Mercury accumulation in fishes from tropical aquatic ecosystems in the Niger Delta, Nigeria

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Fishes are important biomarkers of trace elements in aquatic ecosystems, and are used to evaluate the status of water pollution by mercury in tropical aquatic ecosystems in Nigeria. Common fishes, *Chrysichthys nigrodigitatus*, *Brycinus nurse*, *Hemichromis fasciatus*, *Lutianus ava*, *Oreochromis nilotica*, *Pomadasys jubelini*, *Stellifer stellifer* and *Tilapia guineensis* were analysed for Hg accumulation using the cold vapour atomic absorption spectrophotometry technique. The results showed that Hg concentration in *P. jubelini* was relatively the highest, with a mean concentration of 0.063 ± 0.03 mg kg^{-1}. Other concentration values were 0.044 ± 0.031 mg kg^{-1} for *O. nilotica*, 0.026 ± 0.013 mg kg^{-1} for *B. nurse*, 0.034 ± 0.034 mg kg^{-1} for *H. fasciatus*, 0.023 ± 0.020 mg kg^{-1} for *C. nigrodigitatus* and 0.33 ± 0.016 mg kg^{-1} for *L. ava*. Concentrations of Hg accumulated by the fishes were low and within internationally accepted limit, not likely to cause mercury poisoning. Because of the high Hg accumulating potential of *P. jubelini*, it is recommended as a biomarker for assessment of Hg toxicity in a tropical aquatic environment.

Keywords: Biomarker, fish, mercury, Niger Delta, water pollution.

THE aquatic systems are being daily inundated anthropogenically with chemical pollutants from industrial, domestic and agricultural wastewater[1,2], which are ultimately absorbed by aquatic animals and plants. The vulnerability of aquatic habitats to heavy-metal contamination has been well established[3]. Pollution of aquatic ecosystems by heavy metals is an important environmental problem[4], as heavy metals constitute some of the most dangerous toxicants that can bioaccumulate[5]. Metals that are deposited in the aquatic environment may accumulate in the food chain and cause ecological damage also, posing a threat to human health due to biomagnification over time[6–10].

Aquatic ecosystems are typically monitored for pollution of heavy metals using biological assays[11,12]. Fish species are often the primary consumers in any aquatic ecosystems[13] and thus metal concentration in fish can act as an environmental indicator of the state of any aquatic system[14,15].

Aquatic organisms have been reported to accumulate heavy metals in their tissues several times above ambient levels[16,17]. Fishes have been used for many years to determine the pollution status of water, and are thus regarded as excellent biological markers of metals in aquatic ecosystems[3,18–20]. Bioaccumulation of heavy metals by absorption across the entire body surface of the fish as well as through the gills has been reported[21].

Mercury (Hg) is recognized as a highly toxic metal and is stringently regulated in waste discharges[22]. Movement of Hg(II) into the aquatic ecosystem and its bioaccumulation as methylmercury in higher trophic levels are strongly influenced by the uptake of bioavailable forms of Hg(II) by bacteria. Enhanced levels of mercury have since been found in fish from surface water not affected by direct discharge of Hg. These include dark-water coastal streams and surface waters influenced by wetlands, which are sites of active methylmercury production, humic and low-alkalinity lakes. Fishes obtain methylated mercury through dietary uptake, which could be influenced by size, diet and food-web structure. Increased uptake and bioaccumulation of methylmercury in fish is also influenced by an array of ecological, biotic and environmental factors and processes[23].

Concern about heavy-metal contamination of fish has been motivated largely by adverse effects on humans and wildlife, given that consumption of fish is the primary route of heavy-metal exposure. Presence of unacceptable levels of Hg and Pb in the tissues of the African catfish, *Clarias gariepinus* from River Niger has been reported[24]. Omeregie[25] also reported enhanced levels of Pb, Cu and Zn in *Oreochromis nilotica* (Nile Tilapia) from River Delimi. Higher concentrations of Cd, Cu, Fe, Mn and Zn have been shown to bioaccumulate in muscle, liver and gill tissues of *O. nilotica* and *C. gariepinus*, cultured in some disused mining lakes[26]. Continuous pollution of our streams, rivers, lagoons, estuaries, creeks and other surface water bodies constitutes significant threat to aquatic flora and fauna, posing considerable setback to fishing either for recreation or commercial purposes, and ultimately constitutes adverse health hazards to humans. This is a report on the investigation of the levels of mercury in different types of fishes from rivers, estuaries and creeks in the southeastern part of the Niger Delta region, Nigeria.

