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Bioaccumulation of arsenic and uranium in two fish species (*Clarias lazera* and *Tilapia zilli*) from Alaro stream in Ibadan, Nigeria

Emmanuel Teryila Tyokumbur[1, *], Tonye Grace Okorie[1], Bem Samuel Umma[2]

[1]Ecology and Environmental Biology Unit, Department of Zoology, University of Ibadan, Ibadan, Nigeria
[2]Department of Aquaculture and Fisheries Management, University of Ibadan, Ibadan, Nigeria

Email address

e.tyokumbur@mail.ui.edu.ng (E. T. Tyokumbur)

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Abstract

Studies were carried out on the bioaccumulation of arsenic (As) and uranium (U) in the organs of two fish species (*Clarias lazera* and *Tilapia zilli*) from Alaro stream in Ibadan, Nigeria. Fish were collected from the entire Alaro stream downstream of the industrial effluent outfall for six months from July to December using cast and gill nets. Dissections were carried out to remove the gills, fins, gut, liver, bones and muscle for acid digestion. Samples were analyzed using the inductively coupled plasma-mass spectrometer (ICP-MS) with quality assurance of the results obtained using bovine liver standard reference material (SRM) from the National Institute of Standards and Technology (NIST).The results show that As and U levels in the fish organs exceeded the World Health Organization (WHO) guideline limit and other international standards. This indicates that fish caught in Alaro stream is unfit for human consumption since it contains the carcinogens: arsenic and uranium. It is recommended that the polluted stream should be monitored, treated and controlled for food security and other human uses of the stream.

1. Introduction

Arsenic and uranium are trace metals that are not degradable but are easily assimilated and bioaccumulated in the tissues and organs of living organisms. Like other trace metals, they have high densities and atomic weights like other transition elements in groups III and V of the periodic table [1]. Chemically, arsenic is intermediate between metals and non-metals and so is regarded as a metalloid. Environmental health effects could arise from the intake of these trace metals that are toxic, carcinogenic, mutagenic or teratogenic in repeatedly small doses or mega doses of exposure. Arsenic has been implicated as a causative agent of several types of cancers while radiation from uranium could also exert the same effect and cause organ dysfunction [2,-5]. Arsenic (As) is ubiquitous in the environment and it exists in four oxidation states: arsenate (+5), arsenite (+3), elemental arsenic (0) and arsine (−3). It is released to the environment through both natural processes and anthropogenic activities [6]. Arsenic is widely distributed in the earth, ranking 20th in abundance in the Earth's crust. It has been widely used as pesticides and wood preservatives [7]. Toxicity of uranium has been established by animal studies and human data from uranium miners and workers with accidental exposures indicating that uranium affects the proximal tubules of the kidney; at very high acute doses, tubular degeneration and necrosis which causes death of tissue may occur a few days after the intake of uranium [5]. United States Environmental Protection Agency (EPA) has classified uranium as a group- A human carcinogen [8]. Sometimes, smaller doses of these pollutants are taken up intermittently without the threat of an immediate side effect but become gradually toxic as they accumulate or cause a gradual damage to tissues and organs [9]. Alaro stream that receives untreated industrial effluents has the potential of being polluted by arsenic and uranium from natural and anthropogenic sources. Both arsenic and uranium levels have been reported from studies in Alaro stream [10-12].The two fish species: *Clarias gariepinus* (Burchell,1822) and *Tilapia zilli* (Linnaeus,1758) are widely caught from Alaro stream and could take up arsenic and uranium and bioaccumulate it in their organs for onward passage to higher consumers like man. *C.gariepinus* is found throughout Africa and the Middle East, and lives in freshwater lakes, rivers, and swamps, as well as human-made habitats, such as oxidation ponds or even urban sewage systems. Also known as the African sharptooth catfish, it is a large, eel-like fish, usually of dark gray or black coloration on the back, fading to a white belly. These fish have slender bodies, flat bony head. *C. gariepinus* has an average adult length of 1–1.5 m (3 ft 3 in–4 ft 11 in), reaching a maximum length of 1.7 m (5 ft 7 in) and can weigh up to 60 kg (130 lb).On the other hand, Tilapiines (*T.zilli* inclusive) are among the easiest and most profitable fish for food security due to their omnivorous diet, mode of reproduction since the fry does not pass through a planktonic phase, tolerance of high natural density and rapid growth. Whole tilapia can be processed into skinless, boneless fillets and the yield is from 30% to 37%, depending on fillet size and final trim. There is therefore the need and aim to study the bioaccumulation of arsenic and uranium in the organs of two fish species (*C.lazera* and *T.zilli*) from Alaro stream in Ibadan, Nigeria.

