Status of trace metals in smoked Clarias gariepinus cultured in earthen pond in Lagos state, Nigeria

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Abstract. Catfish consumption has risen over the last 2 decades with its popularity more pronounced in a cosmopolitan, commercial and industrial region like Lagos state. However, there is a need to measure the level of anthropogenic induced impacts on the safety level of fish production within this environment for human consumption. This research determined the level of trace metals bioaccumulation within the three senatorial districts of Lagos state. A total of nine (9) fish farms (three from each senatorial district) operating earthen ponds were randomly selected. Water samples from the farms were also collected and analyzed for heavy metals. Fish samples were smoked before analysis. The trace metals such as chromium, cobalt, iron, lead, aluminum and copper and manganese was analyzed using Atomic Absorption Spectrophotometer. The result of the trace metals were 0.07 – 0.13 mg/kg (lead), 0.01 – 0.02 mg/kg (chromium), 6.75 – 7.77 mg/kg (iron), 3.05 – 3.89 mg/kg (manganese), 0.05 – 0.07 mg/kg (copper), 0.00 – 0.01 mg/kg (cobalt) and 0.00 – 0.01 mg/kg (Aluminum). Statistically, there is no significant difference (P>0.05) among the various locations except for aluminum. The trace metal levels were below the tolerable or allowable level for fish food as recommended by Food and Agricultural Organization or World Health Organization, Median international standard, European Union, United State Environmental Protection Agency and Water Pollution Control Legislation for fish food. The detection of lead above standard in the water suggests the need for frequent monitoring of the water quality and fish food to prevent possible toxicity that could arise from the consumption of the fish food from the study area.

1. Introduction

In recent times, the sustainability of the environment is under a serious challenge [1, 2, 3, 4, 5]. This is largely due to human activities and to a lesser extent to natural effects. Pollution affects all the three major components of the environment which are, soil, water, and air. Human activities on many occasions lead to contamination on land. This mostly ends up in the aquatic ecosystem through runoff. This in turn contributes alterations in the recipient surface waters’ properties in many coastal communities in Nigeria.[6, 7, 8, 9, 10, 11, 12]. The soil has been degraded by human activities in different perspectives
including heavy metals [13, 14, 15, 16, 17, 18, 19, 20] and microbial characteristics [16]. [21] and [22] reported that human activities resulting from palm oil processing is infringing on ambient air quality of the processing communities.

Surface waters are the major means of disposing wastes in many coastal communities in Nigeria. Wastes emanating from abattoir [12, 23], markets [7, 8], municipal solids, and even sewage are usually dumped in surface waters. Furthermore, some toxic cans of pesticides are sometimes discharged carelessly which could end up in surface water system [24, 25, 26, 27].

Fish is a major source of animal protein to man families in Nigeria [28, 29]. But they have the tendency to bio-accumulate toxicants from their environment. Among the toxicants that fishes bioaccumulate are heavy metals [30, 1, 12, 31]. Heavy metals are metalloids that have specific gravity that is greater than or equal to 5 g/cm³ [32, 33, 34, 35, 30, 36, 37]. Many of these heavy metals enter the surface water through runoff after rainfall, direct human activities such as dredging and waste deposition in the water resources.

Heavy metals are grouped as essential (manganese, cobalt, iron, nickel, copper, zinc etc.) and non-essential (cadmium, lead, vanadium, mercury, arsenic) [38]. Non-essential trace metals do not have any biological role in living organisms. Therefore, even low concentration in living organisms could induce severe effect. On the other hand, essential heavy metals are required for the proper functioning of most of the systems, tissues, and organs in humans. This is because most essential trace metals mediate vital biochemical reactions by acting as cofactors to many enzymes [34]. Several diseases are associated with non-essential metals, and excess essential trace metals could also cause a deleterious effect in the human body [34, 35, 39].

