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Bioaccumulation of Heavy Metals in *Tilapia zilli* Exposed to Industrial Effluents Under Laboratory Conditions

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Abstract: Characterization of the effluents from Agbara Industrial Estate treatment plant showed that the effluents were complex and varied in composition. Though the treatment methods used by the treatment plant (aeration and use of chemicals) made the discharged effluents conform to the effluent discharge requirement in Nigeria. As far as the temperature, PH, level of Pb, Zn, Mn, and Cd were concerned. The color (443.00±12.08Hz, BOD (240.50±10.26mgl^{-1}), Fe (9.20±1.28mgl^{-1}) were however above the permissible level of discharge while dissolved oxygen (2.30±0.38mgl^{-1}) was below the permissible level. Tilapia zilli was found to accumulate heavy metals in the effluent above the what was in the media of exposure. After about eight weeks of exposure, the level of heavy metals in the fish were about 10 times in the exposure media. This is a testimony of the amazing power of T. zilli to concentrate heavy metals in its body. In this study, T. zilli was found to accumulate 275.42mgl^{-1} of lead in 40% effluent compared with 88.06 in 10% effluent. After eight weeks of exposure, the heavy metals were 10 times in the fish than the effluent. The amount of heavy metals accumulated were also found to be concentration of effluents and period of fish exposure dependent. In general, the metals were preferably accumulated by T. zilli in the order of Pb>Fe>Cu>Mn>Cd. In the tissues, the heavy metals were accumulated in the order of whole fish>gill>gut>liver>muscles. It is thus not safe to fertilize fish ponds with industrial effluents as this could increase the level of metals in consumers knowing that heavy metals are toxic when above the level recommended in foods.

Keywords: Industrial Effluents, Heavy Metals, Bioaccumulation, *Tilapia zilli*

1. Introduction

Heavy metals are among the most common, toxic, persistent and widespread contaminants of the aquatic ecosystems that are available to plankton, nekton and benthic organisms [1, 2] They are mainly from anthropogenic activities resulting from wastewater discharges, industrial effluents, sediment, soil erosion and run-off, air depositions of dusts and particles [3-6]. The extensive usage of heavy metals in industries qualify them as major sources of toxicants in waste water. The non-biodegradability of metal ions results in its accumulation in living organisms whose effect manifest in form of various diseases and possible death.

The heavy metals in the aquatic environment are not only lethally toxic to the organisms they can also bioaccumulate in the tissues and can be transferred along the food chain until they get into man [7].

In exhibiting their toxic properties, metals are known to disrupt the functions of essential biological molecules such as proteins, enzymes as their presence display co-factors of the enzymes and interact with DNA which showed their carcinogenic properties to animals [8, 9].

Freshwater fish like *Tilapia zilli* is one of the important sources of animal protein in the diet especially as it provides a healthy source of low cholesterol source of animal protein, and omega-3 fatty acid which are very essential nutrients in the diet [10, 11]. It is also very cheap and readily available for all urban and rural communities alike. On this account their consumption has increased among health-conscious human populations [10, 12, 13].

In some parts of the world, fish, are not just important sources of protein in the human diet, they are widely being used for evaluating the quality of the aquatic environment and as bioindicators of environmental pollution. They have also been used extensively to study the physiological behavior of heavy metals in animal body organs [13-16].

The family cichlidae are known to have amazing power of heavy metal accumulation from the medium of exposure [17, 18]. In the fish the accumulated metals are embedded in the tissues of different organs in the body. These different tissues vary in their ability to retain the metals. The amount of metal retained is a function of availability in the medium and the affinity of the tissues for the metals. Metabolically active tissues are reported to have higher concentration of metals compared to tissues that are metabolically less active [19, 20]. Other possible factors that could affect bioaccumulation include concentration in the medium of exposure and the duration of exposure. In most cases more metals are accumulated when period of exposure is increased while increased duration of exposure brings about an increase in the amount of metals accumulated. In general bioaccumulation of heavy metals is the net buildup of what is taken from the medium and the amount excreted from the body. Usually there is enhanced uptake from the medium and slow elimination from the body to the medium [21]. Heavy metals are not biodegradable hence they are permanent addition to the aquatic environment and because of their deleterious effects on the aquatic organisms, detection and measurements are of alter most importance. Most heavy metal intake in fish occur through the gills surface or through the gut. Thus diffusion facilitated transport or absorption in the gills and surface mucus are the mechanisms of uptake from the water [22, 23].

