Bioaccumulation of Heavy Metals in Organs of *Clarias gariepinus* Juveniles Exposed to Sub-Lethal Concentrations of Waste Tire Residues

Abstract

The Unregulated waste tires combustion may be contributing to heavy metal environmental pollution. The present study assessed heavy metals concentration (HV) in waste burnt tire residues (WBTRs) as well as bioaccumulation of heavy metals in gills, liver, kidney, and muscles of *Clarias gariepinus* juveniles upon exposure to sublethal concentrations (SLCs) of water-soluble fractions (WSFs) of WBTRs. One hundred and twenty mixed-sex juveniles of *C. gariepinus*. *C. gariepinus* with average weight of 47.95±0.34g and length of 15.54±0.36cm were then exposed to SLCs of 0.00, 0.23, 0.47, 0.94, 1.87, and 3.74g/L of WSFs of WBTRs for a period of fifty-eight days. Heavy metal concentrations in WBTRs and in the organs of the exposed fish were measured using a handheld X-Ray Fluorescence Analyzer (NitonXL3T). Results showed that strontium, lead, zinc, cobalt, bismuth, rubidium, gold, tungsten, iron, thorium, arsenic, copper, and niobium were detected in WBTRs, and the most detected was zinc. However, no significant difference was observed compared to the control group regarding heavy metal accumulation in muscles, 53.10±12.78; liver, 56.30±76.96; kidney, 164.54±12.78; and gills, 241.36±146.87 of fish, with $P > 0.05$. The high heavy metal concentrations present in WBTRs are really underlined as having the capacity to pollute surrounding environments. The demand to reduce the burning of waste tires, in view of toxic impacts on aquatic life, is once again emphasized to protect both the environment and aquatic species.

Keywords: Burnt tire, Heavy metals, bioaccumulation, Catfish, Pollution

1. INTRODUCTION

The fact that there are around 1.5 billion trash tires produced annually globally poses a serious threat to the environment. as evaluated by [1], waste tires are non-biodegradable. Despite recycling efforts, the majority of tires are now disposed of in landfills or dumped without sufficient treatment, causing environmental harm [2] observes that the majority of them end up in landfills or other untreated places. In Nigerian towns, waste tires from various cars build up enormously. As a result, people burn the tires to recover materials like iron and steel, which are then used for a variety of purposes. But when tires are burned outside, harmful substances including carbon black, zinc oxide, wax, sulfur, and heavy metals like cadmium, Cr, iron, lead, and zinc are released. These substances spread throughout the atmosphere and other habitats before entering aquatic ecosystems and causing pollution there[3]. Undoubtedly, studies have demonstrated that burning tires releases a range of air pollutants, the majority of which are well-known carcinogens, as well as particulate matter and volatile organic compounds [4].

These heavy metals may bioaccumulate in aquatic species upon entry into aquatic systems, causing dysfunction in the environment and possibly even decreases in fish populations [5]. Since the majority of heavy metal accumulation in fish occurs in organs including the gills, liver, kidney, and muscles, it is extremely harmful to both aquatic species and fish consumers [6]. Extensive research has documented elevated concentrations of heavy metals, including cadmium (Cd), nickel (Ni), cobalt (Co), and zinc (Zn), in the vicinity of waste tire burning sites. These levels are frequently greater than the highest permissible threshold values established by global health organizations [7, 8]. Both fish and humans who eat them may be negatively impacted by these metals when they build up to hazardous levels in fish [9]. Excessive consumption of Clarias gariepinus, often known as African catfish, has been linked to heavy metal contamination in other fish species in Nigeria [9]. This species is considered crucial for ecological monitoring.

Numerous studies have documented the bioaccumulation of metals in various fish organs; some of these metals, such chromium and mercury, above WHO/FAO acceptable limits [6]. Indeed, it has been established that XRF analysis is the fastest, non-destructive method for determining if different biological samples, soils, and sediments contain heavy metal pollution [10]. It has been used in research projects to evaluate the number of heavy metals in fish muscles that come from coastal areas where high concentrations of metals like iron, zinc, lead, and copper have been found [11].Similar methods were applied to the analysis of heavy metals from dried fish samples in Bangladesh, where the concentration of metals was determined to be Fe > Zn > Hg > Cu > Cr [12]. These results demonstrate the frequency of metal pollution in fish and emphasize the necessity of routine monitoring, particularly in areas where used tires are burned or disposed of as fuel.

