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Variation in heavy metals bio-accumulation in fish organs in relation to water quality from Wasai reservoir, Kano State

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Abstract

A study was conducted to assess the levels of heavy metals such as Pb and Cd bioaccumulation in the liver and gills of fish species collected from Wasai reservoir covering two seasons. Physico-chemical parameters of the surface water were determined monthly for a period of 10 months (covering wet and dry seasons). Similarly, samples were collected from the muscles of African catfish (*Clarias gariepinus*) and Tilapia (*Oreochromis niloticus*) obtained from the reservoir. The water and fish samples were collected and analyzed for heavy metals using an atomic absorption spectrometer. Data obtained were analyzed using Analysis of Variance with Duncan's New Multiple Range Test used to separate significant means at 5% level. The result obtained revealed significant difference ($P \leq 0.05$) in pH, DO and BOD with location and season. The levels of the heavy metals varied significantly in the water and fish species. The result showed a significant difference ($P \leq 0.05$) in heavy metal accumulation in the water body across the months. Cr level was highest in May 2019 (1.17 mg/L) and lowest in September 2018 (0.28 mg/L). The concentration of Pb was highest in April 2019 with a value of 0.136 mg/L and lowest in March 2019(0.016 mg/L). In the fish muscles, the highest concentration for Pb (0.055±0.005 mg/L) was found at station C in April 2019 while the highest levels of cadmium in the water samples (0.045±0/009 mg/L) was recorded in May 2019 at station B.
Keywords: Bio-accumulation, Heavy metals, Liver, Wasai reservoir

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Introduction

Aquatic environments have been contaminated with pollutants from both natural and anthropogenic activities such as discharge from chemical companies, agricultural activities, solid waste disposal, and flooding (Ali *et al*., 2016). Continuous discharge of industrial and domestic inputs from various processes into water bodies has significantly affected the quality of the aquatic environment, as a result of potentially toxic elements (PTEs) being released into the water during anthropogenic activities (Basheeru *et al*., 2022). Heavy metals are among the most prominent pollutants found in all environments due to their toxicity and ability to contaminate soil, water and biota as well as bio-accumulate in human bodies and ultimately endanger human health (Singh *et al*., 2024). This bio-accumulation could be source from consumption of mostly fish and other aquatic animals present in such polluted water bodies. Although fish are consumed worldwide due to their nutritional and health benefits; however, heavy metal pollution is compromising their safety (Yahaya *et al*., 2024).

Through the consumption of fish sourced from heavy metals polluted water, heavy metals present in the fish tissues were directly transferred to the human body, causing toxic effects and potentially expediting various diseases (Kortei *et al.,* 2020). Malik *et al.* (2015) reported that since fish are situated at the bottom of the aquatic food chain, they may amass heavy metals from the sediment thereby passing it to human through fish consumption and leading to severe health issues. Heavy metals, known for their toxicity, persistence, biodegradability, and accumulative nature, have been implicated in mutagenic, cytotoxic, and carcinogenic effects (Leelapongwattana *et al*., 2020; Dasharathy *et al*., 2022; Tahir *et al*., 2023). Consequently, there has been a growing interest in determining the risk of heavy metals in water bodies and resources worldwide, including fish. This is crucial to prevent or reduce heavy metal-related morbidity and mortality resulting from fish consumption (Yahaya *et al*., 2024). According to Vardi and Chenji (2020) supported by Islam *et al.* (2015) fish and sediments are the best bio-indicator recognised for the assessment of heavy metals in the natural aquatic ecosystem. This study therefore aimed at studying the variation in heavy metals bio-accumulation in fish organs in relation to water quality from Wasai reservoir, Kano state.

Materials and Methods

Study Area

The Wasai- Reservoir is situated on the Jakara River at a point about 2 km South– East of Wasai village in Minjibir Local Government Area of Kano State (Amin, 1992). It is situated on latitude
12^{o}N and 13^{o}N and longitude 8^{o}E and 9^{o}E. The reservoir was constructed in 1976 for recycling purposes. The dam has a maximum height of 9.33 m, while reservoir has a surface area of 1,250
hectares and a total storage capacity of 65.38 m3, this places the reservoir among the medium

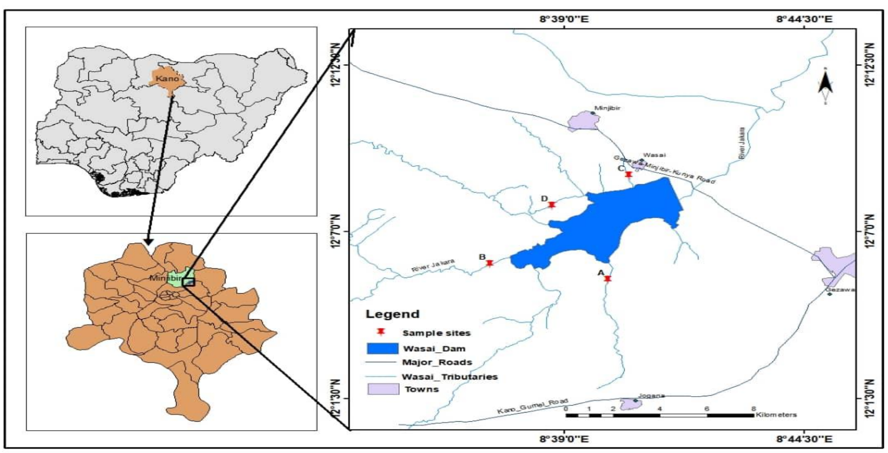

Figure 1: Map of study area showing the sampling Stations
(Source: GIS Lab Department of Geography Using Arc GIS 10.3 Software)

Sampling Stations

Four sampling stations were identified and designated for the purpose of this study, namely 1, 2, 3, and 4 respectively. Transect sampling across the basin was carried out, starting from the two tributaries i.e. Jakara river, the confluence where the two rivers meet, the entry point where the water drains into the Wasai Reservoir, the spillway of the reservoir. Samplings were conducted from 06:00 am-07:00 am monthly. Water samples were collected from the reservoir during the period from September, 2018 to June, 2019.

