International Journal of Fisheries and Aquaculture Vol. 2(3), pp. 55-62, 9 February, 2012
Available online at http://www.academicjournals.org/IJFA
DOI: 10.5897/IJFA11.067
ISSN 2006-9839 ©2012 Academic Journals

Full Length Research Paper

Diversity of the edible fishes of the Lagos Lagoon, Nigeria and the public health concerns based on their Lead (Pb) content

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Accepted 24 August, 2011

In this study, a total of eighteen fish species were recorded in the Lagos Lagoon, Nigeria during a one year survey. Among the animals species recorded, the following, *Galeoides decadactylus, Dentex gibbosus, Elops lacerta, Scomber japonicus, Ethmalosa fimbriata, Lutjanus agennes, Caranx senegallus, Callinectes amnicola, Paeneus notialis* and *Mytilus edulis* were considered to be abundant in the Lagos lagoon based on the frequency of occurrence in fishermen catches. The analysis of the lead content in muscles of the edible fisheries revealed that the animals accumulated measurable quantity of lead in the edible parts. The level of lead detected in most (12 out of 18 species) of the fisheries species were found to be lower than the daily allowable concentration of 2.0 µg/g standard recommended by the World Health Organisation (WHO). Fishes species with high level of lead in their edible parts include Senegal jack, *C. senegallus* (2.188 µg/g), Bobo croaker, *Pseudotolithus elongatus* (2.024 µg/g), Cassava croaker, *Pseudotolithus senegalensis* (3.157 µg/g), crayfish, *Penaeus notialis* (25.46µg/g), edible mussel, *Mytilus edulis* (17.69 µg/g) and crab, *Callinectes amnicola* (10.19 µg/g). The mean levels of lead in *Mytilus edulis, Penaeus notialis*, and *Callinectes amnicola* collected from the Lagos lagoon were about 8 to 24 times higher than the WHO daily allowable standards for lead in sea foods and are therefore unsafe for human consumption. The need for regular monitoring of the levels of metals and other contaminants in edible fisheries resources and collaboration between environmental, health and food agencies to avert human tragedies due to lead accumulation are discussed.

Key words: Bioaccumulation, lead, industrial pollution, aquatic ecosystem, biomonitoring.

INTRODUCTION

Lagos lagoon is a major water body in the Lagos metropolis. It cuts across the southern part of the metropolis, linking the Atlantic Ocean (in the west and south) and Lekki Lagoon (in the east). It is about 6354.708 sq km in area and 285 km in perimeter. The Lagos Lagoon consists of three main segments such as Lagos harbor, the metropolitan end and Epe division segments. The lagoon impacts significantly on the lives of the Lagosians enormously. It is used primarily for fishing, aquaculture, sand mining and recreation activities. It also provides a good platform for inland waterways transportation which has potentialities of reducing transportation problems in Lagos metropolis and a place of abode for the some of the indigenous fishing communities such as the Ilajes and Ijaws (Stilts housing). The Lagos lagoon is one of the four major lagoons in the Nigerian coastal system, and a significant tourist attraction centre in Lagos State.

Due to the level of primary production in the lagoon, it is usually inhabited periodically by fish species of fresh water and marine origins, in search of food and good nursery ground. It has been reported that about 34% of fishes observed in this ecosystem are of freshwater origin and the remaining being marine (Amadi, 1991). Mullets (Mugilidae), sardine and bonga (Clupeidae) were classified as permanent fishes in this habitat (Fagade and

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Olaniyan, 1974; Amadi, 1990). The fisheries productivity of the Lagos Lagoon system is put above 75 kg/ha/year and the fishermen from the Nigerian coastal lagoon and estuaries contribute more than 50% of the current domestic fish production of about 800,000 metric tons (Onefeghare, 1990). It was also reported that about 28 metric tonnes/ha/year of oysters are produced annually from this ecosystem (Afinowi, 1985). As a result of lagoon's rich fauna, especially in fishes, fishing activities are usually witnessed on a daily basis. Recently, the state government is proposing using the Lagos Lagoon for cage culture as a form of contribution to food security and research. Fish and fisheries products are generally regarded as an important part of a healthy diet. In the developing countries, fish and fisheries products apart from being a source of cheap animal protein, are widely consumed as they have high quality protein and other essential nutrients, and are low in saturated fat while containing Omega 3 fatty acids (NSPFS, 2005).

