

Assessment of Trace Metal Levels in Fish Species of Lagos Lagoon

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Abstract

Fish species, surface water, bottom water, epipellic and benthic sediments were collected from Oworonshoki, Lagos lagoon, to determine their trace metal levels using atomic absorption spectrophotometer. The fish species collected were *Tilapia guineensis*, *Chrysichthys nigrodigitatus*, *Liza grandisquamis* and *Psettias sebae*. The results indicated that the highest concentrations of trace metals were present in the fish species, followed by benthic sediments, epipellic sediments, bottom water, and surface water. Levels of trace metals found in males and females of fish species showed significant differences. The female species, except *Tilapia guineensis*, accumulated higher Fe and Zn values. The female species of *Psettias sebae* was a good bio-indicator of trace metal contamination in the lagoon. Cd and Ni were not detected in any of the fish species. Pb levels in the fishes were above the maximum acceptable limit for human consumption, and could have been sourced from the discharge of industrial wastes into the lagoon. The levels of Fe and Zn in the water, sediment and fishes were all within acceptable limits. The highest condition factor of 2.76 was observed in the female of *Chrysichthys nigrodigitatus*, while the female, *Psettias sebae*, had the least condition factor of 0.57, correlating with its high metal contamination.

Keywords: Fish species; Lagos lagoon; Trace metals; Sediments; Water

Introduction

Trace metals are natural components of the earth's crust, the stable and persistent environmental contaminants of coastal waters and sediments. They are serious pollutants due to their toxicity, persistence and bioaccumulation problems [1]. They exhibit toxicity by forming complexes with organic compounds and active sites of enzymes. The impact of anthropogenic perturbation is most strongly felt by estuarine and coastal environments, adjacent to urban areas [2]. Increasing amounts of chemicals may be found in predatory species resulting from bio-magnifications, which is the concentration of chemicals in the body tissue accumulated over the life span of the individual [3]. Metals could be accommodated in water, sediment, and organisms in the aquatic environment. Fishes have been recognized as good bio-accumulators of organic and inorganic pollutants [4]. Trace metals gain access into the aquatic system from natural and anthropogenic sources and get distributed in the water body, suspended solids and benthic sediments during the course of their transportation [5].

Fishes are major sources of protein and could be grouped into finfish and shellfish. Finfish constitute major components of most aquatic habitats, and are important bio-markers of metal levels in aquatic ecosystems. Age of fish, lipid content in the tissues, and means of feeding are important factors that affect the accumulation of trace metals in fishes. The pollution of aquatic ecosystems by trace metals is an important environmental problem, as they constitute some of the most hazardous substances that could bio-accumulate [6]. The trace metal pollution of aquatic ecosystems is usually obvious in sediments and aquatic biota than in elevated concentrations in water [7]. Therefore, aquatic ecosystems are typically monitored for pollution of trace metals using biological assays.

Metals could enter fish either directly through the digestive tract due to consumption of contaminated water and food, or non-dietary routes across permeable membranes such as gills [8]. Over the last few decades, there has been growing interest in the determination of trace metal levels in the aquatic environment, and attention has been drawn to the measurement of contamination levels in public food supplies, particularly fish [9]. The accumulation of metals in fish is mainly traced to the liver and gills, while a small accumulation has been observed in the muscle [10]. Toxicological and environmental studies have

prompted interest in the determination of toxic elements in food. The ingestion of food is an obvious means of exposure to metals, not only because many metals are natural components of foodstuffs, but also because of environmental contamination and contamination during processing [11].

Trace metal levels in biota such as fish could increase through bio-accumulations, and trace metals are known to have toxic effects at high concentrations [12]. Fishes are at the top of the aquatic food chain, and they accumulate trace metals from the surrounding water, the consumption of which has been linked to many diseases in humans. Evaluation of trace metal levels is important due to their effects on the ecosystem. Fishes could take up metal ions in the water and store them in their tissues.

Water pollution is a major environmental concern, especially in the wake of rising population, rapid urbanization and industrialization. Industrial waste discharge has increased the hazard of water pollution [13]. It is also clear that many of the key sources of pollution such as sewage and nutrient are very closely linked. There are many possible impacts of persistent particles on the environment, including trace metals and other contaminants that could be transferred to filter-feeding organisms and other invertebrates, ultimately reaching higher trophic levels.