Water Sampling

Water sampling was carried out according to the method described by Basheeru et al. (2022) with some modifications. Prior to water sample collection, the sampling containers (250 mL plastic bottles) were pre-treated by washing with non-ionic detergent, rinse with potable water and later with distil water followed by soaking in 0.1% nitric acid overnight and rinse three times with distil water. Water samples were collected from four different locations using physico-chemicals parameters analysis. The samplings were carried out midstream by dipping the sample plastic bottle to approximately 20-30 cm below the water surface, projecting the mouth of the containers against the direction of flow direction into air-tightened amber bottles on the field during sample collection. Some physico-chemical parameters of the water samples such as pH, temperature, and electrical conductivity were analyzed on the spot using HANNA instrument (Model: H193703). The samples were transported to the laboratory on an ice chest. This was then followed by the addition of 0.1% nitric acid to the water samples for preservation. .

Fish samples collection

A total of two hundred *Clariasgariepinus* and *Oreochromis niloticus* adults and fingerlings of both sexes were procured from local fishermen around the reservoir. Fish samples obtained were immediately kept in pre-cleaned polythene bags, sealed, labelled and kept in ice boxes for transportation to the Biological Science Laboratory, Bayero University, Kano. The samples were dissected for liver and muscles followed by oven drying at 105 ^oC for 24 h and then powdered using motar and pestle.

Preparation of water samples for heavy metals analysis

The digestion of water samples for heavy metals analyses was carried out according to the procedure described by Adusei-Mensah et al. (2019) with some modifications. About 100 mL of water sample was collected from each station and combined with 5 mL of concentrated nitric acid (HNO_3) and 5 mL of concentrated hydrochloric acid. The product was then simmered over a burner until its volume was decreased to 20 mL. Following the heat treatment, the resultant material was allowed to cool down to ambient temperature and filtrated through a Watman's No 1 filter paper. The resulting amount was then filled up to 100 mL using double distilled water and kept aside for analysis.

Preparation of fish organs samples

The fishes were washed with distilled water in the laboratory. Dissection was done using a sharp stainless-steel knife and each organs of interest such as liver and muscles were isolated. The organs of investigation were kept in oven and dried at a temperature of 105^{o}C following the method of Eneji *et al.* (2011). 10g portion of the grounded samples were carefully weighed using digital chemical balance, 10 ml of HNO_3 and 2 ml of $HClO_3$ were added and heated over a hot plate for one hour. After complete digestion, the filtrate was diluted with 0.2% v/v HNO_3 to 20 mL (APHA, 2005).

Data Analysis

Data collected were subjected to analysis of variance (ANOVA) with Duncan's New Multiple Range Test used to separate significant means at 5% level. SAS (2012) Version 9.1 was used for the analyses.

Results

The result for the analysis of water quality parameters such as temperature, pH and dissolved oxygen is presented in Table 1. The result indicated no significant difference ($P \geq 0.05$) in the water temperature across all the stations in all the ten months. The result showed that, the highest mean temperature value (27.20 ^oC) was found in Station 1 in March, 2019 while the lowest mean temperature value (23.66 ^oC). was found in station 4 in January 2019. The trend in monthly variation in temperature showed that, the temperature values decrease from September 2018 to November 2018 across all the stations except in station 3 where the temperature increases in November. The temperature values continue to decrease from December 2018 up to March 2019; where the temperature values increased.

The results for the pH values of water bodies across four different stations along Wasai reservoir (Table 1) revealed that, the water pH is alkaline throughout the period of study. The highest mean pH value of 8.49 was found in March 2019 at station 1 with the lowest mean value recorded in March (7.19) in station 2. The trend in the monthly variation of pH showed that, the pH values increased from September to November in Station 1 and 4 but decreased in stations 2 and 3. The pH values in all the stations fluctuate with variations in monthly mean values.