In Nigeria, most investigations of the Lagos Lagoon have focused on the sediments and benthic communities (Ajao and Fagade, 1991), the diversity and density of macrobenthic fauna in the western part of the lagoon (Oyenekan, 1975), trend of heavy metals concentrations in Lagos Lagoon (Don-Pedro et al., 2004), the food and feeding interrelationships of the fishes (Fagade and Olaniyan, 1973) and the biology of some fishes and the fisheries (Fagade and Olaniyan, 1974). There is however, a need to update most of these studies and provide current information on the diversity of the edible fishery and the effects of pollutants on the health and abundance of these organisms inhabiting the Lagos Lagoon.

By virtue of its position, the Lagos Lagoon is surrounded by the densely populated (about fifteen million people) and highly industrialized Lagos metropolis, making it a convenient dumping site for numerous industrial and domestic wastes. According to Singh et al. (1995), an estimated 10,000 m^3 of industrial effluents are discharged into the Lagos Lagoon per day. Oyewo (1998) estimated levels of heavy metals discharged into drains/canals/streams and subsequently into the Lagos Lagoon as follows: Fe – 161,718 Kg, Mn – 205,989 Kg, CO – 15,683 Kg, Zn – 7026 Kg, Cr – 5285 Kg, Pb – 2259 Kg, Ni – 6124 Kg, Cd – 538 Kg and Hg – 278 Kg per annum. These estimates also confirmed that the industries are the major source of metal contaminants in the drains, streams and lagoon, since the graded prominence of metal types was similar in the sampled effluents and aquatic systems. The continued discharge of all sorts of untreated waste materials into the lagoon threatens the state of ecological equilibrium and diversity of fisheries resources in the lagoon (Don-Pedro et al., 2004; Otitoloju et al., 2007). According to Singh et al. (1995) the use of the lagoon as a dump for waste materials has reduced annual fish production in the Lagos Lagoon by over five folds between 1970 and 1990. Therefore, there is the need for more studies to establish the present state of pollution in the Lagos Lagoon, the diversity of biological resources and the level of pollutants such as heavy metals which can be detrimental to the health of the consumers (Chindah et al., 2000). In recognition of these needs and in pursuance of the sustainable use of coastal water and the adjacent land, the Federal Government of Nigeria put in place an Action Plan on water pollution control and biological diversity conservation in the country. Internationally, collaborative efforts were also made with the West African sub-region under the Gulf of Guinea Large Marine Ecosystem (GOGLME) Project aimed at monitoring coastal water in terms of pollution and biological diversity conservation. On the basis of the above-mentioned, this present study was carried out to investigate:

(i) The diversity of edible fisheries resources of the Lagos Lagoon.
(ii) The level of pollution-indicator heavy metal (Lead) in the edible parts (muscles) of the fisheries resources collected from different parts Lagos Lagoon, as well as, in sediment and water samples.
(iii) The potential public health risk based on the level of metals in the edible fisheries resources, derived bioaccumulation factors and internationally acceptable maximum allowable limits/standards of metals in food.

MATERIALS AND METHODS

Description of the study area and sampling design

The Lagos Lagoon complex stretches from Cotonou in the Republic of Benin and extends to the fringes of the Niger Delta in Nigeria along its 257 km course (Hill and Webb, 1958). The main body of the lagoon complex which serve as the study site is located between longitude 3° 22' and 3° 40'E and 6°17' and 6°28' N (Figure 1).

Fifteen different stations were sampled on the Lagos Lagoon which covered Oworoshokoki – Ikorodu, Osumare, Ibese, Oreta, Aabo, Tin Can, Apapa, Iganmu, Iddo, Lagos mainland, Okobaba, Okobaba trans Lagos mainland, UNILAG Lagoon front. The fifteen stations were marked with the aid of a Global Geopositioning System (GPS) and recorded as coordinates. Sampling operations were carried out on open fibre-glass boat motorized with a 75 hp Yahama outboard engine.

