kwame Nkrumah University of Science and Technology, Kumasi-Ghana). The high levels of mercury observed in some small fish compared with large ones could be due to the fact that the small fish tend to be benthic and hence are exposed to sediment-bound mercury. It can also be due to the fact that the fish are not representative of their diet because of their fat content since mercury is lipophilic.

To ensure that the health status of the public is not compromised through the consumption of fish contaminated with mercury, the Joint Food and Agriculture Organization and the World Health Organization (FAO/WHO) Expert committee on Food Additives have established a Provisional Tolerable Weekly Intake (PTWI) of 300 µg total mercury per person (WHO 1976). This level is equivalent to 5 µg of total mercury per kg body weight. The calculated weekly intake of mercury using minimum and maximum total mercury concentrations from this study showed that between 30.02 and 258.65 kg of fish has to be consumed per week to attain the PTWI limit of 300 µg. Though there is no data on weekly consumption rate on fresh water fish in Ghana, but considering the amount of fish to be consumed to attain the PTWI threshold, one can assume that ingestion of fish from the Volta Lake at Yeji is unlikely to constitute a significant health hazard to the local population.

Mercury concentrations in sediments of Upper Volta basin at Yeji are presented in Table 2. Total Hg concentration in sediments ranged from 11.87–70.25 ng/g with a mean of 41.60 ng/g dry weight. The levels obtained by Hunter et al. (1987) are also comparable with the levels under this study so far as correlation between Hg concentration in sediments and fish are concerned. However, the levels are far lower than that reported Han et al. (2006) from the Venice Lagoon in Italy. Mercury concentrations in sediments under this study are below IAEA threshold value810 ng/g.

The results of these studies indicate that mean total mercury in fish and sediments from the Upper Volta Basin at Yeji were below the WHO/FAO and the IAEA recommended limit. The low concentration of mercury in fish and sediments in this study suggest a relatively clean aquatic environment that has not yet been significantly impacted by mercury contamination in the study area.

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