Table 1: Monthly Mean Variations of Temperature (°C) in Wasai Reservoir

Parameter	Months	STATION 1 Mean ± S.D	STATION 2 Mean ± S.D	STATION 3 Mean ± S.D	STATION 4 Mean ± S.D	P –Value
Temperature	SEPT	25.03 ± 0.95^{a}	25.05 ± 1.95^{a}	25.57 ± 1.43^{a}	25.20 ± 0.91^{a}	0.958
	OCT	24.70 ± 0.66^{a}	23.90 ± 1.57^{a}	24.46 ± 0.15^{a}	24.97 ± 0.42^{a}	0.528
	NOV	24.33 ± 0.15^{a}	23.80 ± 1.08^{a}	25.17 ± 0.85^{a}	24.63 ± 0.66^{a}	0.252
	DEC	25.33 ± 0.06^{a}	23.86 ± 0.71^{a}	24.67 ± 0.42^{a}	25.03 ± 0.74^{a}	0.054
	JAN	24.10 ± 0.45^{a}	23.73 ± 0.65^{a}	24.47 ± 0.47^{a}	23.66 ± 046^{c}	0.279
	FEB	24.60 ± 0.36^{a}	24.20 ± 0.30^{a}	24.80 ± 0.62^{a}	24.53 ± 0.42^{a}	0.460
	MAR	27.20 ± 2.21^{a}	26.03 ± 1.50^{a}	25.73 ± 1.42^{a}	26.23 ± 2.01^{a}	0.780
	APRIL	25.77 ± 1.36^{a}	25.57 ± 1.45^{a}	25.10 ± 0.85^{a}	25.90 ± 1.93^{a}	0.911
	MAY	25.27 ± 0.94^{a}	25.97 ± 1.54^{a}	25.63 ± 1.35^{a}	25.03 ± 0.95^{a}	0.799
	JUNE	25.07 ± 0.90^{a}	24.57 ± 0.40^{a}	25.10 ± 0.85^{a}	25.53 ± 0.42^{a}	0.442
pH	SEPT	7.35 ± 0.14^{a}	7.24 ± 0.05^{ab}	7.61 ± 0.03^{b}	7.22 ± 0.05^{a}	0.001
	OCT	7.62 ± 0.02^{bc}	7.23 ± 0.01^{ab}	7.23 ± 0.03^{b}	8.14 ± 0.12^{de}	0.000
	NOV	8.16 ± 0.14^{d}	7.27 ± 0.02^{b}	7.90 ± 0.01^{c}	7.95 ± 0.02^{d}	0.000
	DEC	7.75 ± 0.26^{bc}	8.17 ± 0.05^{e}	8.27 ± 0.23^{d}	8.27 ± 0.04^{ef}	0.022
	JAN	7.85 ± 0.04^{c}	7.81 ± 0.06^{d}	7.61 ± 0.02^{b}	7.32 ± 0.02^{ab}	0.000
	FEB	7.58 ± 0.07^{b}	8.22 ± 0.02^{e}	7.68 ± 0.16^{b}	8.37 ± 0.32^{f}	0.002
	MAR	8.49 ± 0.05^{c}	7.19 ± 0.04^{a}	7.25 ± 0.05^{a}	7.68 ± 0.03^{c}	0.000
	APRIL	7.84 ± 0.02^{c}	7.23 ± 0.01^{ab}	7.32 ± 0.07^{a}	7.63 ± 0.03^{c}	0.000
	MAY	7.66 ± 0.04^{bc}	7.25 ± 0.05^{ab}	7.22 ± 0.19^{a}	7.49 ± 0.05^{bc}	0.003
	JUNE	7.21 ± 0.22^{a}	7.47 ± 0.02^{c}	7.62 ± 0.07^{b}	7.25 ± 0.05^{a}	0.009
DO	SEPT	2.33 ± 0.05^{a}	4.23 ± 0.06^{d}	3.16 ± 0.05^{b}	2.27 ± 0.12^{a}	0.000
	OCT	2.26 ± 0.15^{a}	4.20 ± 0.10^{d}	3.17 ± 0.21^{b}	2.37 ± 0.15^{a}	0.000
	NOV	2.27 ± 0.12^{a}	2.10 ± 0.10^{a}	3.50 ± 0.10^{c}	4.23 ± 0.06^{d}	0.000
	DEC	2.20 ± 0.10^{a}	2.33 ± 0.15^{ab}	2.57 ± 0.15^{a}	3.47 ± 0.25^{c}	0.000
	JAN	2.30 ± 0.34^{a}	3.53 ± 0.30^{c}	3.67 ± 0.15^{cd}	4.53 ± 0.21^{d}	0.000
	FEB	2.26 ± 0.15^{a}	2.53 ± 0.15^{b}	4.60 ± 0.20^{f}	4.30 ± 0.17^{d}	0.000
	MAR	2.20 ± 0.26^{a}	3.43 ± 0.21^{c}	3.93 ± 0.06^{d}	4.20 ± 0.26^{d}	0.000
	APRIL	2.46 ± 0.15^{a}	3.60 ± 0.20^{c}	2.66 ± 0.05^{a}	2.77 ± 0.15^{b}	0.000
K	MAY	3.23 ± 0.05^{b}	2.40 ± 0.10^{b}	4.30 ± 0.26^{e}	3.23 ± 0.06^{c}	0.000
	JUNE	4.47 ± 0.21^{c}	3.33 ± 0.11^{c}	4.40 ± 0.20^{ef}	3.33 ± 0.25^{c}	0.000

N.B: Value(s) with the same superscripts across a row are not significantly different at P≤0.05

More so, the mean values of Dissolved Oxygen (DO) in the four sampling stations along Wasai reservoir (Table 1) for ten months showed significant difference (P≤0.05) in the values of Dissolved Oxygen in the four stations across the months. The result also indicated highest DO value of 4.60 mg/L at station 3 in February 2019. However, the least DO value of 2.10 mg/L was found in station in November 2018. A significant increase in DO values was observed from 2.57 mg/L in December 2018 to as high 4.60 mg/L in the month of February, 2019. The trend in the monthly variations in DO showed that, the values almost remain constant from September 2018 to April 2019 in station 1. However, the DO values increased from May to June 2019. Furthermore, in station 4, the values increased from September 2018 to March but decreased in April to June. However, station 2 and 3 showed variation in DO with months.

Similarly, the results for the mean values of Biological Oxygen Demand (BOD) in the four stations along Wasai Reservoir are presented in Table 2. The result showed significant difference (P≤0.05) in the BOD values across the stations between the months. The results indicated highest BOD value of 8.57 mg/l in station 1 in March, 2019 with the lowest BOD value of 2.25 mg/L n June at the same station 1. The result also indicated monthly variation in BOD in all the stations.

