Levels of Some Selected (Essential-Mn, Zn and Toxic-Al, Sb) Metals in *Clariasgariepinus* (Cat Fish) Reared in Plastic Ponds in Benin City.

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ABSTRACT

Background: Increase in world dependence on fish and fish products as source of protein has caused a resultant increase in fish cultivation in artificial habitats including tarpaulin ponds. This may have potential health threat to fish consumers as certain trace and toxic elements have been implicated with such tarpaulin materials which are made from polyvinyl chloride stabilized with additives. This present study is aimed at evaluating the levels of some trace/toxic elements in African Catfish (*Clariasgariepinus*) and the health risk associated with these elements.
Materials and Methods: Fish and water samples obtained from tarpaulin fish ponds and Ikpoba river (control). The fish were dissected, blood samples were obtained and the tissues were digested with standard methods and assayed for levels of manganese, zinc, aluminum and antimony using inductively coupled plasma mass spectrophotometer (ICP-MS).
Results/Discussion: Results obtained showed that the mean concentration of the elements differed significantly in tissue and blood. Levels of manganese and zinc in tissues of fish from all the tarpaulin ponds were higher than those from the control river ($P<0.01$). The concentrations of manganese in blood and antimony in water of controls were higher compared with that of tarpaulin ponds. In general, the concentration of metals (manganese, zinc, aluminium and antimony) were above the standard guidelines stipulated by the World Health Organization and the Food and Agricultural Organization (WHO/FAO).
Conclusion: Consumption of Catfish reared and harvested from these sampled sites over a prolong period might pose health threat to consumers in the sampled area, thus regular awareness campaigns for fish farmers on the impact of the bio-accumulation of trace and toxic metals on human health should be ensured.

Key words: None.

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INTRODUCTION

Fish is reported as one of the chief protein sources for humans that plays role in lowering the blood cholesterol level and offers omega-3 fatty acids that minimize the danger of stroke and heart related disorders (1). It provides about 40% of the dietary intake of animal protein of the average Nigerian (2). In Nigeria, aquaculture is predominantly an extensive land based system, practiced at subsistence levels in fresh waters (3). At present, most fish farmers operate small-scale farms ranging from homestead concrete ponds (25 – 40 meters) to small earthen ponds (0.02 - 0.2 hectares). Facilities used range from small wood boxes lined with tarpaulin to intensive indoor water re-circulatory system using plastic, concrete or fibre-glass tanks. Both local and acclimatized exotic species which have proved successful so far in the country can be utilized. The most commonly cultured species of fish in Nigeria include catfish, tilapia and carp (4). However, many fish farmers in Nigeria focus on African catfish (*Clariasgariepinus*) because it adapts well to culture environment, can easily be retailed live and it attracts premium price. The African catfish (*Clariasgariepinus*) are suitable for stocking in ponds and they tolerate low dissolved oxygen better than other common species in the country. Besides, catfish has wide acceptability as food in Nigeria. Despite these considerably high potentials, local fish production has failed to meet the country's domestic demand (5). Commercial farming has yet to become widespread (6). As the aquaculture industry continues to grow in response to the demand for increased fish products, the need for environmentally conscious operational practices and facility designs becomes more important (7), thus the integration of tarpaulin ponds as artificial fish culture system. Despite the health benefits, there are health risks related to fish consumption, mainly due to potential adverse effects of heavy metal contamination. Heavy metals are well known environmental pollutants that cause serious health hazards to human beings (8). Compared to other types of aquatic pollution, heavy metal pollution is less visible but its effects on the ecosystem and on man are intensive and extensive (8). Certain metals has been implicated in tarpaulin which is a material employed in the construction of the collapsible fish culture tanks (9). Such metals are zinc, antimony, and aluminum, others include manganese, cadmium and arsenic which are or have been added to polymers as pigments, fillers, UV stabilizers, and flame retardants. Typically, these elements are added as compounds which often do not chemically bond with molecules of the tarpaulin material as in the case of plastic but rather create a suspension in solid plastic polymer (10). Therefore, in time they may potentially dislodge from tarpaulin matrix. As an industrial product of polyvinyl chloride (PVC) based tarpaulin contain considerable amounts of chlorine which, when released, facilitates leaching of metals into environment (10). These metals entering the aquatic ecosystem may be precipitated, adsorbed on solid surface, remain soluble or suspended in water and may eventually be accumulated in marine organisms (fauna and flora) through the effects of bioconcentration through the food chain and fish is at the higher level of the aquatic food chain which are ultimately consumed by human beings (11). Fish, in this case, *Clariasgariepinus* accumulate different amounts of metals depending on many factors such as physiological needs, feeding habits, genetic composition, Sex of each fish species and the biochemical role of each metal (11). This creates serious health and environmental problems since most of these elements have been identified as toxic to humans(10).Thus, it has become needful to assess the bioaccumulated level of these toxic metals by the African catfish (*Clariasgariepinus*).