Sediments act as the most important reservoir or sink of metals and other pollutants in the aquatic environment [14]. The quality of sediments has become very important, as it is the primary storage compartment for metals released into surface waters and, in many cases, the major source of contamination of the food chain. Indirect exposure to contaminated sediments takes place when fishes feed on benthic

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invertebrates that are ingesting particular matter. Direct exposure through the sediment could take place by release of contaminated particulate matter into the water column, by both natural and anthropogenic disturbances which could result in metal remobilization [15]. The discharge of rivers into lagoons is the main transport pathway of trace metals. Periodic monitoring of the metal levels in fish species, water and sediment of Lagos lagoon is important, given the rate of industrial growth in Lagos, and the concomitant increase in the rate of dumping of wastes and effluents into the lagoon. Lagos lagoon receives domestic and industrial wastes and serves as a sink for these wastes. This study was undertaken to determine the levels of trace metals in selected fish species, water and sediments from Lagos lagoon.

Materials and Methods

Study area

The study area is the Lagos Lagoon (Figure 1). It is a brackish coastal lagoon, which lies within latitude 6°26'–6°37' N and longitude 3°23'–4°20' E. Lagos Lagoon empties into the Atlantic Ocean through Lagos harbor, and is drained by Ogun, Agboyi, Majidun and Aye rivers. It is more than 50 km long and 3-13 km wide, and is separated from the Atlantic Ocean by long sand bars 2-5 km wide. Human activities carried out at the lagoon include fishing. The fauna is composed of fresh, marine and brackish water species, depending on the season. Among the fauna exploited for commercial purposes are finfish and shellfish. The discharge of sewage into the lagoon, contamination from sawmills, trace metal load coupled with contaminants from domestic and industrial wastes lead to increase in environmental pollution [16].

Sampling procedures

Sampling was conducted at Oworonshoki end of the lagoon during the dry season (February) of 2008, with the aid of an engine boat. Sampling locations were identified with a hand-held global positioning system (GPS 12 Garmin model).

Collection of samples

Two (one male, one female) freshly harvested finfish, characterized by their eating habits were collected. The fish species collected were *Tilapia guineensis*, *Chrysichthys nigrodigitatus*, *Liza grandisquamis* and *Psettias sebae*. The male and female fish samples were separately labeled and packaged in an iced cooler, before being taken to the laboratory.

The surface and bottom water samples were collected from two locations (N 06°56' 35.90", E 003°40' 64.20"; N 06°56' 36.90", E 003°40' 89.10"). Surface water (10-25 cm) sample was directly collected using a plastic bottle, while the bottom water was scooped using the grap sampler. Samples from the two locations were mixed to obtain composite samples, labeled, iced and transported to the laboratory.

Epipellic sediments were collected at two locations (N 06°56' 42.40", E 003°40' 91.40"; N 06°56' 76.90", E 003°41' 10.50"). The samples were scooped at surface layer (0-5 cm), using a short sampler. Samples from the two locations were mixed to obtain composites and packed in cellophane bags. They were labeled and packaged in an iced cooler, before they were taken to the laboratory.

A Van Veen grap sampler was used to collect benthic sediments at two locations (N 06°56' 25.90", E 003°40' 64.20"; N 06°56' 36.90", E 003°40' 89.10"). Composite sediment samples were obtained and packed in cellophane bags. They were labeled and packaged in an iced cooler, before they were transported to the laboratory.

Analysis of samples

Characterization of the fishes: The fishes were placed in aluminium foils, and their sexes determined by examining the gonads. The wet weight, dry weight, total length and standard length of the selected fish species were measured. The samples were dried to constant weight at 105°C in an oven. The condition factor of fish [17] was calculated using the equation:

$$CF = \frac{W}{L^3} \times 100 \text{ ----- Equation 1}$$

Where, W=the fish wet weight (g)

L=the fish total length (cm)

CF=the condition factor

The fish dry weight to wet weight ratio and the percentage dry matter were determined as follows:

$$R = \frac{\text{Dry weight}}{\text{Wet weight}} \text{ ----- Equation 2}$$

$$\% \text{ Dry matter} = R \times 100\% \text{ ----- Equation 3}$$

Determination of fish fat

The fish fat was determined by subjecting the samples to a continuous extraction with petroleum ether, using soxhlet apparatus [18].