This study reflected the amount of heavy metals ingested by *Tilapia zilli* after eight (8) weeks exposure to treated industrial wastewater effluent. The ways the metals were distributed in the different organs of the fish and the extent to which the metals were retained in each organ type were analyzed.

2. Materials and Methods

The waste water effluent used in this study were collected in acid-washed and effluent rinsed 25 litre plastic containers at the point of effluent discharge. Different concentration of the effluents were prepared (0, 10, 20, 30, 40%) using well water of acceptable quality parameter as dilution water [24, 25]. To each of the effluent concentrations were loaded 15 specimens in each concentration. They were fed daily with commercial fish pellets (Nigeria Institute of Oceanography and Marine Research (NIOMR) fish feed) at 5% of their wet weight for the duration of the experiment. On weekly basis, the tanks were cleaned, the media reconstituted and samples taken to determine the level of heavy metals in the whole fish, the gut, the gill, liver and muscle at each effluent concentrations. The dissected tissues were weighed (wet weight) and the tissues separately digested using a mixture of concentrated nitric acid and hydrogen peroxide (1:1 v/v). In each case, the digested tissue in the digestion flask were heated on a hot plate to about 120°C until all were in solution and allowed to cool down to room temperature. The heavy metals dissolved in each sample were determined using an Absorption Spectrophotometer (Perkin Elmer Model #3030 and final metal concentration expressed as in µg metal ion/g wet weight of the organs [25].

Table 1. *The physicochemical characteristics of the treated effluents at the point of discharge.*

Parameters	Range	Mean
Colour TCU	320.50 – 543.08	443.08±12.85
Conductivity µs	236.00 - 462.30	346.30±12.38
Temperature °C	32.00 – 45.00	34.80±6.84
pH	6.8 – 7.6	7.4±0.42
Salinity ‰	220.00 – 260.00	250.00±23.09
Turbidity NTU	43.00 – 60.00	45.00±4.66
Dissolved oxygen	1.85 – 2.80	2.30±0.38
Settleable solids	540.00 – 680.00	650.00±59.65
Total Dissolved Solid	365.30 – 382.50	396.20±9.36
Total hardness as $CaCO_3$	26.40 -105.00	32.40±40.55
Total hardness as $MgCO_3$	410.00 – 560.00	440.00±50.99
Chemical Oxygen Demand	420.30 – 569.62	463.20±8.34
Biological Oxygen Demand (BOD)	159.50 – 298.36	240.50±10.26
Phenol	7.20 – 17.34	9.42±1.39
Chloride	24.60 – 150.00	29.60±40.09
Sulphate	28.60 – 42.50	31.60±4.37
Phosphate	2.20 – 6.80	5.10±0.86
Ammonia	0.06 – 1.20	0.58±0.19
Copper	0.28 – 0.76	0.68±0.08
Lead	0.52 – 1.20	0.82±0.14
Iron	6.40 – 10.35	9.20±1.28
Zinc	0.36 – 0.65	0.56±0.24
Cadmium	0.26 – 0.75	0.48±0.32
Chromium	0.60 – 1.20	0.58±1.09
Manganese	0.24 – 0.44	0.32±0.45

Mean of 8 batches of effluent collected are presented.