With the proportional increase in world population and global demand for fish and derived fish products, especially in Nigeria, West Africa, there has been significant technological advances in aquaculture systems especially with the induction of tarpaulin ponds, aquacultivation of *Clariasgariepinus*has increased greatly. Food safety is a major concern at present, thus increased demand of food safety has accelerated research regarding the risk associated with *Clariasgariepinus* consumption contaminated by heavy metals. However, data of the adverse effect of toxic metals on catfish reared in tarpaulin ponds and ultimately on humans living in Benin city, Nigeria is lacking since toxicological parameters differs by geographical location which may still be influenced by environmental factors. Hence, this study was designed to evaluate the levels of toxic (aluminum and antimony) and essential (zinc and manganese) metals in *clariasgariepinus* reared in tarpaulin ponds in Benin City, Nigeria.

MATERIALS AND METHODS

Study Area

This research was conducted in Benin City, Edo State, Nigeria. Benin City is the capital of Edo State and it is located in south-south Nigeria. She shares boundaries with Ondo State, Delta State, Anambra State, and Kogi State to the (West), (South), (East) and North respectively. From the 2006 national general census, she has an estimated population of over 1,147,188.

Study Population

Exposed Subjects: The group comprises apparently healthy *Clariasgariepinus* from five different tarpaulin fish ponds around Benin City, with a minimum of six months habitation. Thus, a total subject of ten *Clariasgariepinus* (n=10).

Non-Exposed Subjects: Comprising apparently healthy *Clariasgariepinus* from IkpobaRiver, Benin City.

Inclusion and Exclusion Criteria

Exposed subjects comprising of apparently healthy *Clariasgariepinus* reared for six months and above in a tarpaulin pond habitat. Control subjects were apparently healthy *Clariasgariepinus* sourced from riverine water (natural habitat) while *Clariasgariepinus* with less than six months of exposure to tarpaulin pond environment were not considered suitable for the study.

Limitations of the study:
Reluctance of the fisher farmers to sell their products for the purpose of this research was a major problem. This is because of fear that they will be reported to government should they fall short of expectation.

Ethical Approval: The protocol for this work was approved by the Ethical committee of Edo State Ministry of Health, especially because of the public health implication of the study.

Sample Collection and Preparation

Specimens of *Clariasgariepinus* were purchased from five fish farms respectively and namely: Sunny farm, Funke, Chucks, Efex farm, Ilo farm. *Clariasgariepinus* from these different fish farms come into most markets around Benin City. The fishes were wiped dry with a piece of clean towel to avoid haemolysis due to water. Under proper sterile condition, the fish was sacrificed using ceramic knife and blood was obtained. The fish was cut into trunk and tail, collected into polyethylene zipper plastic bag. 20mL of each pond water sample from which each fish was harvested was collected with a chemically clean container and filtered using of a whatman No.1 filter paper into a sterile universal container respectively. Each tissue, blood and water sample were labeled appropriately and transported in a cooler containing ice packs from the fish farm location to a refrigerator (water and blood samples) and a freezer (tissue sample) at -20◦c prior to laboratory analysis. Upon arrival at laboratory, the samples were kept in refrigerator until further analysis.

Digestion of Tissue: The homogenized samples (1.0g each) were digested in a digestion flask in pent plicate (n=5) according to FAO/SIDA manual part 8 (1983).

Procedure: The concentration of Zinc, Aluminum, Zinc, Manganese, and Antimony in the muscles and blood and water samples were determined by Inductively Coupled Plasma Mass Spectrometer (Agilent 7500, Norwalk, USA) according to the methods of [12]. All analytical procedures were carried out at the analytical laboratory of the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria.