Studies have been carried out with regard to level of trace metals in fisheries from several sources including surface water and ponds in different part of Nigeria [30, 31, 40, 41, 42, 33, 43, 44, 45, 46]. Most of the fishes that have been widely studied are fishes living in freshwater. But information about the level of trace metals in earthen fish ponds around Badagry, Alimosho, and Ibeju-Lekki is scanty. Hence this study aimed at assessing the level of selected trace metals in waters of earthen fish ponds in these locations in Lagos state, Nigeria and the bioaccumulation level in the muscles of fish from ponds after smoking. The results from this study were compared with international standard limits for fish foods.

2. Materials and Methods

2.1 Sample collection and preparations

The fish samples were obtained from each of the 3 senatorial districts of Lagos state including which are Lagos central senatorial district there are five local government (Lagos Island, Lagos Mainland, Surulere, Apapa and Eti-osa), Lagos East (Shomolu, Kosofe, Epe, Ibeju-ekki, Ikorodu, Agege and ifako-ijaye) and Lagos West (Alimosho, Ajemori/Ifeledun, Amuwo-odofin, Ikeja, Badargy, Oshodi/Isolo and Mushin). Specifically, the sample was obtained from Badargy (in Lagos West), Ibeju-Lekki (Lagos East) and Alimosho (Lagos Central). In each of the locations, the samples were obtained in 3 different farms which formed the replicates in this study. The fish samples were harvested from earthen fish ponds with the aid of the dragnet and care were taken to avoid unnecessary stress to the fish. Water samples from each of the fish farm were also collected with 1-litre container. Water samples were transported to the central laboratory of Federal University of Technology, Akure, Nigeria. The fish samples were killed in accordance with the guidelines of the animal ethics committee of the Federal University, Oye Ekiti, Ekiti State, Nigeria. Fish were later smoked using FUTA rotatory smoking kiln.

2.2 Laboratory Analysis

The dried fish samples were crushed into powder form before being subjected to laboratory analysis. The trace metals were analyzed following the method previously described by [47, 33, 48]. The trace metals (chromium, cobalt, iron, lead, Aluminum, copper, and Manganese) were dry-ashed, digested with perchloric acid and nitric acid. The resultant solution was aspirated into the atomic absorption
spectrometry where the metals were analyzed at a varying wavelength. The water samples were analyzed following the same method.

2.3 Pollution and Ecological Indexes
The bio-concentration factor (BCF), and Ecological Risk Quotient (ERQ) were calculated using formulas by [55] and [56] respectively to determine the pollution and ecological indexes of the study areas.

I. Bio-concentration factor (BCF) = \( \frac{\text{Concentration of metal in animal tissue}}{\text{Concentration of metal in water}} \)

II. Ecological Risk Quotient (ERQ) = \( \frac{\text{Environmental Concentration (mg/kg)}}{\text{Recommended Limit (mg/kg)}} \)

2.4 Statistical Analysis
SPSS version 20 was used to carry out the statistical analysis. Data were expressed as mean ± standard deviation. One way analysis of variance was also carried to test for significance, and where it exists, Duncan multiple range test was used to compare the means.

3. Results and Discussion
The trace metals of pond water from the investigated fish farms are presented in Table 1. The concentration for chromium, cobalt, iron, lead, aluminum, copper and manganese were in the range of 0.02–0.05 mg/l, 0.01–0.03 mg/l, 0.05–0.47 mg/l, 0.02–0.09 mg/l, 0.00–0.01 mg/l, 0.03–0.07 mg/l and 0.03–0.04 mg/l respectively. Apart from cobalt, the level of trace metal concentration in water were not significantly different (P>0.05). The trace metals in water were within the water quality criteria for drinking established by Nigerian drinking water quality control [57] with limit of 0.05 mg/l, 0.3 mg/l, 0.01 mg/l, 1.0 mg/l, 0.2 mg/l and 0.2 mg/l for chromium, iron, lead, copper, manganese and aluminum respectively [57] except Cobalt which does not have a limit. Based on the average values all the trace metals from the farms were low except for lead. The occurrence of lead in the water could be due to human activities in the area. The study locations are industrialized areas and the presence of high concentration of lead observed in the samples may have been deposited into the fish farm through atmospheric deposition, the soil or even through fish feeds. The result of the heavy metals in water suggests no contamination apart from a slight presence of lead.