Collection of edible fishes resources in the Lagos Lagoon

Edible fishes of the Lagos Lagoon were procured from the fishermen that were fishing on the lagoon on a monthly basis from October 2009 to September 2010 at fifteen different stations. The sampling gears used for fishing by the fishermen include basket traps, baited long lines and set gill net. A total of at least 12 samples of each fish species were collected for the analysis. The samples were transported in an ice chest to University of Lagos, Ecotoxicology Laboratory for proper identification and examination.

Identification of fish species

In the laboratory each specimen was identified (using Field Guide to the Commercial Marine Resources of the Gulf of Guinea, Food

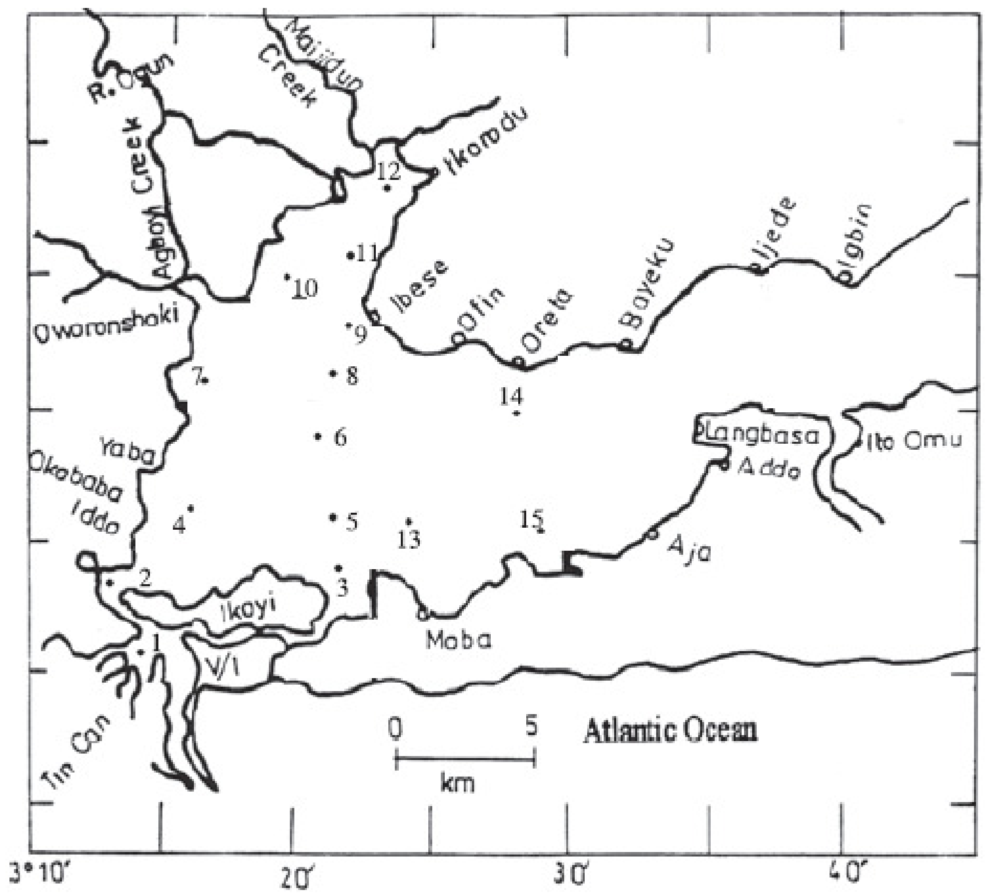

Figure 1. Lagos lagoon showing the sampling stations.

and Agriculture Organisation Species Identification Sheets for Fishery Purposes (FAO, 1990).

Chemical analyses of sample (water, sediment and animals) for lead (Pb) content

Digestion of samples

Water samples were filtered and digested using standard digestion method procedure (APHA/AWWA/WPCF, 1995). Sediment samples were normalised for particle size and digested following method provided by Ageiman and Chau (1976). The animal muscles were filleted and homogenized. A portion (10 g wet weight basis) from the homogenate was digested using the method described by FAO/SIDA (1986). All digestates and extracts obtained were filtered through Whatman No.1 filter paper and made up to the 25cc mark in volumetric flasks.