Thus, using X-Ray fluorescence to measure metal concentrations in fish tissues, this work assesses the level of heavy metal bioaccumulation in the organs of juvenile Clarias gariepinus after exposure to sub-lethal amounts of waste tire residues. The assessment of the environmental impacts resulting from waste tire burning and potential threats to human and ecological health will be improved by knowing the extent of metal buildup in aquatic species.

2. MATERIAL AND METHODS

2.1 Collection of Waste Burnt Tire Residues

Tire waste was collected from Ring Road in Jos North Local Government Area, Plateau State, Nigeria, where an inconceivably large quantity of tires is used every day to tenderize rocks. Remaining (black rubber) and steel components were isolated from waste tire fragments. The latter was ground into a powder using a mortar and pestle, and the resulting 40µm-sized particles were filtered through an ASTM D40µm mesh screen. For 48 hours, the 500g of sieved particles were macerated in 5 L of distilled water while being constantly stirred with a magnetic stirrer. The mixture was passed through a non-absorbent cotton wool-lined plastic funnel, collecting the WSF filtrate in a plastic container for later use [13].

2.2 Collection and Acclimation of Experimental Fish (*Clarias gariepinus*)

Twenty live, apparently healthy mixed-sex juveniles of C. gariepinus, with a mean weight of 46.9±0.3.44g and a total length of 14.54±0.36cm, were acquired from Catfish Expert Global Venture Farm in Zarmaganda, Jos, Plateau State, Nigeria. They were then brought to the Department of Zoology, Aquaculture Laboratory of Hydrobiology and Fisheries Unit, at the University of Jos, Nigeria. A week was spent acclimating fish to laboratory conditions in six (6) 35L plastic tanks that were filled with 20L of borehole water each. Daily around 8:00 a.m., the water in the holding tanks was replaced. Commercial feed (Coppens®) was supplied twice a day, at 8:00 AM and 5:00 PM, until the fish were fully satisfied.To remove feces and leftover feed, three-quarters of the water in the tank was drained off each day and replaced with fresh water.

2.3 Sublethal Exposure to Water-Soluble Fractions of Burnt Tire Residues: Test Procedure

The LC50 (11.22 g/L) was serially diluted to produce successive SLCs of 11.22 g/L at the 1/3rd, 1/6th, 1/12th, 1/24th, and 1/48th levels [13]. Five sublethal test concentrations were used (3.74, 1.87, 0.93, 0.47, and 0.23g/L), as well as a control (0.00g/L). Renewable bioassays lasted 58 days, or two months. The test fish were fed commercial feed (Coppens®) twice a day at 8:00 AM and 5:00 PM until they were satisfied. Photoperiod was normal (12 hours of light and 12 hours of darkness).

2.4 Experimental Design

The sub-lethal toxicity experiment was done in six rectangular glass tanks, employing a randomized complete block design (40x25x23cm) with 120 mixed-sex C. gariepinus juveniles average 47.95±3.44g and 15.54±0.36 cm in length. Each of the six glass tanks was filled with 10L of borehole water, and five of the tanks were infected with varying concentrations of WSFs and WBTRs, followed by the introduction of ten mixed sex C. gariepinus juveniles [13]. The remaining two control tanks (0.00g/L) each held ten juveniles and were not injected with the test substance. The experimental setting was replicated.

2.5 Heavy Metals Loads Determination

Using an X-ray fluorescence analyzer, the NitonXL3T, waste burned tire residues were collected along Ring Road in the Jos North Local Government Area of the Plateau and analyzed for heavy metals. An X-Ray Fluorescence Analyser NitonXL3T was therefore used to study the bioaccumulation of heavy metals in the gills, liver, kidney, and muscles of C. gariepinus juveniles exposed to 58-day SLCs of WSFs or WBTRs.

2.5.1 Heavy Metals Loads in Waste Burnt Tyre Residues

Heavy metals such Mo, Zr, Sr, U, Rb, Th, Pb, Au, Se, As, Hg, Zn, W, Cu, Ni, Co, Fe, Mn, Sb, Sn, Cd, Pd, Ag, Nb, Bi, Pt, Re, Ta, Hf, Cr, V, and Ti were evaluated in WBTRs using the X-Ray Fluorescence Analyzer NitonXL3T. WBTRs were subjected to XRF analysis after being put in an XRF thin film [14].