Determination of trace metals in fish, water and sediment samples

The fish, water and sediment samples were digested according to AOAC method [19]. The levels of the trace metals in the digested samples were determined using Analyst 200 AAS by Perkin Elmer.

Preparation of standard solutions

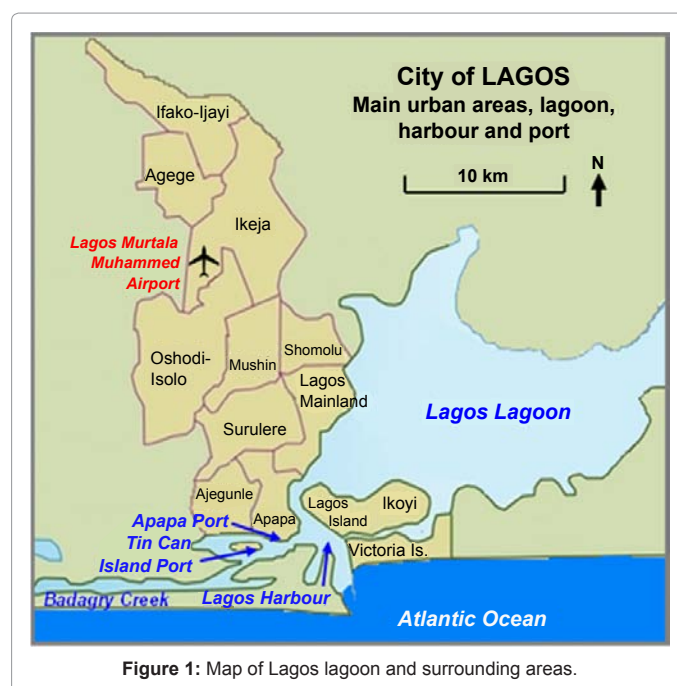


Figure 1: Map of Lagos lagoon and surrounding areas.

Instrumental calibration was carried out, prior to metal determination, by using standard solutions of metal ion prepared from their salts. Calibration standards were prepared from certified commercial standards (Perkin Elmer). Commercial analar grade 1000 ppm stock solutions of Fe²⁺, Zn²⁺, Cd²⁺, Pb²⁺ and Ni²⁺ were diluted in 25 cm³ standard flask, and made up to the mark with deionised water, to obtain working standard solutions of 2.0 ppm, 3.0 ppm and 4.0 ppm of each metal ion. A pure blank (control) was also prepared to check the quality of the samples.

Results and Discussion

Characterization of fish species

Table 1 highlights the mean wet weights, dry weights, % dry matter and fat weights of the fish samples, while table 2 shows their mean total lengths and standard lengths. Table 3 gives the condition factor of the fish species investigated, while Tables 4-6 indicate trace metal levels in fish species, water and sediment samples, respectively. There was largely a correlation between the total length and standard length of the fishes: increasing total length gave a corresponding increase in standard length, and vice versa. Also, it was observed that increasing fish lengths gave corresponding increase in fish weights in most of the fishes. This corroborates earlier studies, which established a relationship between the fish lengths and weights [20]. There was no particular correlation between the wet weights, dry weights and fat weights of the fish species. However, studies have indicated a relationship between the fish fat weight, wet weight, and condition factor [21].

There was a reduction in the fish total and standard lengths after drying. Standard length is a reliable length measurement as the caudal fins of fishes which constitute the total length, could break off during drying.

The condition factor describes the physiological condition of fishes [17], and usually increases when sexual maturation approaches.

Table 1: Mean weights of fish samples.

Fish species	Sex	Wet weight (g)	Dry weight (g)	% Dry matter	Fat weight mg/kg
<i>Tilapia guineensis</i>	Male	77.78	13.01	16.73	58.16
	Female	47.97	15.56	32.44	80.77
<i>Liza grandisquamis</i>	Male	31.26	9.92	31.73	90.05
	Female	34.17	9.79	28.07	81.57
<i>Chrysichthys nigrodigitatus</i>	Male	30.10	8.45	29.09	97.59
	Female	20.10	6.38	31.74	74.79
<i>Psettias sebae</i>	Male	34.14	9.86	28.88	14.61
	Female	40.59	8.70	21.43	75.05

Table 2: Mean lengths of fish samples.