Principle of ICP-MS

ICP-MS is capable of detecting metals and several non-metal ions at concentrations as low as one part in 10^{12} (part per trillion). An Inductively coupled plasma is a plasma that is energized (ionized) by inductively heating the gas with an electromagnetic coil and it contains a sufficient concentration of ions and electrons to make the gas electrically conductive. Quantification of an element in a sample is achieved with the inductively coupled plasma and using a mass spectrophotometer to separate these ions according to their mass to charge ratio and a detector receives an ion signal that is proportional to the concentration of the ions.

Statistical Analysis

Statistical analyses including descriptive statistics was carried out using the Statistical Package for Social Scientists (SPSS) version 16.0. All values were expressed as Mean ± Standard Error of the Mean. Anova and chi-square test were used to determine significant differences in measured parameters. Confidence limit was set at 95%; level of significance ($p < 0.05$).

RESULTS: The results from the analysis are as shown in tables 1-.5 below;

Table 1 showed comparisons of mean ± SEM of the level of manganese, zinc, aluminium and antimony bio-accumulated in tissue of *Clariasgariepinus* reared in tarpaulin ponds and controls. Significant increase in the tissue level of antimony ($p < 0.01$) and decreased tissue level of zinc ($p<0.01$) were observed in sunny farm, compared with river tissue level.

Table 2 showed comparisons of mean ± SEM of the level of measured parameters bio-accumulated in fish blood sample of the individual tarpaulin fish farms and river. Significant decrease in the blood level of manganese ($p<0.01$) and increased blood level of aluminium ($p<0.01$) were observed in Sunny farm when compared with the river blood level.

Table 3: Shows the result of Chi-square test of measured paremeters in fish water of *Clariasgariepinus* in sampled tarpaulin fish ponds and Control. It showed a significant ($p>0.05$) low antimony and a significant ($p>0.05$) high water level of zinc in Chucks Farm compared with the other tarpaulin fish farms and Owinna river.

Table 4 Showing correlation between manganese (Mn), zinc (Zn), aluminium (Al) and antimony (Sb) in tissue, blood and water. The correlation between zinc and manganese in tissue was not statistically significant ($p<0.05$), while the correlastion between zinc and aluminium in water was significant ($p>0.05$).

Table 5 Showed maximum acceptable limits of Manganese, Zinc, Aluminium and Antimony in *Clariasgariepinus* and river water.

Table1 Comparism of the Mean ± SEM of Manganese, Zinc, Aluminium and Antimony bio-accumulated in the tissue of *Clariasgariepinus* of sampled tarpaulin ponds and controls.
*SEM= Standard error of mean, Note: **P<0.01- highly significant

TRACE /TOXIC METALS	**SUNNY FARM TISSUE**	**FUNKE FARM TISSUE**	**CHUCKS FARM TISSUE**	**EFEX FARM TISSUE**	**ILO FARM TISSUE**	**CONTRO L TISSUE**	**p-VALUE**
Mn (mg/g)	172.44^{a}±2.54	147.83 ^{a}±4.05	203.23^{a}±1.44	158.39^{a}±1.50	169.71^{a}±1.25	97.40±0.51	**P<0.01
Zn (mg/g)	186.81^{a}±2.75	160.15 ^{a}±4.38	220.17 ^{a}±1.56	171.59^{a}±1.62	183.86 ^{b}±1.35	88.03±0.78	**P<0.01
Al (mg/g)	0.02^{b}±0.00	0.04 ±0.00	0.02^{b}±0.00	0.03 ^{b}±0.00	0.02 ^{b}±0.00	0.04 ±0.00	**P<0.01
Sb (mg/g)	0.04 ^{a}±0.00	0.06 ^{a}±0.00	0.03 ^{a}±0.00	0.05^{a}±0.00	0.04^{a}±0.00	0.01 ±0.00	**P<0.01

The data are of mean+STD, ^{a}p< 0.01 indicates higher significance compared with control ^{b}p<0.01 control is significantly higher than test groups. Sample size N=3.

Table 2 Comparism of the Mean ± SEM of Manganese, Zinc, Aluminium & Antimony in the blood of *Clariasgariepinus* of sampled ponds & controls.