3. Results

The results obtained from the analysed samples were as presented in Figures 1-5. The results showed that the different organs of the fish accumulated the metals in the effluents to a large extent. The amount of metal accumulated was found to be directly related to the concentration of the effluents to which the fish were exposed. The level of the metals in the whole fish were in the decreasing order of Pb>Fe>Cu>Zn>Mn>Cr>Cd. The different organs of the fish were found to accumulate the metals to different extent. More was accumulated by the gut was followed by the gill, then the liver and lastly the muscle (Figures 1-5). The level of the metals in the organs was found to be a measure of the concentration of effluents to which the fish were exposed. The different organs did not accumulate the metals to the same degree. The metal burden in the whole fish and gill were in the decreasing order of Pb>Fe>Zn>Cu>Mn>Cr>Cd (Figures 1-2) except the control. In the gill and liver the decreasing order was Pb>Fe>Cu>Zn>Mn>Cr>Cd (Figures 2 and 4). In the gut, the decreasing order was Fe>Pb>Cu>Zn>Mn>Cr>Cd (Figure 3). These showed that the metals were not accumulated to the same extent by the different organs even in the same effluent concentrations. Iron was accumulated more than the other metals in the gill followed by Lead, Zinc, Copper, Manganese, Chromium and least was Cadmium. In the muscle the order of metals accumulation followed the same trend in all the effluent concentrations. The decreasing order was Pb>Fe>Zn>Mn>Cr>Cu>Cd except 40% effluent concentration. The levels of these metals were very low in the muscles compared with other organs. The levels were also a function of effluent concentration.

Based on individual metals, lead was accumulated to a large extent by the whole fish followed by the gill, gut and least was the muscle (Figures 1-5). Iron was found to be accumulated in the decreasing order of whole fish>gill>gut>liver>muscle. Copper, Zinc, Chromium and Manganese were accumulated in decreasing order of whole fish>gill>liver>gut>muscle. The level of Cadmium was found to be lowest in the muscle compared with other organs of the body. Statistical tests (ANOVA) showed significant difference (p<05) in metal accumulated by the fish in different effluent concentrations to which they were exposed.

All values except temperature, p^H, salinity, conductivity and colour are expressed in mgl^{-1}.

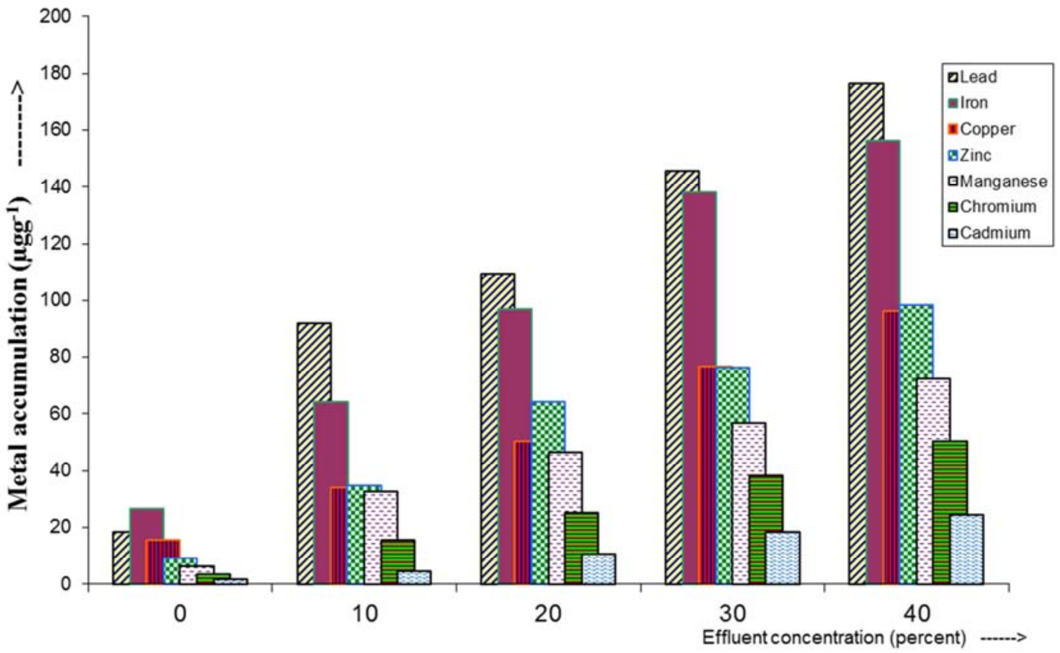

Figure 1. *Whole fish metal burden (µgg-1) in T. zilli exposed to effluents for eight weeks.*