Fish species	Sex	TLW (cm)	SLW (cm)	TLD (cm)	SLD (cm)
<i>Tilapia guineensis</i>	Male	15.10	11.75	14.65	10.75
	Female	14.75	11.20	14.30	10.85
<i>Liza grandisquamis</i>	Male	15.50	12.65	15.05	11.35
	Female	15.15	12.35	15.00	12.00
<i>Chrysichthys nigrodigitatus</i>	Male	10.80	8.60	10.50	8.15
	Female	9.00	7.10	8.80	6.70
<i>Psettias sebae</i>	Male	16.20	12.65	15.00	12.00
	Female	19.20	14.35	17.45	13.85

TLW = Total length of wet fish species; SLW = standard length of wet fish species
TLD = Total length of dry fish species; SLD = standard length of dry fish species

Table 3: Condition factor of fish samples.

Fish species	Sex	Condition factor
<i>Tilapia guineensis</i>	Male	2.26
	Female	1.49
<i>Liza grandisquamis</i>	Male	0.84
	Female	0.98
<i>Chrysichthys nigrodigitatus</i>	Male	2.39
	Female	2.76
<i>Psettias sebae</i>	Male	0.80
	Female	0.57

Table 4: Trace metal levels in fish samples.

Fish species	Sex	Fe (mg/kg)	Zn (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Ni (mg/kg)
<i>Tilapia guineensis</i>	Male	19.02	13.66	ND	17.98	ND
	Female	16.82	11.41	ND	10.81	ND
<i>Liza grandisquamis</i>	Male	16.26	12.39	ND	12.81	ND
	Female	18.04	13.67	ND	10.92	ND
<i>Chrysichthys nigrodigitatus</i>	Male	29.69	21.17	ND	15.75	ND
	Female	30.59	28.13	ND	32.14	ND
<i>Psettias sebae</i>	Male	21.85	16.33	ND	11.66	ND
	Female	316.02	26.55	ND	152.42	ND

Table 5: Trace metal levels in water samples.

Water samples	Fe (mg/L)	Zn (mg/L)	Cd (mg/L)	Pb (mg/L)	Ni (mg/L)
Surface water	1.07	1.16	ND	ND	ND
Bottom water	1.17	0.10	ND	ND	ND

Table 6: Trace metal levels in sediment samples.

Sediment samples	Fe (mg/kg)	Zn (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Ni (mg/kg)
Epipellic sediment	9.04	12.09	ND	ND	ND
Benthic sediment	12.23	25.72	ND	1.47	ND

Undernourished or thin fish has a condition factor of less than 1, while adequately fed or fat fish has a condition factor greater than 1. The condition factor could be very variable between samples due to anatomical differences. Some fish breeds are short and stout with small cranium/head. These have an appreciably higher condition factor than breeds of slender and more streamlined shape. In this study, the highest condition factor of 2.76 was observed in female of *Chrysichthys nigrodigitatus*. The female specie of *Psettias sebae* was particularly stressed, as it had the least condition factor of 0.57. This underscores why it had a very high concentration of trace metals compared to other fishes.

The determination of fish fat was necessary because the fat weight is an indicator of the level of bioaccumulation of trace metals in the fish tissues. The highest fat weight was found in the species *Chrysichthys nigrodigitatus* (male), with fat weight of 97.57 mg kg⁻¹, while the least fat weight of 14.61 mg kg⁻¹ was found in *Psettias sebae* (male). There was no particular relationship between the fat weight and trace metal accumulation.