Table 2: Monthly Mean Variations of Biological Oxygen Demand in Wasai reservoir

Months	STATION 1 Mean ± S.D	STATION 2 Mean ± S.D	STATION 3 Mean ± S.D	STATION 4 Mean ± S.D	P –Value
SEPT	8.23 ± 0.21^{ef}	3.48 ± 0.02^{ab}	5.35 ± 0.33^{b}	7.70 ± 0.26^{e}	0.000
OCT	7.13 ± 0.61^{cd}	2.73 ± 0.46^{a}	5.45 ± 1.77^{b}	8.20 ± 0.26^{e}	0.001
NOV	7.33 ± 0.72^{cde}	6.23 ± 0.40^{d}	2.91 ± 1.05^{a}	2.96 ± 0.45^{ab}	0.000
DEC	6.65 ± 1.06^{c}	6.13 ± 0.51^{cd}	7.30 ± 0.10^{c}	3.87 ± 0.51^{abc}	0.001
JAN	6.35 ± 0.13^{c}	4.00 ± 0.61^{ab}	3.37 ± 0.14^{a}	2.88 ± 0.57^{ab}	0.000
FEB	8.03 ± 0.21^{e}	6.30 ± 0.61^{d}	2.97 ± 0.50^{a}	2.53 ± 0.51^{a}	0.000
MAR	8.57 ± 0.57^{f}	5.23 ± 0.06^{bcd}	2.53 ± 0.59^{a}	3.17 ± 1.15^{abc}	0.000
APRIL	7.00 ± 0.20^{c}	3.47 ± 0.05^{ab}	6.17 ± 1.41^{bc}	6.03 ± 0.49^{d}	0.002
MAY	3.63 ± 0.50^{b}	4.43 ± 2.80^{abc}	2.30 ± 0.10^{a}	4.42 ± 1.58^{c}	0.389
JUNE	2.25 ± 0.12^{a}	3.47 ± 0.03^{ab}	3.10 ± 0.10^{a}	4.19 ± 0.54^{bc}	0.000

N.B: Value(s) with the same superscripts across a row are not significantly different at P≤0.05

The result for heavy metals concentration in surface water of Wasai reservoir is shown in Table 3. The result showed a significant difference (P≤0.05) across the months in the level of heavy metals concentrations. Cr level was highest in May 2019 (1.17 mg/L) and lowest in September 2018 (0.28 mg/L). The concentration of Pb was highest in April 2019 with a value of 0.136 mg/L and lowest in March 2019(0.016 mg/L).The concentration of Cr was 0.012 mg/L in November 2018 but rose to 0.106 mg/L by March 2019. The result for the spatial and monthly concentrations of each heavy metal in surface water for all the stations is presented in Table 2. The mean concentration (mg/L) of heavy metals in water ranged from 0.019-0.288 mg/L. Cr highest level of0.41±0.01 mg/L was recorded in samples collected at station D in May 2019. Similarly, there was an increasing trend in Pb concentration from the month of September, October to June in all the sampling the study stations along Wasai Reservoir. The concentrations of the heavy metals were significantly different (P≤0.05) across the stations with station C having the highest mean concentration for Cr (0.24 mg/l), station A with highest mean concentration for Pb (0.288 mg/l) and station B had the highest concentration of Cd (0.234 mg/L).

Table 3: Concentrations of heavy metals in surface water of Wasai Reservoir (mg/L)

Month	Cr	Pb	Cd
Sept	0.28 ± 0.01^{e}	0.06 ± 0.01^{ab}	0.022 ± 0.01^{c}
Oct	0.80 ± 0.02^{ab}	0.076 ± 0.01^{ab}	0.026 ± 0.01^{c}
Nov	0.65 ± 0.02^{c}	0.077 ± 0.01^{ab}	0.012 ± 0.01^{d}
Dec	0.59 ± 0.02^{d}	0.026 ± 0.01^{a}	0.016 ± 0.01^{d}
Jan	0.65 ± 0.02^{c}	0.034 ± 0.01^{b}	0.027 ± 0.01^{c}
Feb	0.82 ± 0.04^{ab}	0.033 ± 0.01^{b}	0.028 ± 0.01^{c}
Mar	0.80 ± 0.04^{ab}	0.016 ± 0.01^{c}	0.106 ± 0.01^{a}
kApril	0.76 ± 0.01^{b}	0.136 ± 0.01^{a}	0.023 ± 0.01^{c}
May	1.17 ± 0.01^{a}	0.032 ± 0.01^{b}	0.032 ± 0.01^{b}
June	0.61 ± 0.01^{c}	0.024 ± 0.01^{c}	0.086 ± 0.01^{ab}
Mean	0.71	0.051	0.038

N.B: Value(s) with the same superscript(s) down a column are NOT significantly different (P≤0.05)

The result for the heavy metals bio-accumulation in the muscles of two species of fish obtained from Wasai reservoir is presented in Table 4. The result showed that, the highest accumulation of Pb (0.07 mg/kg) in *C. gariepinus* is found in January and March 2019. Similar trend was found in *O. niloticus* with a bio-accumulation value of 0.08 mg/kg. However, the highest value (0.22 mg/kg) of Cd accumulation in the muscles of *C. gariepinus* is found in April and June 2019. Similarly the highest value of Cd (0.24 mg/kg) accumulated in the muscles of *O. niloticus* is found in June 2019. The result of Cr bio-accumulation in the muscles of *C. gariepinus* showed that the highest value (0.32 mg/kg) was found in September 2018. Similarly, the result in *O. niloticus* showed highest value (0.35 mg/kg) of Cr was found in September, 2018. The trend for heavy metals bio-accumulation in the two species of fish showed that Cr>Pb>Cd