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Materials and methods

Collection and preparation of samples

Common fishes, namely *Chrysichthys nigrodigitatus*, *Brycinus nurse*, *Hemichromis fasciatus*, *Lutianus ava*, *Oreochromis nilotica*, *Pomadasys jubelini*, *Stellifer stellifer* and *Tilapia guineensis* from different aquatic systems within the Niger Delta were collected for analysis. Fish species were obtained from eight locations: Enyong Creek of Itu (EYC); Cross River at Inua-Abasi (CRI); Iko River in Mbo (IRM); Imo River at Ogbigbo (IRO); Oron River in Oron (ORR); Stubbs Creek (SCI), Douglas Creek (DCI) and Qua Iboe Estuary (QRE) at Ibeno, within the Niger Delta region (Figure 1).

A total of 128 fish samples comprising four from each species were obtained for analysis. Undissected fish samples were identified and labelled. A log of their date and place of collection, weight (TW) and length (TL) of each fish were recorded before transportation in ice packs to the laboratory, where they were digested.

Prior to digestion, the condition factor (CF) which describes the physiological condition of the fishes[27,28], was calculated according to the equation[29]:

$$CF = \frac{TW}{(TL)^3} \times 100.$$

where TW is the total weight and TL the total length of the fish.

Sample pre-treatment and digestion procedure

Fish samples were filleted and dissected, and their liver tissues were placed in glass petri dishes and dried in an oven for 24 h at 58–60°C. After drying, the liver samples were ground into powder using pre-cleaned porcelain mortar and pestle, and then transferred into pre-cleaned brown
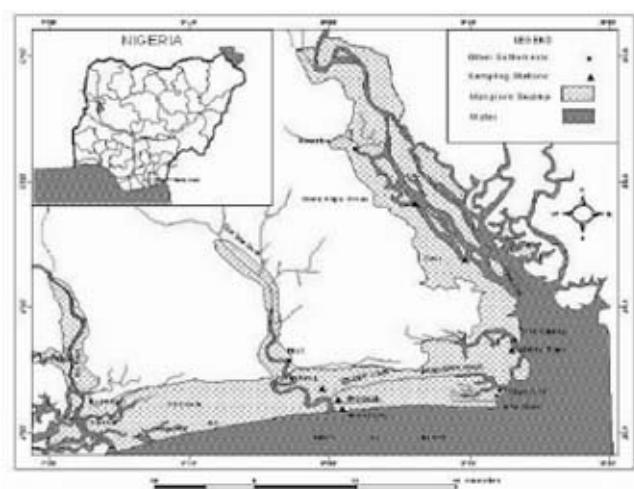

Figure 1. Map of the Niger Delta region, Nigeria showing major rivers and associated creeks where fish samples were obtained.

plastic containers. The samples were kept in the freezer before subsequent analysis. All acids used in the digestion were heavy-metal grade (Analar Grade). Precisely, 0.1 g of dry ground liver tissue was put into a pre-cleaned 30 ml PTFE Teflon container and then 2.0 ml concentrated HNO_3 and 2.0 ml of HCl were added to the digestion flask which was capped, well-sealed and allowed to stay for 12 h. The samples were heated on a hot plate and an ice-bath was used to cool the samples. Then 50 ml of 2.5% HNO_3 was added to each residue and heated again. After digestion, each sample was allowed to cool at room temperature. The solution was thereafter transferred to a 25 ml volumetric flask and brought to mark by adding distilled water. Mercury levels were determined using the cold vapour atomic absorption spectrophotometry technique with $SnCl_2$ as a reducing agent[30,31]. All the samples were analysed in duplicate and the validity of measurements was checked using blanks and a reference material (CRM: DORM-2). Data analyses were carried out using Analyze-It + 1.73 General® statistical software package with confidence level maintained at 0.05.

Results

Table 1 shows the sample ID, type of aquatic ecosystem and location from which the fishes were harvested. The range, mean concentration and relative standard deviation in the different fish species are presented in Table 2. The mean and range of total length and weight of the fish species and their correlation with Hg concentration are summarized in Table 2. The condition factors are also highlighted.