The levels of trace metal concentration in some selected smoked *Clarias gariepinus* cultured fish in earthen ponds in some locations in Lagos state, Nigeria are presented in Table 2. The concentration of lead in the smoked fish samples ranged between 0.07 and 0.13 mg/l. The observation showed that there was no significant variation among the 3 locations of study. The values were lower than the recommended concentration for fish food by various agencies such as European Union (maximum allowable limit of 0.2 µg/g), [58 cited in 59]; [60], Median International Standard (tolerable level of 2.0 µg/g) [61 cited in 59; [60], FAO/WHO (maximum allowable limit of 0.5 mg/kg) [62 cited in 63], and within USEPA (0.11 mg/kg) limits [64; cited 65], and higher than WPCL (0.05 mg/kg) limits [66 cited in 65] and WHO (0.01 mg/kg) [67 cited in 65]. The trend of heavy metals concentrations in the samples used for this study has some similarity with the works of other authors on level of concentrations of lead in some common freshwater fish (*Tilapia zilli, Oreochromis niloticus, Chrysieithys walker*, *Chrysieithys...*)
furcatus, Arius gigas, llisha africana, Ethmalosa fimbriata, Parachana obscura, Clarias garepinus, Clarias lazera, Clarias camerunensis [31; 12, 1]. Lead concentration level in the fish and water samples used in this experiment suggests low risk impact considering the fact that its toxic trace metal that does not have biological functions; however, lead in the body has been linked to poor mental ability, muscle weakness, stomach disturbances and brain damage [39,34, 33].

Chromium concentration in the fish ranged between 0.01 and 0.02 mg/kg, is not significantly different (P>0.05) in the locations. The value reported in this study is lower than the tolerable level of 1.0 µg/g, as recommended by Median International Standard for fish food [61cited in 59; 60]. The concentration is higher than the values reported in Tilapia zilli [33] and has some similarity on the values reported in Clarias camerunensis and Oreochromis niloticus [1]. Chromium has some biological functions and it plays an essential role during oxidation processes. High concentration of chromium in human is often characterized by gastrointestinal and central nervous system disorder, [34,33].

Iron concentrations ranged from 6.75 – 7.77 mg/kg, is not significantly different (P>0.05) in the locations. The values are higher than the respective limits presented by various agencies including USEPA (0.5 mg/kg) [64 cited in 65] WHO (0.30 mg/kg) [67; cited in 65] and WPCL (0.45 mg/kg) [66 cited in 65]. Typically iron is among the essential heavy metals that play essential roles in human. Higher concentration could lead to health challenges. Authors have variously reported high iron could cause abdominal discomfort, choroiditis, and retinitis among others [68, 69].

The manganese levels were in the range of 3.05 – 3.89 mg/kg. There were no significant variations (P>0.05) among the various locations. The concentrations are higher than the recommended value for fish food by USEPA and WPCL (0.02 mg/kg) [64; cited in 65] WHO (0.50mg/kg) [67, 66; cited in 65]. High manganese has the tendency to cause stomach upset and impact on the respiratory system. Muscles are the main edible parts of fish and therefore if any contamination from toxic substances occurs in it can adversely affect human health [70].

The concentration of copper in the fish food ranged from 0.05 – 0.07 mg/kg. There were no significant variations (P>0.05) between the various locations. The concentrations were lower than the tolerable limits of 20.0 µg/g, as specified by Median International Standard [61cited in 59; 60], maximum allowable level of 30.0 mg/kg as recommended by FAO/WHO [71 cited in 63], 2.0 mg/kg as recommended by WPCL [66 cited in 65] and USEPA and WHO limit of 2.25 mg/kg [64, 67 cited in 65]. In this study, the copper level is low and so cannot cause toxicological discomfort such as vomiting, cramps, convulsions and worst still death in human [33].