2. Materials and methods

2.1. Study Area

Alaro Stream is part of the hydro-ecological system of the Oluyole Industrial Estate in Ibadan, Nigeria that receives effluents from diverse sources of macro and trace metal pollution. The Alaro stream flows into Oluyole Estate in a west–south east direction from its source at Agaloke near Apata in Ibadan. It joins River Ona at the south east end of a meat processing factory as its main tributary. The stream receives effluents from diverse industries. Effluents from both natural and anthropogenic sources are discharged into Alaro stream directly or indirectly through run-off, leaching or seepage especially during the rainy season or as windblown materials during the dry season. The Oluyole industrial estate is located between latitude 7^{o} 21’N -7^{o} 22’N and longitude 3^{o} 50’-3^{o} 52’E. Table 1 shows the types of industries that discharge effluents into Alaro Stream and their potential pollutants.

Table 1. *Industrial activities and their potential pollutants in Alaro Stream*

Industry	Number of industries	Potential pollutants
Food processing		
i. carbonated beverages	2	Alkalis, phenols, suspended solids, detergents, fermented starches, pathogens, nitrates, trace metals from oiling machine parts and organic wastes
ii. confectionery and biscuit	2	Organic wastes (solids and suspended), macro metals, pathogens, total suspended solids (TSS), biochemical oxygen demand (BOD), PH
iii. animal husbandry and meat processing	1	Organic wastes, macro and trace metals
Iron and fabrication		
i. steel	2	Trace metals, cyanide, fluorides, chromates, thiocyanates, naphthalenes
ii. metal foundry	2	Diverse trace metals
iii. crown corks	1	Metal filings, macro and trace metals
Wood processing	1	Waste lignin, organic sulphur, mercury, magnesium, sulphide, terpenes, arsenates mercaptans, macro and trace metals

2.2. Fish Sampling and Identification

Fish were collected from the entire Alaro stream downstream of the industrial effluent outfall for six months from July to December. Fish were collected using the following techniques: Cast nets with mesh sizes ranging between 30-50mm with varying dimensional sizes were used .These nets were left for about three minutes before retrieving with a drawing string to check for any entangled fish. In addition, gill nets with mesh sizes of 30-50mm and varying dimensions were tied to stakes with a lead weight on the stream bed and maintained vertically in water with the aid of floats overnight. One hundred (100) fishes were caught in the sampling of Alaro stream with *C.gariepinus* making up 57 of the total while *T.zilli* were 43 during the six-month period.

Fish collected were identified using the textbooks [13,14] .The dissections were carried out using dissecting set to remove the gills, fins, gut, liver, bones and muscle. These tissues were oven dried at 105^{0}C for 6hours .Each organ was pulverized separately by means of a porcelain mortar and pestle. The pulverized samples were kept in sample sachets and sealed prior to analyses.

2.3. Fish Organ Digestion for Macro and Trace Metal Analyses

Tissue digestion was carried out by adding 2mL trace metal grade HNO_3 to 0.5g of each sample in Teflon digestion tubes which were heated at 105 ^{0}C for 1 hour in a heat block. The clear solution was then allowed to cool down, followed by addition of 1mL H_2O_2, after the simmering, boiled and left overnight. The digested sample was diluted to the 10ml mark using MilliQ water for inductively coupled plasma mass spectrometer (ICP-MS) analyses. Standard Reference Materials (SRM) comprising of bovine liver from the National Institute of Standards and Technology (NIST-1577) were used to obtain accurate values for fish tissue.

3. Results and Discussion

3.1. Standard Reference Materials and Quality Assurance

Percentage recoveries from the reference material were all above 70% with a range of 85.9% (As) to 95.1% (U). The results were also corrected for errors using MilliQ water as the blank using the inductively coupled plasma-mass spectrometer.

3.2. Fish Arsenic and Uranium Levels in the Organs

The results of the arsenic concentration level in the organs of *C.gariepinus* and World Health Organization (WHO) guideline limit for comparison is shown in figure 1.

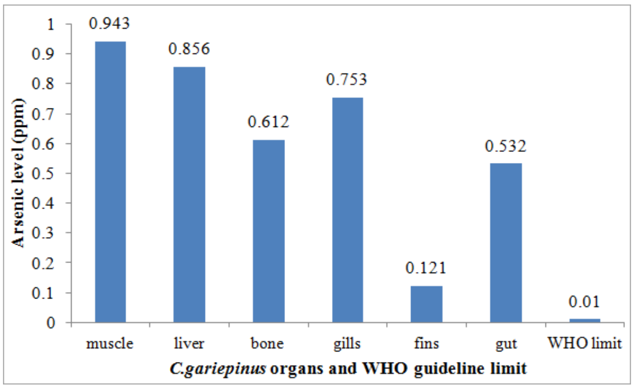

Figure 1. *Mean As levels in the organs of C.gariepinus and World Health Organization guideline limit*

The range of the As levels in the organs of *C.gariepinus* was 0.121-0.943ppm with the highest in the muscle and the lowest in the fins. The As levels in the organs were significantly higher than the World Health Organization guideline limit of 0. (10ug/l) in drinking water.

The mean As concentration levels in the organs of *T.zilli* are given in figure 2.