Hg concentration in *O. nilotica* ranged from 0.012 to 0.086 mg/kg. The coefficient of variation calculated for *O. nilotica* samples (ON-1 to ON-16) was 70.97%, with a mean concentration of 0.044 m/kg dry weight (Table 2). Mercury concentration in *T. guineensis* was the least, ranging from 0.011 to 0.028 mg/kg, with a mean concentration of 0.019 mg/kg. However, coefficient of variation for *T. guineensis* was 48.28% (Table 2).

Mercury concentration in *C. nigrodigitatus* ranged from 0.010 to 0.053 mg/kg with a mean concentration of 0.023 mg/kg. The relative standard deviation recorded was 86.55% (Table 2). *B. nurse* accumulated the lowest Hg concentration of 0.007 mg/kg. Its concentration ranged between 0.007 and 0.033 mg/kg, with a mean concentration and relative standard deviation of 0.026 mg/kg and 48.85% respectively (Table 2). Similarly, the mean mercury levels in *H. fasciatus*, *S. stellifer* and *L. ava* were 0.034, 0.031 and 0.033 mg/kg respectively. The relative standard deviation obtained, in decreasing order of variability, was 50.93% for *L. ava*, 52.90% for *S. stellifer* and 100.00% for *H. fasciatus*. Variability in *H. fasciatus* may be attributed to the wide range of Hg concentration. This is suggestive of the unsuitability of *H. fasciatus* for use as a biomarker of Hg pollution in aquatic ecosystem.

Table 1. Fish species, sample ID and location harvested

Fish sample	Sample ID	Location	Nature of ecosystem
Oreochromis nilotica	0N-1–ON-16	Imo River	Freshwater
Pomadasys jubelini	PJ-1–PJ-16	Oron River	Freshwater
Brycinus nurse	BN-1–BN-16	Douglas Creek	Freshwater
Tilapia guineensis	TG-1–TG-16	Enyong Creek	Freshwater
Hemichromis fasciatus	HF-1–HF-16	Stubbs Creek	Freshwater
Chrysichthys nigrodigitatus	CN-1–CN-16	Cross River	Freshwater
Stellifer stellifer	SS-1–SS-16	Iko River	Freshwater
Lutianus ava	LA-1–LA-16	Qua Iboe Estuary	Brackish water

Table 2. Concentration, average wet weight and total length, correlation and condition factors in different fish species

Species	Mean TL (range, cm)	Mean TW (range, cm)	Concentration (mg/kg)	RSD (%)	r Concentration: TW (R^2)	r Concentration: TL (R^2)	CF
O. nilotica	9.48 ± 0.73 (8.90–10.50)	14.28 ± 2.47 (11.50–17.43)	0.044 ± 0.031 (0.012–0.086)	70.97	–0.51 (25.70%)	–0.35 (11.96%)	1.69 ± 0.26
P. jubelini	24.88 ± 0.48 (24.50–25.50)	267.71 ± 0.50 (266.96–267.98)	0.063 ± 0.030 (0.023–0.086)	47.87	–0.49 (23.53%)	0.11 (1.28%)	1.74 ± 0.09
B. nurse	15.74 ± 0.33 (15.25–16.00)	57.61 ± 1.06 (56.30–58.78)	0.026 ± 0.013 (0.007–0.033)	48.85	–0.27 (7.34%)	–0.56 (30.94%)	1.48 ± 0.08
T. guineensis	24.94 ± 0.66 (24.00–25.50)	246.64 ± 4.17 (240.39–248.94)	0.019 ± 0.009 (0.011–0.028)	48.28	–0.54 (29.66%)	0.74 (54.92%)	1.59 ± 0.14
H. fasciatus	21.06 ± 3.22 (16.25–23.00)	89.94 ± 2.97 (86.99–94.04)	0.034 ± 0.034 (0.011–0.021)	100	–0.11 (1.25%)	0.32 (10.13%)	1.12 ± 0.72
C. nigrodigitatus	22.71 ± 0.58 (22.00–23.25)	70.03 ± 1.55 (68.50–72.13)	0.023 ± 0.020 (0.010–0.053)	86.55	0.96 (92.19%)	0.49 (23.95%)	0.60 ± 0.05
S. stellifer	21.39 ± 0.41 (21.10–22.00)	125.27 ± 0.92 (124.40–126.53)	0.031 ± 0.016 (0.013–0.052)	52.90	–0.91 (83.38%)	–0.25 (6.12%)	1.28 ± 0.07
L. ava	23.78 ± 1.68 (21.30–25.00)	93.58 ± 1.32 (92.25–95.40)	0.033 ± 0.017 (0.017–0.050)	50.93	0.06 (0.34%)	–0.55 (30.02%)	0.033 ± 0.017

TW, Weight; TL, Length; r, Correlation coefficient; R^2, Coefficient of determination; CF, Condition factor.