TRACE ELEMEN TS	SUNNY FISH BLOOD	FUNKE FISH BLOOD	CHUCKS FISH BLOOD	EFEX FISH BLOOD	ILO FISH BLOOD	CONTROL FISH BLOOD	p-VALUE
Mn (μg/dl)	6.98 ±0.08^{b}	5.20 ±0.07^{b}	11.07±0.17^{b}	8.56 ±0.11^{b}	12.02±0.05^{b}	42.85±6.57	**P<0.01
Zn (μg/dl)	90.67 ±0.77^{a}	79.60±0.64$_{b}$	113.38 ±1.06^{a}	101.27 ±1.28^{a}	118.72 ±1.16^{a}	89.92 ±0.80	**P<0.01
Al (μg/dl)	0.01 ±0.01^{b}	0.004±0.01	0.009 ±0.01^{a}	0.007±0.01^{a}	0.010 ±0.01^{b}	0.003±0.01	**P<0.01
Sb (μg/dl)	0.05 ±0.01^{a}	0.03^{b}±0.01	0.07^{a}±0.01^{a}	0.06±0.01^{a}	0.08 ±0.01^{a}	0.04±0.01	**P<0.01

The data are of mean+STD, ^{a}p< 0.01 indicates higher significance compared with control ^{b}p<0.01 control is significantly higher than test groups. Sample size N=3

Table 4: Correlation of levels of Manganese, Zinc, Aluminium and Antimony in the tissues, blood and water of *Clariasgariepinus* of sampled tarpaulin ponds and controls.

CORRELATION BETWEEN GROUPS	CORRELATION COEFFICIENT (R-VALUE)	P-VALUE
Mn Fish tissue and Mn Fish blood	0.927	<0.01
Mn Fish tissue and Mn Pond water	-0.352	>0.05
Mn Fish blood and Mn Pond water	-0.189	>0.05
Zn Fish tissue and Zn Fish blood	1	<0.01
Zn Fish tissue and Zn Pond water	-0.189	>0.05
Zn Fish blood and Zn Pond water	-0.189	>0.05
Al Fish tissue and Al Fish blood	1	<0.01
Al Fish tissue and Al Pond water	-0.486	>0.05
Al Fish blood and Al Pond water	-0.486	>0.05
Sb Fish tissue and Sb Fish blood	1	<0.01
Sb Fish tissue and Sb Pond water	-0.486	>0.05
Sb Fish blood and Sb Pond water	-0.486	>0.05

CRITICAL r (0.05, df=10(α2)) = 0.632, ; CRITICAL r (0.01, df=10(α2) = 0.765; Bolded values are significant; P<0.05; Bolded values with underline are highly significant; P<0.01

Table 5: Maximum acceptable limits of Manganese, Zinc, Aluminium and Antimony in *Clariasgariepinus*.

TRACE ELEMENTS	MAXIMUM LIMIT IN CATFISH Mg/g	REFERENCES
Mn (mg/g)	0.0055	WHO/FAO, 2011
Zn (mg/g)	0.015	WHO/FAO, 1989
Al (mg/g)	0.002	WHO/FAO, 1989
Sb (mg/g)	0.002	WHO/FAO, 1989

FAO = Food and Agricultural Organization; WHO = World Health Organization
Mn= Manganese, Zn= Zinc, Al= Aluminium, Sb= Antimony

DISCUSSION

The increase in human population and reports of large numbers of undernourished or starving people, especially in the developing countries have made the need for increased food production a major worldwide issue of concern [13]. The African catfish (*Clariasgariepinus*) is reared commonly in both natural and artificial ponds such as tarpaulin ponds. However, certain trace and toxic elements have been implicated in these additives which may include; zinc, aluminium, antimony, lead, cadmium, e.t.c [14]. Undergoing weathering, these elements may leach from tarpaulin into the water body and ultimately into the fish.

The data obtained from this study showed that the mean concentration of the manganese, zinc, aluminum, and antimony were highly significant (p<0.01) in the tissue and blood and not significant (p>0.05) in the pond water of tarpaulin ponds.