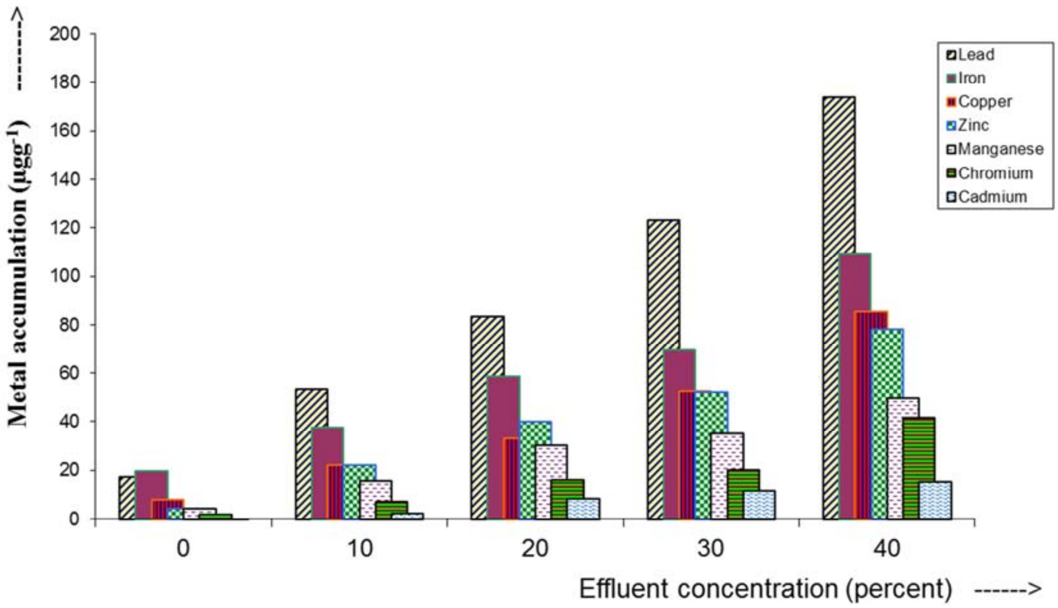

Figure 2. *Gill metal burden (µgg-1) in T. zilli exposed to effluents for eight weeks.*

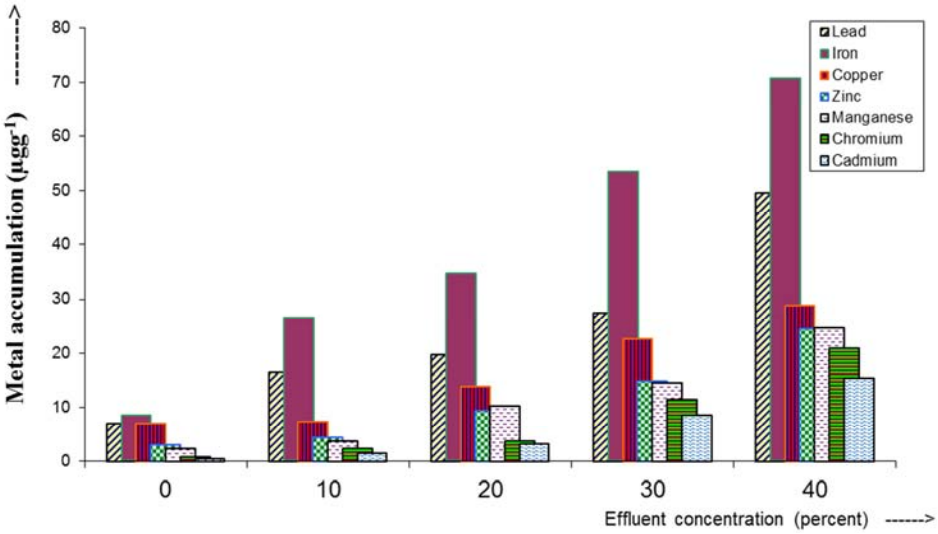

Figure 3. *Gut metal burden (µgg-1) in T. zilli exposed to effluents for eight weeks.*