2.5.2 Heavy Metal Accumulation in *Clarias gariepinus* Organs Exposed to Sublethal Levels of Burnt Tyre Residue

Blood traces were removed from *C. gariepinus* organs treated with SLCs or WSFs or WBTRs after 58 days of inoculation with distilled water. An air-dry method and a laboratory mortar and pestle were used to pulverize the removed organs. X-ray fluorescence (XRF) thin film mounting of dried organs was done, and the organs were reviewed using XRF [15].

Three locations on each of the ground-up fish samples received the radiation beam directed from the instrument aperture. Subsequently, it was controlled via a soft-touch, intuitive screen interface, and the outcomes were shown on the connected PC for printing. The instrument software computed the quantitative results. The results given for each sample are the average of the three measurements that were made, with the principal elements being identified and expressed in parts per million.

Results

Heavy metals loads

Heavy metals load in WBTRs recovered from Ring Jos, Plateau State; the bioaccumulation of heavy metals in the organs of *C. gariepinus* juveniles on 58-day WSFs of WBTRs are presented. WBTRs Table 1 in Ring Road, Jos Plateau State, Nigeria included the following, Sr, Pb, Zn, Co, Bi, Rb, Au, W, Fe, Th, As, Cu, and Nb. The highest and lowest mean Zn and Nb levels were 92540.31±1439.69 and 5.76±3.05 ppm, respectively. Th, Sr, As, Bi, Au, and Pb showed less than 100 ppm values; the respective values are 16.52±5.69, 17.99±2.66, 18.50±11.41, 72.62±12.19, 83.59±13.07 and 98.12 ± 11. 51 ppm, whereas those of Cu, W, Fe, Co, and Zn were above 100 to 201.52±30.54, 931.03±190.19, 2079.23±93.83, 2858.17±125.09, and 92540.31 ± 1439.69, respectively. The increasing order of the number of heavy metals in the test material is given as: Nb < Th < Sr < As < Bi < Au < Pb < Cu < W < Fe < Co < Zn.

Table 1: Mean Heavy Metals Loads in Waste Burnt Tires Residues Obtained from Site of Tenderizing Rock at the Ring Road of Jos North, Plateau State, Nigeria

Heavy Metals	**Mean Conc. Of HM (ppm)**	**Percentage (%) of HM**	WHO Permissible Level (mg/L)	US EPA Permissible Level (mg/L)
Nb	5.76±3.05	0.01	No specific limit	No specific limit
Th	16.25±5.69	0.02	No specific limit	No specific limit
Sr	17.99±2.68	0.02	No specific limit	No specific limit
As	18.50±11.41	0.02	0.01	0.01

Bi	72.62±12.19	0.07	No specific limit	No specific limit
Au	83.58±13.07	0.09	No specific limits	No specific limits
Pb	98.12±11.51	0.10	0.01	0.015
Cu	201.52±30.54	0.20	2.0	1.3
W	931.03±190.19	0.94	No specific limits	No specific limits
Fe	2079.23±93.83	2.10	Up to 0.3	0.3 (secondary standard)
Co	2858.17±125.09	2.89	<0.05	No specific limit
Zn	92540.31±1439.7	93.54	Up to 5.0	5.0

(Sr=Strontium, Pb = Lead, Zn = Zinc, CO = Cobalt, Bi = Bismuth, Rb = Rubidium, Au = Gold, W = Tungsten, Fe = Iron, Th = Thorium, As = Arsenic, Cu = Copper, Nb = Niobium, ± = Mean standard error and WBTRS = Waste burnt tyre residues) No specific limit indicates that there are no specific recommended limits for those metals by the WHO or US EPA.