Mercury concentration was comparatively high in *P. jubelini* samples analysed. It ranged from 0.023 to 0.086 mg/kg. The mean Hg concentration and coefficient of variation recorded for *P. jubelini* samples were 0.063 mg/kg and 47.87% respectively (Table 2). The low coefficient of variation is indicative of the stability of a metal in fish liver tissues and a key attribute of biomarking.

In general, the trend in mean concentration in the various fish species was *P. jubelini* > *O. nilotica* > *H. faciatus* > *L. ava* > *S. stellifer* > *B. nurse* > *C. nigrodigitatus* > *T. guineensis*. Also, a comparison of the relative standards of variation, an index of stability obtained revealed that the trend of variability was *H. faciatus* > *C. nigrodigitatus* > *O. nilotica* > *S. stellifer* > *L. ava* > *T. guineensis* > *P. jubelini*.

The condition factor (CF) highlighting the relative physiological conditions of the analysed fish samples revealed that the fishes were in good health with no visible severe malformations. A correlation of CF with Hg concentration in all fish species gave statistically insignificant negative correlations (CF–Hg) in *H. fasciatus* ($r = -0.28$), *C. nigrodigitatus* ($r = -0.29$), *O. nilotica* ($r = -0.11$), *P.* *jubelini* ($r = -0.14$), *T. guineensis* ($r = -0.78$), and statistically insignificant positive correlations (CF–Hg) in *B. nurse* ($r = 0.59$), *L. ava* ($r = 0.60$) and *S. stellifer* ($r = 0.13$). A linear correlation of the weight and length of each species with the concentration of Hg in the liver tissues indicated that the correlation of Hg in *C. nigrodigitatus* against its weight showed the only statistically significant ($P > 0.05$) relation. The concentration of Hg in *C. nigrodigitatus* increased as its weight increased. This apparent relation may be attributable to the feeding habits of the species. *C. nigrodigitatus* is an omnivore and feeds on plants, benthic invertebrates and insects[32].

Discussion

Bioaccumulation of heavy metals in aquatic life, especially in fish is of imperative interest owing to the direct toxic effects to aquatic animals and the potential detrimental effect on human health[33]. However, the concentrations acquired through bioaccumulation have been reported to be a function of the length and weight of the fish species[34,35].

Heavy-metal concentrations in aquatic fauna are often proportional to the levels in the aquatic environment in which the fauna resides[26]. This suggests that such fauna can be used as biological indicators of metal pollution, as documented by Flessas et al.[36]. Variations in feeding habits of fish species can be a function of the levels of heavy metal found in their tissues[37]. Romeo et al.[38] showed that Hg concentrations in edible muscles of pelagic fish species are lower than those of benthic fish species. In general, results indicate that the accumulation of Hg was significantly higher in liver tissues of *P. jubelini* and *O. nilotica*. The use of *P. jubelini* and *O. nilotica* as biological indicators for Hg metal pollution in the coastal freshwaters and brackish ecosystems of the Niger Delta is strongly recommended. This study, however, confirms earlier reliability of *O. nilotica* as a good bioindicator[26]. Thus we conclude that *P. jubelini* could be a better bioindicator of Hg pollution than *O. nilotica*.

The use of only liver tissues in this study was based on assertions that target organs such as liver, gonads, kidney and gills have a tendency to accumulate enhanced levels of heavy metals than the muscles[39]. As pointed out by Avenant-Oldewage and Marx[40], liver tissues of fishes accumulate relatively high levels of trace metals because the liver is a primary organ for storage and detoxification of these metal toxicants as well as an organ where the specific metabolic and enzyme-catalysed processes related to each heavy metal take place[26]. It is generally accepted the metals do not accumulate in the muscles of fishes[41].

Conclusion

A comparison of Hg concentrations accumulated by fishes with standard permissible Hg levels in them, indicates that the levels accumulated were within recommended limits for human consumption[42]. Presently, consumption of these species of fish from the rivers, creeks and estuaries in the Niger Delta region, Nigeria is high and may obviously, not lead to mercury poisoning. However, long-term bioaccumulation through food chain is a major concern. Our findings have shown that *P. jubelini* has a good Hg accumulation potential and may serve as a biological marker of Hg toxicological studies in tropical aquatic ecosystems.

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