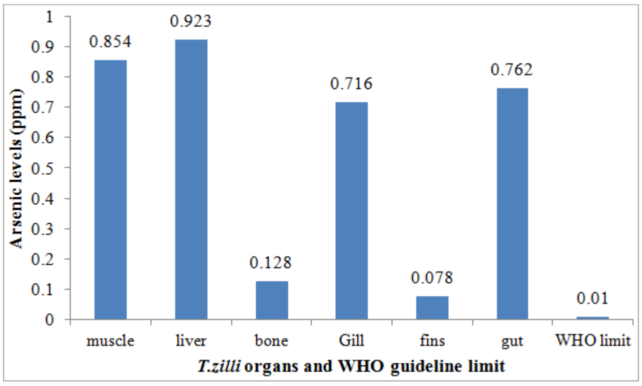

Figure 2. *Mean As levels in the organs of T.zilli and World Health Organization guideline limit*

The range of the As in the organs of *T.zilli* was 0.078-0.923ppm with the lowest in the fins and the highest in the liver. All organ levels were higher than the WHO guideline limit of 0.01ppm [15]. Comparatively, the organ levels in *C.gariepinus* were higher than that of *T.zilli*.This can be due to differences in the food and feeding ecology of the two fish species [14]. It can also be attributed to the rates of excretion and physiology of the fish [16].The high As in the organs of the fish species can be attributed to natural and anthropogenic sources in the Alaro stream. Effluents from wood processing discharged into Alaro stream are a major source of arsenic as asserted in other studies by Sun [6] and Gress with colleagues [17].This study corroborates high As levels earlier reported in Alaro stream by Akinyeye and Okorie [11] in the sediments and Komolafe with colleagues [12] in the water where they become bioavailable to the fish species.

Results of the mean uranium-238 concentration levels in the organs of *C.gariepinus* and *T.zilli* are shown in figure 3 and 4.

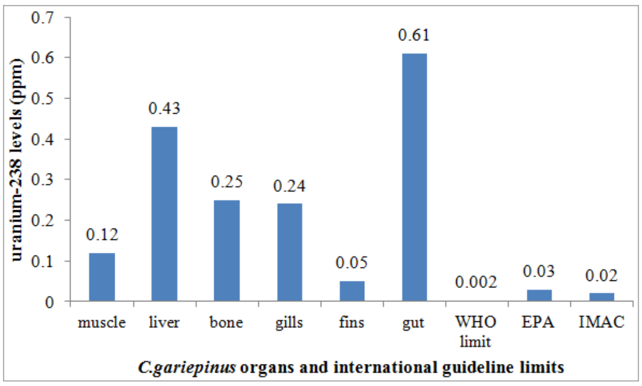

Figure 3. *Mean uranium-238 (U) levels in C.gariepinus organs and International guideline limits*

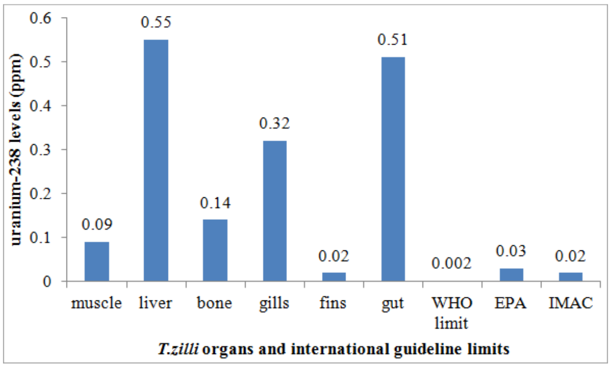

Figure 4. *Mean uranium-238 (U) levels in T.zilli organs and International guideline limits*

The range of the U levels in *C.gariepinus* was 0.05-0.61ppm with the highest in the gut and the lowest in the fins. In figure 4, the range for uranium levels in *T.zilli* was 0.02-0.55ppm with the highest in the liver and the lowest in the fins. U levels in the liver and gills of *T.zilli* was more than that of *C.gariepinus.* All the U in the organs of *C.gariepinus* and *T.zilli* exceeded the International guideline limits given by World Health Organization (WHO) as reference level of 0.002ppm (2ug/l) [15],United States Environmental Protection Agency's (USEPA) maximum contaminant level (MCL) of 0.03ppm (30ug/l) and Canada's interim maximum acceptable level (IMAC) of 0.02ppm (20ug/l).The high uranium-238 levels in the fishes can be attributed to metal foundry activities that discharge effluents into Alaro stream and due to natural background levels from the physical geology of the hydrologic catchment area [5,10].Physiological functions such as excretion and storage in tissues is responsible for the differences in the levels of uranium in the organs and between the two fish species [16]. High uranium levels had been reported in edible vegetables cultivated in the riparian environment of Alaro stream by Tyokumbur and Okorie [10].

4. Conclusion

This study shows a high level of As and U in the organs of *C.gariepinus* and *T.zilli* and differences between them that exceeds the World Health Organization and other International guideline limits. This shows that fish caught in Alaro stream is unfit for human consumption due to public health consequences inherent in consuming it. This implies that industrial effluents discharged into Alaro stream in Ibadan has to be monitored, treated and controlled. The study also corroborates findings from previous research that Alaro stream is polluted by As and U, hence the need to treat the effluents before discharging them into Alaro stream.

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