Heavy Metal Load in *Clarias gariepinus* Exposed to Sublethal Burnt Tyre Residue Fractions

After the juvenile *C. gariepinus* fish were exposed to the WSFs of WSBTRs for 58 days, the heavy metal burden in their muscles, liver, kidney, and gills was determined using an XRF machine.Heavy metals such as Sr, Rb, Pb, As, Zn, Fe, and Nb were found in the gills of the C. gariepinus juveniles that were exposed for 58 days to SLCs of WSFs of WBTRs (Table 2). Rb, Pb, As, and Zn had the maximum values at 1.87g/L, with values of 29.01±20.36, 75.79±5.79, 18.74±8.74, and 314±95.57 ppm, respectively. Sr and Nb had maximum values of 21.09±1.74 and 19.32±2.00 at maximum concentrations, respectively, whereas Fe levels were highest at 9.40 and lowest at control concentrations of 229.56±29.56 and 0.00±0.00, respectively, at minimum concentrations. All of the heavy metals with a P-value of >0.05 showed no discernible change when compared to the control.

Table 2: Heavy Metals Loads in the Gills of *Clarias gariepinus* Juveniles

Conc(g/L)	Heavy metals in Gills (ppm)							
	Sr	Rb	Pb	As	Zn	Fe	Nb	Total
0.00	20.85±1.1	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	18.21±3.7	39.06±4.87
0.23	21.05±1.8	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	18.49±0.8	39.54±2.63

0.47	19.71±2.8	11.5±11.5	44.31±44.3	6.82±6.82	208.16±208.2	31.18±31.2	14.78±2.4	336.48±307.2
0.94	21.33±2.6	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	229.56±9.6	18.52±1.1	269.41±13.3
1.87	17.95±3.9	29.1±20.4	75.79±0.8	18.74±0.7	314.40±95.8	50.47±0.47	14.65±0.4	521.01±122.4
3.74	21.02±1.7	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	19.32±2.0	40.34±3.74
Pvalues	0.92	0.31	0.57	0.55	0.54	0.60	0.46	

Values with asterisks () in the same column indicate significant difference (P<0.05) compared with the control (Conc.=Concentrations, Sr=Strontium, Pb=Lead, Zn=Zinc. Rb=Rubidium, Fe=Iron, As=Arsenic Nb=Niobium and ±= Mean standard error)

Heavy Metals Load in Liver of *Clarias gariepinus* Juveniles

Heavy metals such as Sr, Fe, and Nb were found in the livers of C. gariepinus juveniles exposed to WSF or WBTR SLCs for 58 days. The maximum Sr and Nb values were 24.74±1.85 and 17.29±2.32ppm at 0.94 and 0.00 g/L, respectively. Table 3 shows that the minimum Sr and Nb values were 22.77±1.24 and 15.99±0.52ppm in 1.87 g/L, respectively. There was no significant difference in the identified heavy metals compared to the control

Table 3: Bioaccumulation of Heavy Metals in Liver of *Clarias gariepinus* Juveniles

Conc.	**Heavy metals (ppm)**			
(g/L)	**Sr**	**Fe**	**Nb**	**Total**
0.00	22.77±0.07	0.00±0.00	17.29±2.32	40.06±2.39
0.23	22.66±1.22	72.79±0.40	16.33±0.61	111.78±2.23
0.47	23.57±0.03	0.00±0.00	17.24±1.32	40.81±1.35
0.94	24.74±1.85	0.00±0.00	16.20±0.45	40.94±2.30
1.87	22.55±1.24	0.00±0.00	15.99±0.52	38.54±1.76
3.74	24.34±0.63	7.99±7.99	17.09±0.18	49.42±8.80

Conc.=Concentrations ±= Mean standard error
Sr= Strontium, Fe = Iron, Nb= Niobium

Heavy Metals Load in Kidney of *Clarias gariepinus* Juveniles

Among the detectable heavy metals in the kidney of the exposed fish were Sr, Rb, Pb, As, Zn, Fe, Cu, and Nb (Table 4). In the control tank (0.00g/L), only Sr, Fe, and Nb were detected in the kidneys. Maximum values of Rb as 9.08±0.92ppm, Pb as 117.67±11.29ppm, and Fe as 89.16±33.67ppm were recorded at 0.94g/L. The maximum value for Cu as 224.64±0.64ppm was recorded at 0.47g/L. Maximum quantity of As and Zn were 23.49±0.49ppm and 5.01±0.01 ppm, respectively, at 3.74g/L with no significant difference of P value >0.05 between the identified heavy metals and the control.