The mean manganese concentration in the fish tissue ranged from highest in Chucks farms; 203±1.44 mg/g and lowest in Funke farms; 147.83±4.05mg/g in the sampled *Clariasgariepinus*. This showed a higher concentration when compared to control (97.40±0.51mg/g) (p<0.01). There was a highly significant (P<0.01) decrease in the mean manganese concentration in the blood samples for all *Clariasgariepinus*reared in tarpaulin ponds when compared with control. This significant variation in the tissue and blood may due to the feed formulation [15]. Also, manganese level in the pond water shows no significant (p>0.05) increase or decrease when compared to the river control. However, the levels of manganese in the tissues of the sampled fish farms and controls occurred in descending order as follows; Chucks farms (203.23±1.44 mg/g)> Sunny farms (172.44±2.54 mg/g)>Ilo farms (169.71±1.25 mg/g)>Efex farms (158.39±1.50 mg/g)>Funke farms (147.83±4.05 mg/g)> Controls (97.40±0.51 mg/g). Lower levels of manganese in control indicate that fishes obtained from this site is may be more tolerable for human consumption than those obtained from the other tarpaulin fish ponds. The maximum permissible limit of manganese in fish tissues set by the F.A.O/W.H.O [5] is (0.0055mg/g), manganese concentration obtained from this study exceeded this limit. This indicate that *Clariasgariepinus* purchased and consumed from these tarpaulin fish pond may impose possible toxic effect as manganese is thought to increase the risk of developing Parkinson's disease [16]. Although, Manganese is a metal with a relatively low acute toxicity, but may result in adverse effects from prolonged excess exposure [16]. Manganese deposition occurs higher in the brain leading to observed neurobehavioral deficits observed by magnetic resonance imaging [17]. High levels of manganese in the blood of sampled control could also be traced to entry to the river through industrial effluents from steel industries around the catchment area of this study [18].

From this Study, the observed mean zinc concentration in the tissues was highest in sample of Chucks farms and lowest in Funke farms. This had a decreasing order of Zinc concentration in the tissues of the sampled fish farms and controls occurred in descending order as follows; Chuks farms (220.17±1.56 mg/g)> Sunny farms (186.81±2.75 mg/g)>Ilo farms (183.86±1.35mg/g)>Efex farms (171.59±1.62 mg/g)>Funke farms (160.15±4.38 mg/g)> Controls (88.03±0.78 m/g). This result shows that fishes of the control is more tolerable for human consumption than those obtained from the tarpaulin ponds. There was a highly significant (P<0.01) increase in the mean zinc concentration in the blood samples for all *Clariasgariepinus* reared in tarpaulin farms when compared with the sample obtained from control. However, zinc concentration in the ponds water shows similar correlation as in the case to manganese. This may be as a result of a corresponding distribution of zinc in the water supply [19]. Water supply by means of bore holes which is a form of underground water is the most prevalent source of water supply in these farms [19]. With the permissible zinc tissues level of 0.015mg/g by [20], the concentration obtained from this study exceeded this limit. Consumption of fishes reared in these tarpaulin ponds possess a significant toxicity alarm as taking up excess zinc over an extended period has been associated with copper deficiency [21] and may resulting in disturbed copper homeostasis [17].

Highest levels of aluminium in the tissues occurred in Controls and Funke farms (0.04±0.00mg/g), this was followed by Efex farms (0.03±0.00 mg/g). The lowest levels of aluminium occurred in samples of Sunny, Chucks and Ilo farms (0.02±0.00mg/g). Considering the health threats on human health posed by aluminium toxicity, results shows that samples obtained from Sunny, Chucks and Ilo farms may be more tolerable for human consumption when compared with those obtained from the other ponds and controls. Blood concentration of aluminum in *Clariasgariepinus* obtained from the tarpaulin ponds were highly significant when compared with that of control. Highest aluminum level was observed in *Clariasgariepinus* obtained from Efex farm. Variation in bioaccumulation among sampled *Clariasgariepinus* may be due to leaching activity of tarpaulin addictive resulting in the bioaccumulation. The permissible level of aluminum in tissues as stipulated by the [22] is 0.002mg/g. Results obtained from this studies shows that levels of aluminum in the sampled *Clariasgariepinus* were higher than the permissible level. A report presented by the WHO in 1997, shows that aluminum is present in foods naturally or from the use of aluminum-containing food additives, thus indicating that aluminum is acutely toxic by oral exposure despite its widespread occurrence in foods, drinking-water, and many antacid preparations.