Table 4: Heavy Metals in Muscles of *Clarias gariepinus* and *Oreochromis niloticus* fromWasai reservoir, Kano

Month	Lead		Cadmium		Chromium	
	Clarias gariepinus	*Oreochromis niloticus*	*Clarias gariepinus*	*Oreochromis niloticus*	*Clarias gariepinus*	*Oreochromis niloticus*
Sept	0.02±0.00	0.03±0.01	0.01±0.001	0.017±0.005	0.32±0.01	0.35±0.03
Oct	0.02±0.002	0.02±0.006	0.009±0.001	0.019±0.01	0.10±0.01	0.09±0.05
Nov	0.06±0.01	0.06±0.01	0.011±0.002	0.015±0.004	0.03±0.01	0.04±0.01
Dec	0.01± 0.001	0.02±0.004	0.012±0.001	0.013±0.00	0.16±0.12	0.17±0.11
Jan	0.0±0.01	0.08±0.02	0.010±0.001	0.017±0.004	0.03±0.006	0.04±0.002
Feb	0.02±0.002	0.02±0.001	0.015±0.005	0.020±0.003	0.03±0.001	0.04±0.03
Mar	0.07±0.01	0.08±0.01	0.127±0.005	0.133±0.015	0.31±0.015	0.32±0.03
April	0.06±0.01	0.06±0.007	0.022±0.001	0.022±0.002	0.13±0.01	0.133±0.01
May	0.03±0.002	0.03±0.002	0.019±0.001	0.022±0.007	0.04±0.005	0.04±0.01
June	0.04±0.004	0.04±0.006	0.022±0.001	0.024±0.002	0.07±0.006	0.07±0.01

N.B: Value(s) with the same superscripts across a row are not significantly different at P≤0.05

Results for the bio-accumulation of heavy metals in the liver of two fish species obtained from Wasai reservoir is shown in Table 5. The result showed that the highest value of Pb (0.17 mg/kg) was accumulated in *Oreochromis niloticus* followed by 0.16 mg/kg in the liver of *Clarias gariepinus* in October 2018. The least value of Pb (0.02 mg/kg) was found in the liver of *C. gariepinus* in September 2018. However, the highest concentration of Cd was found in the liver of *C. gariepinus* with a value of 0.18 mg/kg in March 2019. The lowest Cd bioaccumulation of 0.01 mg/kg was found in the liver of *O. niloticus* in January 2019. The highest value of Cr bioaccumulation was found in the liver of *C. gariepinus* and *O. niloticus* in June 2019. The least value of Cr was found in the liver of *C. gariepinus* in February 2019.

Table 5: Heavy Metals in liver of *Clarias gariepinus* and *Oreochromis niloticus* fromWasai reservoir, Kano

Month	Lead (Pb)		Cadmium		Chromium	
	Clarias gariepinus	*Oreochromis niloticus*	*Clarias gariepinus*	*Oreochromis niloticus*	*Clarias gariepinus*	*Oreochromis niloticus*
SEPT	0.02 ± 0.003 [f]	0.03 ± 0.006[e]	0.03 ± 0.012	0.04 ± 0.02	0.12 ± 0.03	0.22 ± 0.11
OCT	0.16 ± 0.01[a]	0.17 ± 0.01[a]	0.17± 0.004[b]	0.02 ± 0.005	0.12 ± 0.01	0.14 ± 0.005

NOV	0.03 ± 0.001^{e}	0.04 ± 0.004^{d}	0.03 ± 0.002	0.03 ± 0.003	0.07 ± 0.10	0.07 ± 0.03
DEC	0.025 ± 0.01^{e}	0.03 ± 0.006^{e}	0.02 ± 0.003	0.02 ± 0.009	0.02 ± 0.001	0.022 ± 0.01
JAN	0.03 ± 0.006^{e}	0.03 ± 0.004^{e}	0.014 ± 0.001	0.01 ± 0.002	0.02 ± 0.001	0.02 ± 0.001
FEB	0.03 ± 0.013^{e}	$0.03 \pm 0.\ 01^{e}$	0.014 ± 0.002	0.015 ± 0.001	0.016 ± 0.003	0.12 ± 0.02
MAR	0.06 ± 0.007^{c}	0.04 ± 0.02^{d}	0.18 ± 0.01^{a}	0.17 ± 0.005	0.11 ± 0.01	0.09 ± 0.010
APRIL	0.05 ± 0.002^{d}	0.06 ± 0.002^{c}	0.03 ± 0.001	0.03 ± 0.005	0.08 ± 0.015	0.046 ± 0.01
MAY	0.05 ± 0.002^{d}	0.06 ± 0.001^{c}	0.02 ± 0.003	0.022 ± 0.002	0.04 ± 0.01	0.05 ± 0.01
JUNE	0.07 ± 0.003^{b}	0.07 ± 0.004^{b}	0.05 ± 0.011	0.06 ± 0.00	0.08 ± 0.006	0.08 ± 0.01

N.B: Value(s) with the same superscripts across a row are not significantly different at $P \leq 0.05$