Table 4: Heavy Metals Load in the Kidney of *Clarias gariepinus* Juveniles

	Heavy Metals (ppm)								
Conc (g/L)	**Sr**	**Rb**	**Pb**	**As**	**Zn**	**Cu**	**Fe**	**Nb**	**Total**
0.00	22.55±0.05	0.00±0.0	0.00±0.00	0.00±0.00	0.00±0.0	0.00±0.00	7.40±0.40	4.78±2.42	34.73±2.87
0.23	23.98±1.00	0.00±00	0.00±0.00	0.00±0.00	0.00±0.0	0.00±0.00	0.00±0.00	17.19±0.00	41.17±1.00
0.47	24.49±1.93	0.00±0.0	0.00±0.00	0.00±0.00	0.00±0.0	224.64±0.6	0.00±0.00	16.20±0.84	265.33±3.4
0.94	21.67±0.32	9.08±0.9	17.67±11.2	19.71±10.3	4.68±0.7	0.00±0.00	89.16±33.7	14.76±0.18	276.7±57.3
1.87	24.97±0.55	0.00±0.0	0.00±0.00	0.00±0.00	0.00±0.0	0.00±0.00	0.00±0.00	16.05±0.89	41.02±1.44
3.74	22.33±1.91	4.54±4.5	108.07±8.1	23.49±0.49	5.01±0.0	0.00±0.00	22.72±0.72	13.73±0.045	199.9±15.8

Where: ±= Mean standard error, Conc.= Concentrations, Sr = Strontium, Pb = Lead, Zn = Zinc, Rb = Rubidium, Fe = Iron, As = Arsenic, Cu = Copper, and Nb = Niobium

Heavy Metals Load in Muscles of *Clarias gariepinus* Juveniles

After C. gariepinus was exposed to SLCs of WSFs of WBTRs, three heavy metals—Sr, Fe, and Nb—were found in its muscles (Table 5). The highest result for Sr, 26.38±2.16ppm, was found in the muscles of the experimental fish subjected to 0.94g/L of WSFs or WBTRs. Recorded at 3.74g/L, the maximum Nb value was 17.28±0.14ppm. 20.12±1.06 and 15.13±0.01 ppm, at 3.74 and 0.47 g/L, respectively, were the lowest values for Sr and Nb. In the muscles of all fish exposed to SLC, as well as in the controls, Fe was not found.

Table 5: Bioaccumulation of Heavy Metals in Muscles in *Clarias gariepinus* Juveniles

Conc. (g/L)	Heavy metal in muscle (ppm)			
	Sr	**Fe**	**Nb**	**Total**
0.00	23.78±3.53	0.00±0.00	15.97±0.29	39.75±3.82
0.23	22.62±0.97	0.00±0.00	15.75±1.96	38.37±2.93
0.47	23.81±1.22	70.01±0.01	15.13±0.01	108.95±1.24
0.94	26.38±2.16	0.00±0.00	15.97±1.57	42.35±3.73
1.87	21.38±0.61	0.00±0.00	17.07±0.46	38.45±1.07
3.74	20.12±1.06	0.00±0.00	17.28±0.14	37.40±1.20

Note: ± = Mean standard error, Conc.= Concentrations, Sr = Strontium, Fe = Iron, Nb = Niobium

Comparative Heavy Metals Loads in Gills, Liver, Kidney and Muscles of *Clarias gariepinus* Juveniles Exposed

After 58 days of exposure to SLCs of WSFs of WBTRs, C. gariepinus juveniles had mean heavy metal levels of 53.10±12.78, 56.30±7.69, 164.54±12.78, and 241.36±146.87ppm in their muscles, liver, kidney, and gills (Table 6). Heavy metal loads in C. gariepinus juveniles exposed to WSFs of WBTRs were measured in the following order: muscles, liver, kidney, and gills. Heavy metal concentrations of 1.87 and 0.00g/L resulted in the greatest (187.89±78.30) and lowest (38.40±3.48) mean values, respectively (Table 7). There was no significant difference (P>0.05) in heavy metal levels in all organs tested in C. gariepinus juveniles exposed to 58-day SLCs of both W

Table 6: Heavy Metals Loads in Gills, Liver, Kidney and Muscles of *Clarias gariepinus* Juveniles