Atomic absorption spectrophotometry (AAS)

The Pb concentration in each digested sample was determined by comparing their absorbance's with those of standards (solutions of known Pb concentration) using an Alpha-cathodeon AAS. For data quality assurance, 10 samples of each blanks and muscle of fish spiked with known amount of analytical standard Pb solution were analyzed and recoveries calculated. The recoveries were 101.2 to 102.3% for blanks and 100 to 101.8% for fish muscle. In addition, diluted factory prepared AAS standard solutions were run as samples for accuracy check after every five measurements.

All digested samples were analyzed three times to obtain a mean value. The Pb concentration in each digested sample was determined by comparing their absorbance's with those of standards (solutions of known Pb concentration) using an Alpha-cathodeon AAS. Analytical blanks were run in the same way as the samples and concentrations prepared in the same acid matrix. For data quality assurance, the results were checked by analyzing standard reference material (SRM, TIL1 – Tilapia muscle) obtained from the National Reference Lab and factory prepared AAS standard Pb solutions. The results indicated good agreement between certified and the analytical values (Table 1). The recoveries of the certified standard reference material and AAS solution was 103 and 98% respectively.

Statistical analysis

Analysis of variance (ANOVA) was used to compare means of Pb concentrations in the fishes species of the lagoon using SPSS 17. Further analysis was carried out only where there was a significant difference at the 5% ($P<0.05$) level of significance (taken as minimum requirement). Further analyses were conducted where necessary by comparing pairs of mean (that is, individual treatment

Table 1. Concentration of metals in standard reference materials (TIL1 – Tilapia muscle) and standard AAS Pb solution.

Parameter	TIL1 (mg/kg)	AAS solution (µg/L)
Certified	0.066	10.3
SE	0.006	0.12
Observed*	0.068	10.1
SE	0.007	0.1
Recovery	103	98

*The value is the average of three determinations.

Table 2. Concentration of Pb in sediment and water samples collected from the different sampling stations.

Stations	Concentration in sediment (µg/g)	Concentration in water (µg/L)
1	0.005	0.012
2	0.001	0.008
3	0.007	0.01
4	0.01	0.008
5	0.001	0.025
6	0.001	0.05
7	0.001	0.025
8	0.001	0.02
9	0.008	0.03
10	0.002	0.015
11	0.05	0.035
12	0.003	0.026
13	0.002	0.02
14	0.001	0.018
15	0.005	0.015
Mean	0.0065	0.0211
*SD	0.0124	0.0113

*SD – Standard Deviation.

means with controls or themselves based on least significant differences (LSD) at 0.05 and 0.001 levels of significance.

Bioconcentration factor (BCF)

Bioconcentration factor (BCF) was estimated as the ratio of the concentration of the metal in animal tissue to the concentration of metal in the lagoon water.

$$\text{Bioconcentration factor (BCF)} = \frac{\text{Concentration in animal tissue}}{\text{Concentration in water}}$$

Bioaccumulation factor (BAF)

Bioaccumulation factor (BAF) was also estimated as the ratio of the concentration of the metal in animal tissue to the concentration of metal in the lagoon sediment.

$$\text{Bioaccumulation factor (BAF)} = \frac{\text{Concentration in animal tissue}}{\text{Concentration in sediment}}$$

RESULTS

Lead concentrations in lagoon sediment and water samples

The results of the Pb concentrations in sediment and water samples collected from the sampling stations are provided in Table 2. The results show that the level of Pb in the environmental media range from 0.001 to 0.05 µg/g for sediment and 0.008 to 0.035 µg/L for water samples. The mean concentration of Pb in the sediment samples was 0.0065 µg/g while the mean concentration in the water was 0.0211 µg/L.

Fisheries resources of the Lagos Lagoon

The results of the survey of the edible fisheries of the Lagos Lagoon are presented Table 3. The survey

Table 3. Fisheries resources of the Lagos lagoon during the survey.