Discussion

Variation in physico-chemical parameters of a water body with different location have been reported by several studies. In the present study, the range of surface water temperature in the four stations was below the limits of the Federal standard (<35°C) and also within the values reported by some other researchers: 26.5-33°C by Oluyemi *et al.* (2010), 26.4-31°C by Rim-Rukeh (2013), 24.2-26.2°C by Nwoko *et al.* (2015) and 25.6-27.8 ^{o}C by Andong *et al.* (2019). The slight variation in water surface temperature can be attributed to the changes in the atmospheric temperature which on the other hand influence other water quality indices as stressed by Dirican (2015). This study reported that, the temperature values decrease from September 2018 to November 2018 across all the stations except in station 3 where the temperature increases in November. The temperature values continue to decrease from December 2018 up to March 2019; where the temperature values increased. This could be associated with the changing atmospheric weather conditions of the area as the wet season usually ceases in September and dry season associated with harmattan starts November to February and in some instances to early March. This finding is in agreement with that of Abdullahi.et al. (2018) who reported variation in season as the major reason behind variation in water temperature of Kanye Dam reservoir in Kano state. The pattern of temperature changes from rainy season to dry season could be attributed to low solar radiation, low evaporation and rainfall. Similar finding was reported in the work of Ezra and Abdulhameed (1997) the high values of temperature recorded could be associated with high solar radiation, high evaporation and low rainfall, while the relatively low mean values of temperature recorded at site „B" could be due to low values of these parameters. The fluctuation in the surface water temperatures during the period of study reflected that, the water body under study is of tropical region. It increased from March to April and decreased gradually through May to August as reported by Abdullahi et al. (2018). The slight variation in pH values observed in the present study corroborates with the finding of Ahmad *et al.* (2018) who reported slight variation in pH between months at Kafinchiri reservoir Kano with values between 7.60 to 8.52. Similar finding was reported by the work of Samuel and Alabi (2022) who reported that, the pH of Shiroro Lake, Minna, Niger State was all basic throughout the period of the study across all the stations. The pH value recorded fall within the acceptable limits of 5.9-9.3 for fresh water bodies according to FAO (2004) standards. More so, Agada et al. (2024) reported the pH values of surface water in Kaduna metropolis to be all basic. However, the finding of this study contradicts that of Maishanu and Muhammad (2024) who reported the pH of surface water of Shella Fadama, Usmanu Danfodiyo University Sokoto, to be slight acidity to basic. This disparity might probably be due to the nature of pollutants which are mainly agricultural wastes such as fertilizers and pesticides.

The values of DO reported by the present study agrees with the findings of Indabawa and Abdullahi

(2004) who reported a DO of 0.51-9.25mg/L but contradicts the values (5.6-6.2 mg/l) reported by Gebresilasie *et al.* (2021) in hand-dug well water samples of Kafta HumeraWoreda, Tigray, Ethiopia. This difference can probably be attributed to the rate of pollution between the two compared water samples and the number of organisms utilizing Oxygen in the two areas.. The samples from this study area were more polluted as such the value of its DO is less compared to that of the Ethiopian well. In the present investigation, dissolved oxygen ranged between 2.20-4.60 mg/L, which is quite satisfactory to support aquatic life perhaps due to good aeration rate and photosynthetic activity as reported by Ibrahim and Nafiu (2017) and Jaji *et al.* (2007).

High level of DO noticed is an indication of aquatic life sustenance as WHO stipulates 5 mg/L as adequate limit for aquatic organisms whereas concentration below this level could adversely affect aquatic life. Even, concentration below 2 mg/L may lead to death for most fishes as suggested Chapman (1997). Elevated levels of DO recorded could be attributed to precipitation of nutrients associated with organic matters brought in by domestic and fertilizer application as suggested by Yasmeen *et al.* (2010). High concentration in DO observed could be traced to heavy application of chemicals as dissolved oxygen is a measure of the degree of pollution by organic matters. WHO (1985) sets 9.20 mg/L as maximum limit for DO in wastewater indicating this site is less in dissolved oxygen with International standards limit. Yasmeen *et al.* (2010) reported 6.60 mg/L and Akan *et al.* (2008) reported 6.22 – 8.43 mg/L as Do in wastewater which were similar to results obtained in this study.

The distribution of dissolved oxygen in water body has been reported to be governed by a balance between input from the atmosphere, rainfall, photosynthesis and losses by the chemical and biotic oxidations (Arimoro *et al.*, 2000). The values of DO reported by this study were less than 10 mg/L which indicate optimal conditions for the growth of aquatic fauna as reported by Bhatnagar and Singh (2010) and Ekubo and Abowei (2011). High DO concentrations may indicate excessive algal proliferation (Reynolds, 2006). Here, DO recorded at the three stations was not beyond the Federal limit (7.5 mg/L) and the values were considered around values recommended for fish to survive (3-5 mg/L) as reported by Gorde and Jadha (2013).

The mean BOD reported by this study is below the limits of the WHO (2011) standard of 8.5 mg/L. The high levels of BOD observed during sampling periods could be attributed to the use of chemicals such as mechanic paints sprays, herbicides, pesticides and Nitrogen fertilizer which were organic or inorganic that are oxygen demand in nature as stressed by Akan *et al.* (2008) as BOD is known as a measure of the oxygen required by microorganisms while breaking down organic matters. WHO (2018) recommends 50 mg/L as maximum allowable limit for BOD in wastewater before it could be discharged into the stream indicating wastewaters from these sampling sites are not polluted with BOD. Similarly Akubugwo *et al.* (2012) reported 2.48 – 20.74 mg/L and Yasmeen *et al.* (2010) reported 362 mg/L as BOD in wastewater which were higher than concentration obtained in this study.