Cobalt in the smoked fish ranged from 0.00 – 0.01 mg/kg and was not significantly different (P>0.05) among the various locations. Though cobalt has no recommended limit for fish food, in adult human bodies, the concentration of cobalt is 1.1g with the body requiring an average of 0.0001mg/day [34]. Copper plays essential roles in the body because it is part of vitamin B12; and is essential in methionine metabolism where it controls the transfer of enzymes such as homocysteinemethyl-transferase [34]. High concentration could be detrimental to the body. Based on the body requirement, the concentration of cobalt in the fish food does not pose any health effect when consumed.

Aluminum was only detected in Badagry with a concentration of 0.02 mg/kg. While the other two locations (Alimosho and Ibeju-Lekki) the concentration was 0.00mg/kg. Aluminum can enter the human body through food materials (aluminum foil), cosmetic products, and drugs. According to the European Food Safety Authority (EFSA) the tolerable weekly intake of aluminum is 1 mg/kg body weight which can be reached through dietary exposure alone [72]. Based on this the value detected in one location alone is not enough to cause major effect in human body.

The Bio-concentration Factor was calculated and the result presented in Table 3. Iron and manganese concentration were very high when compared to other metals. This is similar to the findings of [73] who
discovered similar trend in the accumulation of heavy metals in the tissue of fish from Osse river in Edo State, Nigeria. This implies that the bio-cocentration factors may cause chemicals of low concentrations in the aqueous phase to rise to dangerous levels in biota [74].

The calculated ecological risk quotients (table 4) ranged between 0.47±0.17 - 0.93±0.47 for chromium, 0.17±0.08 - 1.57±1.40 for iron, 2.00±1.53 - 9.33±5.36 for lead, 0.02±0.02 - 0.05±0.05 for aluminum, 0.03±0.01 - 0.05±0.03 for copper and 0.13±0.02 - 0.21±0.06 for manganese in all the study areas. Ibeju-Lekki happened to have the highest risk for all tested metals. Concentrations of chemicals above permissible limits in the aquatic environment elicit high levels of ecological risks [73]. In this study, the risk quotient of lead in Ibeju-Lekki is above 6. This is considered to be very high according to [75].

Conclusion
This study investigated the trace metals concentrations in *Clarias gariepinus* cultured in earthen fish ponds in some region in Lagos state. It was observed that Iron (Fe) and Manganese (Mn) were maximally bioaccumulated in the muscles of the smoked fish investigated while copper (Cu), lead (Pb), cobalt (Co), Aluminum and Chromium (Cr) are the least accumulated. While the water trace metals were found to be within the specified level by Standard Organization Nigeria for safe drinking except for lead. However, the same cannot be said of the fish cultured using the water as bioaccumulation of Fe and Mn in the muscle of fish which could pose a health threat to the consumers. This study recommends the need for constant monitoring of trace metals concentration in all the water bodies being used for aquacultural activities in the study areas so as to prevent their toxicity over a long period of time because fishes have the tendency to bioaccumulate heavy metals in their tissues/organs.

### Table 1. Level of some selected trace metals in earthen fish pond water in some locations in Lagos state, Nigeria.

| Metals          | Badagry ± standard deviation | Alimosho ± standard deviation | Ibeju-Lekki ± standard deviation | Overall mean ± standard deviation |
|-----------------|------------------------------|-------------------------------|---------------------------------|---------------------------------|
| Chromium (mg/l) | 0.02±0.02 a                  | 0.04±0.03 a                   | 0.05±0.04 a                     | 0.04±0.03                      |
| Cobalt (mg/l)   | 0.01±0.01 a                  | 0.03±0.03 a                   | 0.02±0.01 a                     | 0.02±0.02                      |
| Iron (mg/l)     | 0.05±0.04 a                  | 0.10±0.11 a                   | 0.47±0.73 a                     | 0.21±0.42                      |
| Lead (mg/l)     | 0.02±0.03 a                  | 0.05±0.02 a                   | 0.09±0.09 a                     | 0.05±0.10                      |
| Aluminium (mg/l)| 0.01±0.01 a                  | 0.00±0.00 a                   | 0.01±0.01 a                     | 0.01±0.01                      |
| Copper (mg/l)   | 0.03±0.01 a                  | 0.04±0.02 ab                  | 0.07±0.02 b                     | 0.05±0.02                      |
| Manganese (mg/l)| 0.03±0.01 a                  | 0.03±0.01 a                   | 0.04±0.02 a                     | 0.03±0.01                      |