S/N	Scientific name of fish sample	Frequency of occurrence in fishermen catch	Common name of fish sample
1	*Galeoides decadactylus*	+++	Threadfins
2	*Pomadasys jubelini*	++	Sompat Grunter
3	*Dentex gibbosus*	++	Pink dentex
4	*Elops lacerta*	+++	Ten ponders/West African Ladyfish
5	*Lisa falcipinnis*	+++	Sicklefin mullet
6	*Scomber japonicas*	++	Chub mackerel
7	*Ethmalosa fimbriata*	+++	Bonga shad
8	*Lutjanus agennes*	+++	African red snapper
9	*Caranx senegallus*	++	Senegal jack
10	*Sphyraena barracuda*	+	Great barracuda
11	*Pseudotolithus elongates*	++	Bobo Croaker
12	*Pseudolithus senegalensis*	++	Cassava Croaker
13	*Mormyrus rume*	+	Mormyrids
14	*Synodontus clarias*	+	Mandi/Upside-down catfishes
15	*Tilapia guineensis*	+++	Guinean Tilapia
16	*Mytilus edulis*	++	Edible Mussels
17	*Penaeus notialis*	++	Crayfish
18	*Callinectes amnicola*	+++	Crab

+++: Very high, ++: High, +: Seldom.

revealed fifteen fish species belonging to the class Actinopterygii, Crab (*Callinectes* species), class Malacostraca, Crayfish (*Penaeus notialis)*, Class Malascotraca and Mussel (*Edulis mytilus*), Class Palecypoda (Bivalva).

Bioaccumulation studies

The results of the level of Pb accumulated in the edible part (muscle) of the fish from the Lagos Lagoon are presented in Table 4. The results showed that the edible fish contained measurable quantities of Pb in their edible parts ranging from 0.046 to 25.46 µg/g. The highest concentration (25.46 µg/g) of Pb was found in the crayfish, *P. notialis* while the lowest concentration (0.046 µg/g) was detected in threadfins, *Galeoides decadactylus*.

On the basis of the computed bioaccumulation factor with reference to the concentration of lead in the sediment, the crab, *Callinectes amnicola* was found to have the highest ability to accumulate Pb in the muscle followed by *Lutjanus agennes* and then *Pseudotolithus senegalensis*. Comparisons of the derived concentration factors showed that the bioaccumulation factors are about three to four folds higher than the bioconcentration factors, which were derived based on Pb concentration in the water samples (Table 4). Statistical comparisons by ANOVA of the metal level in the fish samples and sediment showed that the levels of Pb detected in the fish species were significantly ($P < 0.05$) higher than the concentrations detected in the sediment or water samples.

DISCUSSION

In this study, fifteen edible fish species, one species each of crab, crayfish and mussel were recorded during the period of study. Among the species recorded the following *G. decadactylus, Dentex gibbosus, Elops lacerta, Scomber japonicus, Ethmalosa fimbriata, Lutjanus agennes, Caranx senegallus, Callinectes amnicola, P. notialis and Mytilus edulis* were considered to be of commercial important in Nigeria. Nine of these edibles species are of brackish water origin, while four of them are found in both freshwater and brackish water environment, and only two of the species are basically freshwater species. The results of the fisheries diversity of the Lagos lagoon is in agreement with the study by Fagade and Olaniyan (1973) who reported on the food and feeding habits of commonly found fish species of the Lagos Lagoon. Out of the twenty six recorded fish species in the study, twelve of the species such as *G. decadactylus, Pomadasys jubelini, Elops lacerta, Lisa falcipinnis, Scomber japonicas, Ethmalosa fimbriata, Lutjanus agennes, Caranx senegallus, Sphyraena barracuda, Pseudotolithus elongates, P. senegalensis,* and *Tilapia guineensis* were encountered during the study. The other species that were not recorded during this study may have been missed during the survey or their abundance may have been reduced drastically due

Table 4. The mean concentration of lead (Pb) accumulated by edible fisheries resources of the Lagos Lagoon.