Heavy metals are believed to be potent toxic substances due to their slow degradation rate and long half-life period (Prajapati *et al.*, 2012). The results from the present study revealed that fish exhibited wide range of variations in inter specific metal concentration in all organs. Several studies indicated high metal concentration to feeding habitat of the fish. Khalid (2004) argued that Sirivutas being an herbivore thus bioa-ccumulate higher metal concentration in their flesh than the carnivore Sargus. This suggestion is in an agreement with the current study as *Oreochromis niloticus* (herbivore) recorded higher concentration than *C. gariepinus*. However, the heavy metals level in water and their bioaccumulation in the tissues and organs of fish species in the study area differed significantly. This finding agrees with that of Abalaka (2015) who reported similar finding between Tiga dam reservoir and the tissues of *Auchenoglanis occidentalis*. The accumulation of these heavy metals differ with sampling sites and months and fish tissues and organs. These variations found within even same species depends on many factors such as age of the fish migratory ability of fish, differential exposure and health conditions (ElMoselhy *et al.*, 2014; Ekweozor *et al.*, 2017). The highest concentration of Cd in the fish liver was found to be 0.18 mg/kg which is less than the value reported by Moses (2018) in catfish liver from Bakolori dam of

Zamfara State. Cadmium is one of the most toxic elements with reported carcinogenic effects in humans. High concentrations of Cd have been found to lead to chronic kidney dysfunction. Cd can bioaccumulate at all levels of aquatic and terrestrial food chains (Moses, 2018). Similarly, 0.16 to 0.54 μg/g of Cd was obtained by Akan *et al.* (2012) when they analyzed the liver of a fish sample in Vinikiland of Adamawa state. More so, a value of 0.09 mg/kg was reported by Ibrahim *et al.* (2018) in the liver of catfish species sampled from Lake Njuwa of Adamawa state. Another study by Faye-ofori *et al.* (2015) on the level of Cd in the liver of catfish species from Okilo Creek of Rivers state, Nigeria reported a value of 0.001mg/kg which is lower than the ones reported by this study. A higher value of Cadmium bioaccumulation was reported by Brightone (2015) in a tilapia sample from a river in Libya to be 7.41±1.45 mg/kg. The concentrations of Cd in fish liver, muscles and gills analyzed in this study were above the 0.01 mg/kg maximum permissible level in fish as described by WHO(2004) standard. This finding is in agreement with that of Christof *et al.* (2019) who reported that, Cd even if not detected in gills can be traced in the liver at lower concentration. The level of Cd in the liver of *Labeo capensis* reported by Lynch (2016) was 1.03 ± 0.61 mg/kg which is higher than the values reported in *O. niloticus* and *C. gariepinus* tissues and organs by the present study. The high levels of Cd in the study areas might be attributed to contamination of the water with heavy metals through agricultural and domestic run-offs.

Chromium act as regulator of metabolisms of glucose and cholesterol but in higher concentration chromium is proof to be toxic. The values of Cr obtained by the present study agrees with that of Ahmad *et al.* (2018) in tissues of Tilapia zilli obtained from Kafinchiri reservoir, Kano state. The Chromium level recorded in this study is lower than 29.8–31.6ppm in T. zilli and 28.1 – 32.2ppm in *C. gariepinus* recorded from River Benue by Ishaq *et al.* (2011). Cr might have come from mechanic paint sprays, car-wash detergents, lubricating oils and domestic chemicals by the inhabitants along the reservoir tributaries as reported by Yilmaz (2009).

The concentration of Cr was generally high in both livers and gills of fishes from the four sampling sites. This could be as a result of run-offs around the sampling areas where Chromium rich fertilizers are applied during agricultural activities. A similar higher concentration of chromium was reported by (Moses, 2018) in Abare River of Zamfara state to be 1.313 mg/kg. Similarly, Ibrahim *et al.* (2018) reported 0.77 mg/kg in gills of catfish sampled from Njuwa lake of Adamawa state. The level of Cr reported by this study is higher than that reported by Orosun *et al.* (2016) in catfish sampled from Kiru dam and River Gongola of Adamawa state.

Lead is non-essential element that constitutes body burden and a great threat to life if present in substantial quantity. It is toxic even at minimal concentrations and has no known function in biochemical processes (Moses, 2018). The standard level of Pb was reported to be 0.5 mg/kg dry weight (FAO, 2007). Similar to Cd, lead concentration in this work was also found to be lower than the recommended limit. The values of Pb obtained by this study are in line with that of the work of Faye-ofori *et al.* (2015) who reported 0.039±0.009 mg/kg.

The mean concentrations of heavy metals in the fish organs reported by the present study were less than the values reported from from Ajiwa dam by Musa (2021) from liver and gills. The concentrations of Cd, Cr and Pb reported by the this study are above the WHO and FEPA prescribed limits for food fish. This corroborates with the work of Nwani *et al.* (2009) who reported similar finding in fresh water fish species of Anambra river South-east Nigeria.

Conclusion

It was concluded that, there is variation in physico-chemical parameters of Wasai reservoir with location and months. The concentrations of Lead, Cadmium and Chromium in water (Pb=0.008-0.05mg/kg, Cd=0.003-0.045 mg/kg, Cr= 0.02-0.41 mg/kg) and fish muscles of *Clarias gariepinus* (Pb=0.02-0.12 mg/kg in gills, 0.02-0.16 mg/kg in liver, 0.01-0.07 mg/kg in muscles: Cd= 0.02-0.35 mg/kg in gills, 0.014-0.18 mg/kg in liver, 0.009-0.022 mg/kg in muscles; Cr=0.02-0.26 mg/kg in gills, 0.01-0.12 mg/kg in liver and 0.03-0.16 mg/kg in muscles)and *Oreochromis niloticus*(Pb= 0.07-0.12 mg/kg in gills; 0.03-0.17 mg/kg in liver, 0.02-0.08 mg/kg in muscles; Cd= 0.02-0.35 mg/kg in gills, 0.01-0.17 mg/kg in liver, 0.019-0.02 mg/kg in muscles; Cr= 0.02-0.26 mg/kg in gills, 0.02-0.14 mg/kg in liver and 0.04-0.32 mg/kg in muscles).