Conc. (g/L)	HMLG (ppm)	HMLL (ppm)	HMLK (ppm)	HMLM (ppm)	MTCHMC (ppm)
0.00	39.06±4.87	40.06±2.39	34.73±2.87	39.75±3.82	38.40±3.48
0.23	39.54±2.63	111.78±2.23	41.17±1.00	38.37±2.93	57.72±2.20
0.46	336.48±307.17	40.81±1.35	265.33±3.41	108.95±1.24	187.89±78.30
0.94	269.41±13.28	40.94±2.30	276.73±57.30	42.35±3.76	157.36±19.16
1.87	521.01±122.35	38.54±1.76	39.58±0.00	38.45±1.07	159.40±31.30
3.740	40.34±3.74	49.42±8.80	199.89±15.79	37.40±1.20	81.7625±7.38
MHLO	241.36±146.87	56.30±76.96	164.54±12.78	53.10±12.78	123.13±63.52
P value	0.17	0.00	0.01	0.00	0.02

HMLS=Heavy Metals load in skin HMG= Heavy Metals load in gills
HMLL= Heavy Metals load in liver HMTM= Heavy Metals load in kidney
HMLM=Heavy Metals load in muscles MHLO=Mean heavy load in organs
MTCHO=Mean Total Concentrations of Heavy Metals (ppm) in each Concentration

DISCUSSION

One of the main causes of heavy metal pollution in the environment has been shown to be open waste tire burning [7]. There were variations in the average concentrations of the heavy metals found in WBTRs gathered from Ring Road in Jos Plateau State, according to the findings of a heavy metal analysis conducted utilizing portable XRF equipment. Nb > Th > Sr > As > Bi > Au > Pb > Cu > W > Fe > Co > Zn was the trend order for heavy metals. [7] also made a similar discovery and discovered that the scrap tire burning site had rising orders of concentrations of the following heavy metals: Cd, Ni, Co, As, Cr, Mn, Fe, Cu, Pb, and Zn. The waste tires of the passengers also revealed heavy metals like Fe, Zn, Cd, Cr, and Pb in the ashes. The highest number of metals among these was from Pb and Zn [16], in agreement with this study. These results are consistent with a study by [17] that found that the highest Zn concentrations were found in passenger vehicle and motorcycle end-of-life tire ashes, followed by Cu, Cr, Cd, and Pb. Thus, our findings are consistent with those published by [18], who found that among tire samples from South Korea, France, and China, Zn had the highest average levels, followed by

Cu, Pb, Sn, Sb, Ni, Cr, As, and Cd. The increasing order of concentrations of heavy metals Cd, Pb, Mn, Cu, Co, Ni, Cr, Mg, Fe, and Zn in the emissions from burning particulate matter of discarded vehicle tyres was given as [19], which corroborates the trend established in this study.

The XRF results for the collected WBTRs sample reveal a higher level of heavy metals than those reported by [17] and [18], who used an atomic spectrometer machine to report that the metal load was relatively low at the scrap tire burning site and, in the end, -of-life tyre ashes from passenger cars and motorcycles. The findings additionally validated that XRF is a reasonably priced, quick, and non-destructive screening method for identifying heavy metals in contaminated soils, sediments, and biological materials [10].

In relation to aquatic life, metal buildup in fish organs can therefore be interpreted as a broad indicator of metal contamination [6]. When C. gariepinus juveniles were exposed to sublethal doses of WSF of WBTRs for 58 days, the heavy metal burden rose in the following order: muscles (53.10 ± 12.78), liver (56.30 ± 76.96), kidneys (164.54 ± 12.78), and gills (241.36 ± 146.87).

The muscles of C. gariepinus juveniles treated for 58 days with sublethal dosages of WSF of WBTRs bioaccumulated the fewest heavy metal residues; this observation may be explained by the fact that the muscles do not come into direct contact with the WSF of WBTRs. The reason for this could be because muscle tissue has a higher growth factor, which lowers the amounts of heavy metals. Muscle does not work as actively as the kidney, liver, and gills do in terms of aggregating metals [20]. Inadequate muscle protein binding may be linked to a low propensity for metal aggregation [20].