Fish sample	Common names of fish sample	Mean concentration of lead in fish sample (µg/g)	Mean concentration of lead in water sample (µg/L)	Mean concentration of lead in sediment sample (µg/g)	BCF	BAF
Galeoides decadactylus	Threadfins	0.046±0.02	0.02±0.011	0.0065±0.012	2.3	7.08
Pomadasys jubelini	Sompat Grunter	0.054±0.03	0.02±0.011	0.0065±0.012	2.7	8.31
Dentex gibbosus	Pink dentex	0.068±0.01	0.02±0.011	0.0065±0.012	3.4	10.46
Elops lacerta	Ten ponders/West African Ladyfish	0.074±0.02	0.02±0.011	0.0065±0.012	3.7	11.39
Lisa falcipinnis	Sicklefin mullet	0.079±0.01	0.02±0.011	0.0065±0.012	3.95	12.15
Scomber japonicas	Chub mackerel	0.852±0.15	0.02±0.011	0.0065±0.012	42.6	131.08
Ethmalosa fimbriata	Bonga shad	0.894±0.12	0.02±0.011	0.0065±0.012	44.7	137.54
Lutjanus agennes	African red snapper	1.616±0.43	0.02±0.011	0.0065±0.012	80.8	248.62
**Caranx senegallus*	Senegal jack	2.188±0.65	0.02±0.011	0.0065±0.012	109.4	366.62
Sphyraena barracuda	Great barracuda	1.824±0.54	0.02±0.011	0.0065±0.012	91.2	280.62
**Pseudotolithus elongates*	Bobo Croaker	2.024±0.64	0.02±0.011	0.0065±0.012	101.2	311.39
**Pseudotolithus senegalensis*	Cassava Croaker	3.157±0.74	0.02±0.011	0.0065±0.012	157.9	485.69
Mormyrus rume	Mormyrids	0.938±0.15	0.02±0.011	0.0065±0.012	46.9	144.31
Synodontus clarias	Mandi/Upside-down catfishes	1.973±0.66	0.02±0.011	0.0065±0.012	98.65	303.54
Tilapia guineensis	Guinean Tilapia	1.412±0.55	0.02±0.011	0.0065±0.012	70.6	217.23
**Mytilus edulis*	Edible Mussels	17.69±2.54	0.02±0.011	0.0065±0.012	884.5	2721.54
**Penaeus notialis*	Crayfish	25.46±3.46	0.02±0.011	0.0065±0.012	1273	3916.92
**Callinectes amnicola*	Crab	10.19±2.25	0.02±0.011	0.0065±0.012	509.5	1567.69

*Lead concentration detected in fishes species higher than the World Health Organisation (WHO) daily allowable concentration of 2.0 µg/g in sea foods.

to the problem of pollution as a result of the discharge of untreated waste materials into the lagoon.

Out of the various fish species obtained during the survey, *Callinectes amnicola* was found to have the highest ability to accumulate Pb in its body tissues followed by *L. agennes* and *P. senegalensis* in that order. This observation is in agreement with the findings of Otitoloju and Don-Pedro (2002) who reported the high level of accumulation of Pb by some benthic animals of the Lagos Lagoon. Baron (1995) reported that bioaccumulation occurs as a result of competing rates of chemical uptake and elimination, the latter comprising of biotransformation and excretory process. The biotransformation of metals in animal tissues involve the synthesis of low-molecular weight proteins e.g. metallothionien in the animal tissues which then form complexes with the metals, where the resultant metal-protein complexes formed are not water soluble, they become sequestered in lipids or fatty tissues resulting in metal bioaccumulation (Langston and Zhou, 1987; George, 1989). The practical implications of the results of the findings of this study is that in the wild, animals which occupy higher trophic level including man, feeding on organisms which have accumulated the environmental metal, Pb in their body tissues, may in turn acquire a greater concentration of the metal in their bodies. The concentration of toxin along the food chain is known as biomagnification. The transfer of toxins along the food chain will be particularly hazardous to man when they consume edible fishes from the Lagos Lagoon which have high concentration of the environmental lead (Pb) in their body tissues.