Antimony concentration obtained from this study shows that results obtained from *Clariasgariepinus* tissues reared in various tarpaulin ponds was highest in Funke farms and lowest in Chucks farms. This occurred in descending order as follows; Funke farms (0.06±0.00 mg/g)>Efex farms (0.05±0.00), followed by Sunny and Ilo farms (0.04±0.00mg/g) as similar levels of antimony were observed in both farms. This was followed by Chucks farms (0.03±0.00 mg/g) and the lowest levels of antimony occurred in Control (0.01±0.00 mg/g). Due to the possible toxic effects of antimony on human health, fishes obtained from the control may be more tolerable for human consumption as it may pose less heath threat to human consumers when compared with samples obtained from the other tarpaulin ponds. Although, mean antimony concentration in blood of *Clariasgariepinus* sampled from the tarpaulin farms ranged from highest (0.08±0.00) mg/g to lowest (0.03±0.00) mg/g for Ilo and Funke farms respectively varied significantly when compared with results obtained from control (0.004±0.00)mg/g. However, antimony concentration in water sampled from the all the tarpaulin farms did not varied significantly (>0.05) when compared with control. This significant increase in the antimony level in tissue and blood of *Clariasgariepinus* sampled from the tarpaulin may be as a result in the bioaccumulation of antimony in the tissue and blood due to imbibing of leached trace elements from the tarpaulin material. The permissible level of antimony in tissues of fish as stipulated by the [23] is 0.002mg/g. The average intake of antimony from food and water was estimated to be roughly 5 µg/day in a study [24].

Correlation of levels of manganese, zinc, aluminium and antimony of tissue (trunk) and blood and water of were all highly significant ($p<0.01$). Observation from their correlation with the pond water were not significant ($p>0.05$). This may be due to the toxic metal concentration in the formulation of the fish feed administered to these fishes. Also, leached metal addictive into water and subsequent bio-accumulation in the tissue (tissue) and blood of the sampled *Clariasgariepinus* may also contribute significantly to this observation. These elements could be lethal to aquatic biota [25]. Generally, all heavy metals cause toxicity to cells. After competing with the nutritional minerals, they render them unavailable to body, leading to ill-health. These metals are toxic since they are bioaccumulated in biological organisms in due course of time. Manifestation of toxicity of individual heavy metal differs depending on dose and duration of exposure, species, gender, and environmental and nutritional factors [14]. Inverse correlation observed in the decreased levels of manganese, zinc, aluminium and antimony in pond water may be due to the regular disposal and replacement of water. However, the NSPFS [19] recommends that for highest fish production, pond system that has a water supply that replaces only water evaporation and seepage losses and do not flow through should be adopted. Thus, this system may cause increased tendency of bioaccumulation of heavy metals in tissues and blood of fishes reared in such pond systems due to prolong exposure to contaminants in the pond water [25]. Therefore, Human consumption of contaminated *Clariasgariepinus* as observed in this study possess major health concern.

CONCLUSION

The concentration of trace elements detected in *Clariasgariepinus* sampled from the tarpaulin fish ponds and controls (Ikpobariver) were quite variable. Levels of zinc, manganese, aluminium and antimony in tissues, blood and water of the fish samples were higher than the control except for manganese in blood and antimony in water samples as they were higher in controls. However, levels of the measured trace elements in both tarpaulin and control fish samples were above the WHO/FAO stipulated maximum permissible limits. High concentration of these measured trace metals were attributed to probable influx of metals as a result of population of metals leaching from the tarpaulin materials, source of water, feed formulation for the fish samples obtained from the tarpaulin ponds and also anthropogenic activities such as agricultural and industrial influx water and domestic wastes thus increased possibility of bio-concentration in fish and ultimately may pose health threat to humans depending on these fishes as a source of food.

RECOMMENDATION

Strict implementation and compliance to set maximum permissible toxic levels in fish and fish products should be enforced by the National agency for food and drug administration and control (NAFDAC), Nigeria and adhered to by fish farmers and feeds manufactures to secure the health of the Nigeria population consuming *Clariasgariepinus*. This could be achieved by regular awareness campaigns for fish farmers and fish feed manufacturers on the impact of the bio-accumulation of heavy metals on human health. Also, levels of toxic metals in addictive of polyvinyl chloride should be reviewed and reduced to a significant level that will pose no health challenge to fish and fish product consumers in Nigeria. Considering the limitations of this present study, further investigation should be could be conducted in the following; Assessment of other toxic metals levels of in

*Clariasgariepinus*reared in tarpaulin ponds; Assessment of levels of toxic metals in fish feeds (local or imported).

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