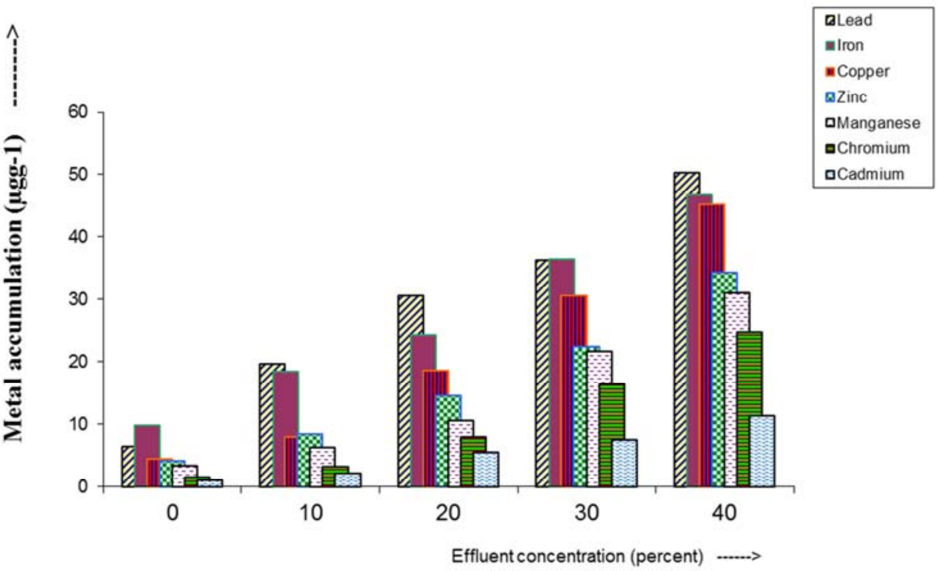

Figure 4. *Liver metal burden (µgg-1) in T. zilli exposed to effluents for eight weeks.*

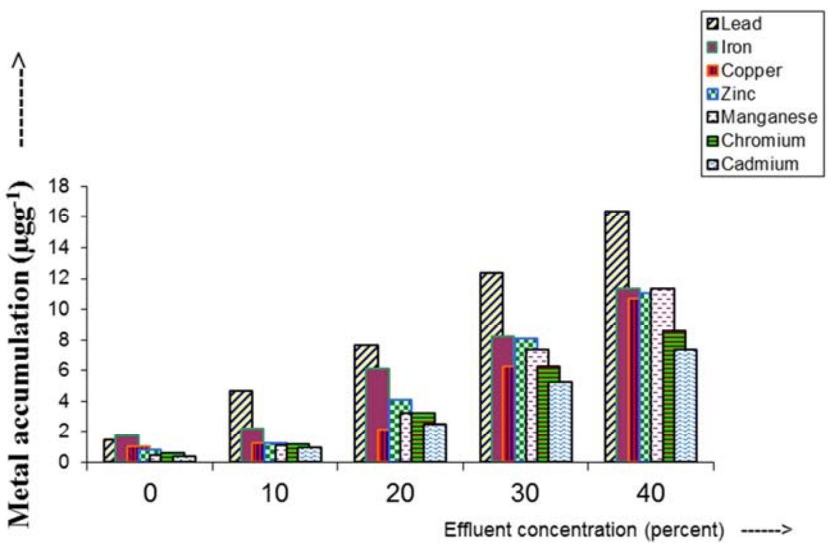

Figure 5. *Muscle metal burden (µgg-1) in T. zilli exposed to effluent for eight weeks.*