Data is expressed as mean± standard deviation; Different letters along the row indicate significance difference (P<0.05) according to Duncan Statistics
Table 2. Level of some selected trace metals in smoked Clarias gariepinus cultured in earthen pond in some locations in Lagos state, Nigeria.

| Metals         | Locations       | Overall mean |
|----------------|-----------------|--------------|
|                | Badagry         | Alimosho     | Ibeju-Lekki  |
| Chromium (mg/l)| 0.01±0.01a      | 0.02±0.02a   | 0.02±0.01a   |
| Cobalt (mg/l)  | 0.01±0.01a      | 0.01±0.01a   | 0.00±0.00a   |
| Iron (mg/l)    | 6.75±0.48a      | 7.37±0.29a   | 7.77±1.77a   |
| Lead (mg/l)    | 0.07±0.06a      | 0.13±0.06a   | 0.10±0.00a   |
| Aluminium (mg/l)| 0.02±0.01b     | 0.00±0.00a   | 0.00±0.00a   |
| Copper (mg/l)  | 0.06±0.01a      | 0.07±0.02a   | 0.05±0.01a   |
| Manganese (mg/l)| 3.89±0.48a   | 3.05±0.48a   | 3.33±0.83a   |

Data is expressed as mean± standard deviation; Different letters along the row indicate significance difference (P<0.05) according to Duncan Statistics.

Table 3. Bio-centration Factor of the study areas.

| Parameters | Badagry       | Alimosho     | Ibeju-Lekki |
|------------|---------------|--------------|-------------|
| Chromium   | 0.67 ± 0.17a  | 0.96 ± 0.54b | 0.62 ± 0.27a|
| Cobalt     | 0.50 ± 0.29b  | 0.51 ± 0.29b | 0.00± 0.00c |
| Iron       | 207.96 ± 79.33c| 180.45 ± 94.56d| 138.9 ± 93.57a|
| Lead       | 4.00 ± 3.06b  | 2.89 ± 0.24a | 3.44 ± 0.87a |
| Aluminium  | 0.00± 0.00a   | 0.00± 0.00a  | 0.00± 0.00a |
| Copper     | 2.08 ± 0.46c  | 1.84 ± 0.44b | 0.80 ± 0.20a |
| Manganese  | 131.92 ± 38.49b| 120.28 ± 24.45a| 105.42 ± 51.79a|

Mean ± S.E with different superscripts along the row are significantly different at p < 0.05.

Table 4. Ecological Risk Quotient (ERQ) of the study areas.

| Metals     | Badagry       | Alimosho     | Ibeju-Lekki |
|------------|---------------|--------------|-------------|
| Chromium   | 0.47 ± 0.17a  | 0.90 ± 0.31b | 0.93± 0.47b |
| Iron       | 0.17 ± 0.08a  | 0.34 ± 0.21a | 1.57 ± 1.40b|
| Lead       | 2.00 ± 1.53a  | 4.67 ± 1.20b | 9.33 ± 5.36c|
| Aluminium  | 0.05± 0.03b   | 0.02 ± 0.02a | 0.05± 0.05b |
| Copper     | 0.03 ± 0.01a  | 0.04 ± 0.01a | 0.05 ± 0.03a|
| Manganese  | 0.17 ± 0.03a  | 0.13 ± 0.02a | 0.21 ± 0.06a|
Mean ± S.E with different superscripts along the row are significantly different at p < 0.05

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