The analysis of the lead content in muscles of the edible fisheries revealed that the animals accumulated measurable quantity of Pb in the edible parts. The level of Pb detected in most (12 out of 18 species) of the fisheries species were found to be lower than the daily allowable concentration of 2.0 µg/g standard recommended by the FAO/WHO (1989) and WHO (1997). On this basis, most of the fisheries species analyzed in this study can be considered safe for consumption with regards to lead content since the detected levels of Pb were below the recommended standard. It is however important to note that the 2.0 µg/g standard is based on the FAO recommended annual per capita fish consumption rate of 13 kg. However, bearing in mind that consumption of fish among members of coastal / urban areas like Lagos is usually several folds higher than that of water "deprived" / rural populations (Amao et al., 2006). According to FAO (1989), the annual per capita fish consumption in African countries including Nigeria is usually above 20 kg, especially among members of coastal communities. Therefore, exposure of people from the Lagos area to lead (Pb) arising from consumption of fishes that were captured from the lagoon with high lead content is likely to be higher than the daily allowable levels. Therefore, these fish species that are currently contain lower level of Pb in the muscle may still pose a public health risk due to consumption of higher quantity of fish than the recommended annual per capita fish consumption rate of 13 kg in the area.

Other fish species encountered during the survey which contained higher level of Pb than the allowable 2.0 µg/g are *C. senegallus* (Senegal jack) which had a mean Pb level of 2.188 µg/g, *P. elongatus* (Bobo croaker) 2.024 µg/g; *P. senegalensis* (Cassava croaker) 3.157 µg/g; *P. notialis* (crayfish) 25.46 µg/g; *M. edulis* (edible mussel) 17.69 µg/g and *C. amnicola* (crab) 10.19 µg/g. The mean levels of Pb in *M. edilis, P. notialis* and *C. amnicola* were about 8 – 24 times higher than the recommended standard for Pb in sea foods. Therefore, consumption of these species collected from the Lagos lagoon might pose real public health risks especially among members of the fishing communities who have a large number of menu in which crabs, mussels, oysters and periwinkles constitute the dominant portion of the dishes.

Edible fishes from the Lagos Lagoon serve as a cheap source of protein forming part of the diet of the coastal populations (especially residents of riverine communities) in Nigeria. The resources of the Lagos Lagoon and coastal region of the country are being exposed to high degree of contaminants and toxicants, which when consumed may lead to conditions such as anaemia, renal toxicity, hearing loss, low Intelligent Quotient (IQ), hypertension and behavioural disorders. (Bellinger, 2004). The public health implication of consuming metal contaminated fishes from the Lagos lagoon is that organisms higher in the food chain such as man that feed on them may in turn be exposed to very high concentration of these pollutants accumulated in the animal tissues. The consumption of fisheries species with high concentration of heavy metals has been reported to have caused serious cases of human tragedies such as the Minamata disease and Itai-Itai disease tragedies (Kurdland, 1960; Varma et al., 1976). The lesson from these human tragedies is the obvious need for continuous monitoring of edible organisms for their heavy metal contents to avert such occurrences. It is however, regrettable to note that most regulators in many developing countries such as Nigeria have learnt little from these lessons and do not carry out any form of monitoring of fisheries species for their metal contents before they are allowed for human consumption. It is therefore important for environmental regulatory agencies such as Ministry of Environment and Environmental Protection Agencies (EPAs) to regularly monitor the levels of metals and other contaminants that are being discharged into the aquatic ecosystem which can in turn be accumulated by fisheries resources. The need for the Food and Drug Administration Agencies e.g. NAFDAC in Nigeria to also collaborate with the environmental agencies by monitoring edible fisheries species for their pollutant contents is also required. The results of such measurements when compared against set standards and maximum allowable limits can form the basis for allowing or disallowing the sales and consumption of sea foods based on the level of pollutant accumulated in the body tissues and therefore help in averting human tragedies such as the Minamata disease in these developing countries.

ACKNOWLEDGEMENTS

The authors are grateful to staff of the Analytical Laboratory, University of Lagos for the analysis of samples and Prof. Olusola Ogunwenmo of Babcock University for assisting in reviewing the manuscript.

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