The present studies' findings are consistent with those of other earlier research, some of which are included below. Compared to other tissues, the muscle of fish exposed to contaminants, specifically heavy metals, has consistently bioaccumulated a lower heavy load [21]. This is consistent with [21], who observed that following a six-week sublethal exposure, Zn bioaccumulation in the muscles of O. niloticus was less than that in the liver, kidney, and gills.

The results of [22] after 20 days of exposure to lead nitrate Pb (NO3)2 in C. gariepinus muscles showed reduced bioaccumulation in comparison to gills and liver. According to [23], muscle of P. lineatus juveniles subjected to acute doses of 0.00, 25, 250, and 2500 mg/L for 96 hours showed the least amount of Ni accumulation. These results are consistent with their findings.

Within a laboratory setting, yearlings of Tor putitora and Ctenopharyngondon idella were exposed to varying amounts of lead nitrate for a duration of sixty days [24].

The authors also observe that Pb bioaccumulation happened in the following order after 60 days of exposure: gill, liver, gut, swim bladder, muscle, and skin. Although the Mahseer and Grass carp species under investigation had the greatest and lowest levels of lead found in their gills and epidermis, the results of the study contradict this conclusion. When C. gariepinus juveniles were exposed to SLCs of WSF or WBTRs for 58 days, there was a greater accumulation of heavy metals in their gills. The results of the current investigations also align with a number of previously published papers, including the following few: For sixty days, yearlings of T. putitora and C. idella were subjected to varying concentrations of lead nitrate in a controlled environment [24]. The gills of T. putitora and C. nidella have the greatest Pb content. The same pattern was found in [9] for large meals that bioaccumulated in the following order: gills > bones > head regions and muscles in tissues removed from C. gariepinus in the Asa River. The kidney accumulated the most quantity of Ni in our study, according to the results of [23], who also found that the liver, gills, and muscles of P. lineatus juveniles subjected to acute doses of 0.00, 25, 250, and 2500 mg/L for 96 hours accumulated the most Ni.

This is in contrast to our findings, as per the heavy metal Hg was primarily accumulated in the liver, kidney, muscle, brain, and gills of C. batrachus treated to SLCs (0.00, 0.19, 0.09, 0.05, and 0.03 mg/l) of mercuric chloride for 10, 20, and 30 days [25]. It is contrary to this study that during the 30-day SLCs exposure of lead acetate Pb $(C_2H_3O_2)_2$, the liver, gill, and muscle of M. cephalus had the maximum accumulation of heavy metals, as reported by [26], in the order of liver > gill > muscle, respectively.

There have been reports of a somewhat high concentration of heavy metals in C. gariepinus gills. Several research reported the following explanations, which can be related to the C. gariepinus juveniles exposed to SLCs of WSFs of WBTRs for 58 days. Fish bodies are susceptible to heavy metal entry through the gills, digestive system, and body surface [27]. Metals can easily pass through the thinnest epithelium seen in gills [28]. Because the metal ions are positively charged and these surfaces are negatively charged, there is a strong attraction for bonding between them [29]. The following heavy metal concentrations were seen to rise in WBTRS: Nb, Th, Sr, As, Bi, Au, Pb, Cu, W Fe, Co, and Zn. Consequently, exposed C. gariepinus has high metal burdens. In juvenile C. gariepinus, the organs are arranged as follows: muscles, liver, kidney, and gills. Thus, in Jos North Local Government Area, Plateau State, tire waste incineration could be a source of heavy metal contamination.

4.CONCLUSION

The examination of the heavy metal loading in WBTRs from Ring Road, Jos, Plateau State, and their bioaccumulation in juvenile Clarias gariepinus showed concerning pollution levels. Zinc is the most significant of the metals found, along with lead, cobalt, copper, and strontium. As a result, there may be health risks to aquatic life and organisms up the food chain. The young C. gariepinus fish had the highest levels of heavy metal bioaccumulation in their gills, kidneys, liver, and muscles. Sub-lethal amounts of heavy metals were observed despite these findings, which did not show any significant alterations when compared to the negative control.

5. RECOMMENDATION

The purpose of this paper is to limit the potential environmental impact of waste management practices by emphasizing their monitoring and control, particularly in metropolitan areas. Long-term exposure to heavy metals and its effects on human health and the aquatic ecosystem are issues that need more investigation; additionally, it would aid in the development of efficient waste management strategies and remediation approaches.

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