Trace metal levels in the fish species

Bio-accumulation of trace metals in aquatic life, especially fish is of interest, owing to the potential detrimental effect and direct toxic effects on human health. A comparison between the concentration of each metal found in males and females showed significant differences between the sexes for all metals. The data represented in this study showed that the highest concentration of trace metal was found in the female specie of *Psettias sebae*, with concentration of 316.02 mg kg⁻¹ for Fe. The female fish species, except *Tilapia guineensis*, accumulated higher Fe and Zn values than the male species. The female species of *Psettias sebae* was noted as a good bio-indicator of trace metal

contamination in the lagoon. The values obtained in this study are in agreement with the trace metal levels in *Chrysichthys nigrodigitatus*, in a recent investigation [22]. Cadmium and nickel were not detected in any of the fish species. This may have been due to the dry ashing of the fish samples. Pb levels in the fishes were above the maximum acceptable limit for human consumption [23], confirming earlier studies carried out in the lagoon [24]. The level in female *Psettias sebae* (152.42 mg kg⁻¹) was significantly high, correlating with its low condition factor of 0.57. The high Pb levels could be traceable to the dumping and discharge of industrial wastes into the lagoon. It could be an indication of leakage of oil, grease and antifouling paints, which are serious pollution sources for Pb [25]. Besides, samples for this investigation were collected from Oworonshoki end of the lagoon, where the polluted Iya Alaro River empties into. The Zn levels were within recommended limit. Zn is an essential element which is regulated and maintained at certain concentrations in fish [26], due to homeostatic regulation. Fe is not considered as toxic to aquatic organisms.

The Fe levels in the male species followed the order: *Tilapia guineensis*>*Chrysichthys nigrodigitatus*>*Psettias sebae*>*Liza grandisquamis*. The Zn levels followed the order: *Chrysichthys nigrodigitatus*>*Psettias sebae*>*Tilapia guineensis*>*Liza grandisquamis*, while the Pb levels were *Tilapia guineensis*>*Chrysichthys nigrodigitatus*>*Liza grandisquamis*>*Psettias sebae*. The Fe levels in the female species followed the sequence: *Psettias sebae*>*Chrysichthys nigrodigitatus*>*Liza grandisquamis*>*Tilapia guineensis*. The Zn levels followed the sequence: *Chrysichthys nigrodigitatus*>*Psettias sebae*>*Liza grandisquamis*>*Tilapia guineensis*, while the Pb levels were *Psettias sebae*>*Chrysichthys nigrodigitatus*>*Liza grandisquamis*>*Tilapia guineensis*. There appears to be a relationship between sex, feeding habits, and trace metal accumulation in the fishes. It should be noted, however, that whole fishes were used for the analyses. This method could cause discrepancy in the results. It may have a dilution effect as some organs have been proved to accumulate metals in significantly greater proportions than others [27]. Besides, it is difficult to obtain true metal levels due to large fluctuations, even within fish of the same species living in the same ecosystem.

Trace metal levels in water sample

Cd, Pb and Ni were not detected in the surface and bottom water. The trace metal levels were lower than the values obtained in a recent study carried out in the lagoon [28]. Fe and Zn levels in water were within permissible limit [29].

Trace metal levels in sediments

The Zn level was the highest in the epipellic and benthic sediments. Cd and Ni were not detected in the sediments, probably due to the ashing condition of the samples during pre-treatment. Pb was not detected in epipellic sediments, but was detected in the benthic sediments. The concentrations of the metals were more in the benthic sediments, confirming that benthic sediments serve as sinks for the metals. Trace metals are non-degradable and tend to persist in the environment. They enter the environment *via* natural and man-made sources. Many fishes spend their lives on aquatic sediments, and can thus transfer accumulated metal levels from the sediments to humans who eat fishes. In this study, the Fe, Zn and Pb levels in the sediments were lower than the values obtained in earlier [24] and recent studies [28] carried out in the lagoon, and within tolerable limits [29,30].

Conclusion

The results showed that the highest concentrations of trace metals

were present in the fish species, followed by benthic sediments, epipellic sediments, bottom water and surface water. The female species, except *Tilapia guineensis*, accumulated higher Fe and Zn values, when compared with the male species. The female species of *Psettias sebae* was particularly noted as a good bio-indicator of trace metal contamination in the Lagos Lagoon. Cd and Ni were not detected in any of the fish species. Pb levels in the fishes were above the maximum acceptable limit for human consumption, and could have been sourced from the discharge of industrial wastes into the lagoon. The levels of Fe and Zn in the water, sediment and fishes were all within acceptable limits. The highest condition factor of 2.76 was observed in the female of *Chrysichthys nigrodigitatus*, while the female *Psettias sebae* had the least condition factor of 0.57, correlating with its high metal contamination.

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