4. Discussion

Exposure of the test organism to sublethal concentration of the effluents led to metal accumulation by *T. zilli*. The amount of metals accumulated was found to be a function of the effluents concentrations and period of exposure. Similar results have been reported by other authors [17, 26-28]. Members of the family cichlidae to which *T. zilli* belongs have been reported to have amazing power to concentrate metals [17]. In this study, *T. zilli* accumulated as much as 275.42mgl^{-1} of lead in 40% effluent and 88.06ugg^{-1} in 10% effluent over a period of eight weeks. The metals were found to be preferentially accumulated in the fish in the increasing order of Pb>Fe>Cu>Zn>Mn>Cr>Cd. Onwurere and Oladimeji, [17] reported the order in *O. niloticus* to be Pb>Cu>Zn>Mn>Cr>Ni>Cd. Different organs of the fish were also found to accumulate the metals to different extent. More was accumulated by the gill followed by the liver and lastly the muscle at the different effluent concentrations (Figures 1-5). Different authors have reported this trend in other studies. In *O. niloticus* the metals were preferentially accumulated in the order gill>liver>kidney [17]. The order of metal accumulation in *Tilapia zillii* and *Chrysichthys nigrodigitatus* from Epe and Badagry Lagoons were sediment>fish>water [29]. Similar results have also been reported by Davies *et al.* [30]. Allen and Masters [31] showed that different organs of the body accumulate a particular metal to a high level while other organs do not accumulate the metals though present in medium in high concentrations [32]. Significant accumulation of metals have been reported in metabolically active tissues such as the gills and liver compared with the muscles which are less active compared with the gills and liver [33, 34]. Some metals such as cu, zn and cd have been identified as metals that reach toxic concentrations in aquatic foodstuffs through food chain biomagnification [7, 35]. In this study, the gill was found to be a very important organ in metal accumulation. At the different effluent concentrations, the metals were found to have the highest concentration in the gills. This is not unconnected with the role of the gill in aquatic animals. The gill is well vascularised being specialized organ of gas exchange. In most aquatic organisms, water-borne toxicants will be absorbed by the gills before they can be taken up in any other organ. The gills have been identified by different authors as one of the primary routes for the uptake of water borne pollutants [33, 36]. Differences in toxicant concentration found in aquatic animals are influenced by various environmental factors. These factors include temperature that affects fat metabolism [37]; level of dissolved oxygen which affect respiratory processes and pH which influences the bio-availability of the metals [38]. In this study, these factors were not individually investigated, but there were no significant fluctuations in their values throughout the period of investigation. They are therefore not likely to influence the metal uptake from the effluent.

Tilapia zilli are of economic importance as cheap source of animal protein; hence the health implication of their ability to accumulate heavy metals to a high level cannot be ignored. Man that feeds on the fish will eventually incorporate some of these metals into the body system. In this study, the concentration of metals accumulated by the organs were higher than that recommended for intake by FAO and WHO for human intake [39, 40]. Thus the *T. zilli* from water body receiving this effluent will present health risks to consumers. Though the effluents were treated before discharge into the environment, the level of treatment does not meet the WHO standard for drinking water quality [40], and the FAO standard for hazardous substances in fish and fisheries products [39]. The fishing industry is critical since it provides fish, a known source of proteins besides being a source of income and thus plays an important role in socioeconomic empowerment for livelihoods among fishermen. The detection of high concentrations of heavy metal in faunal muscles consumed as delicacies present potential health risk among the inhabiting population. Exposure of workers to Cadmium in form of oxide has been reported to be the reason for the development of hypertension among workers [41]. In certain situations, there may be no adverse health effects but the palatability of fish or shellfish may be adversely affected through the tainting of their flesh [42].

In Nigeria, the growing rate of industrialization is gradually leading to contamination and deterioration of the environment, thus industrialization and heavy metal pollution are positively correlated [43]. Excessive levels of heavy metals may occur in the biosphere as a result of normal geological phenomena such as ore formation, weathering of rocks and leaching or degassing (in the case of Hg). Other activities that could contribute to excessive release of these metals into the environment include burning of fossil fuels, smelling, and discharges of industrial, agricultural, and domestic wastes as well as deliberate application of pesticides.

Anthropogenic contributions or human activities such as petroleum mining and prospecting as well as oil spillage are also major sources of these metals [44, 45]. In recent times, there has been considerable interest in the level of heavy metallic elements in foods because of their deleterious effect on human health. Apart from those communities exposed to high levels of pollution by industrial effluent or emissions rich in heavy metals, it is evident that, for most individuals food and diet are the most common source of these potentially toxic elements. Heavy metal contamination can be transferred to animals through direct exposure, polluted water, crops grown on irrigated sewage, industrial effluents, vehicle emission, and dirty slaughter houses.

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