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References

Abalaka, S. E., Enem, S. I., Idoko, I. S., Sani, N. A., Tenuche, O.Z., Ejeh, S. A. and Sambo, W. K. (2020). Heavy metals bioaccumulation and health risks with associated histopathological changes in *Clarias gariepinus* from the Kado Fish Market, Abuja, Nigeria. *Journal of Health & Pollution*, 10: 1-12.

Abdullahi,. Y., Indabawa, I.I, and Sindama,. A (2018). Physico-Chemical Attributes of Kanye Dam Reservoir For Algal Growth, In Kano North-Western Nigeria. *Bima Journal of Science and Technology Vol 2(1)*

Agada, J.U., Ojochegbe, A.F., Bilikisu,S,. and Bright, A.R. (2024). Physico-chemical and heavy metal analysis of ground and surface water obtained from some selected areas in Kaduna metropolis. *International Journal of Science and Research Archive*, 13(02), 981–988

Ahmed Q, Benzer S, and Ali QM.(2018). Heavy metal concentration in Largehead Hairtail (Trichiurus lepturus Linneaus, 1758) and Savalai Hairtail (Lepturacanthus savala (Cuvier, 1829)) obtained from Karachi Fish Harbour, Pakistan. Bull Environ Contam Toxicol 101 (4): 467-472. DOI: 10.1007/s00128-018-2418-1

Akan, J.C. Abdulrahman, F.I. Dimari, G.A. and Ogugbuaja, V.O. (2008). Physicochemical determination of pollutants in wastewater and vegetable samples along Jakara wastewater channel in Kano metropolis, Kano state, Nigeria. *European Journal of Scientific Research*, 23: 122-133.

Akubugwo, E.I. Ude, V.C. Uhuegbu, F.O. and Ugbogu, O. (2012). Physicochemical properties and heavy metals content of selected water sourced in Ishiagu, Ebonyi state, Nigeria. *Journal of Biodiversity and Environmental Sciences*, 2: 21-27.

Amin, M.M. (1992). An Assessment of the seasonal quality of Jakara Reservoir Wastes for Drinking and Irrigation. M.Sc. Thesis, Bayero University, Kano. p 123.

Andong, F. A., Melefa, T., Hinmikaiye, F., and Olufemi, O. (2019). Assessment of the physical and chemical properties of Lake Oguta (Nigeria) about the water quality standard established by the Nigerian Federal Ministry of Water Resources. *Advances in Oceanography and Limnology*, 10: 74-80 https://doi.org/10.4081/aiol.2019.852

APHA (2005).Manual of Standard Methods for Examination f o r Water and Waste water. 14th Edition. Washington DC. pp. 121-132

Basheeru. K. A, · Adekola,. F.A., Abdus‑ Salam,N and Okoro.,H.K (2022). Spatio‑ temporal monitoring of potentially toxic elements in Lagos harbour water and its health risk implications. *A Springer Nature Journal*. 4:298 https://doi.org/10.1007/s42452-022-05186-7

Dasharathy S, Arjunan S, Maliyur Basavaraju A, Murugasen V, Ramachandran S, and Keshav R, (2022). Mutagenic, carcinogenic, and teratogenic effect of heavy metals. *Evid Based Complement Alternat Med*. :8011953. doi: 10.1155/2022/8011953.

Dirican, S. (2018). *Assessment of Water Quality Using Physico-chemical Parameters of Camligoze Dam Lake in Sivas, Turkey*. *January*. https://doi.org/10.3923/ecologia.2015.1.7

Dike, N.I., Ezealor, A.U., and Oniye, S.J., & Ajibola, V.O(2013). Pollution studies of River Jakara in Kano, Nigeria,using selected physico-chemical parameters. *internationalJournal of Research in Environmental Science and Technology, 3(4), 122-129*.

FAO (2007). *Joint FAO WHO food standards programme Codex Committee on contaminants in foods. Beijing, China.*

Faye-ofori, G.B., Okorinama, A., Wokoma, F. and Friday, U. (2015). Heavy metal concentration in some organs of *Clarias gariepinus* (African catfish) from Okilo creek, Rivers state, Nigeria. *Annals of Biological Research*, 6(11): 68-71.

Ibrahim, S. and Nafi'u, S. A. (2017). *In vitro* effects of tannery effluents on seed germination and growth performance of Maize (*Zea mays*), Spinach (*Spinacia caudatus*) and Lettuce (*Lactuca sativa*). *International Journal of Applied Biological Research*, 8(1): 160 – 173

Imam. T.S. (2012). Assessment of Heavy Metals Concentrations in the surface water of Bompai -Jakara drainage basin, Kano state, Northern Nigeria..*Bayero Journal of Pure and Applied Science*, 5(1), 103–108

Ishaq, S.E; Rufus, S. A and Annune, P.A. (2011). Bioaccumulation of Heavy Metals in Fish (*Tilapia zilli* and *Clarias gariepinus*) organs from river Benue, North-Central Nigeria. *Pakistan Journal of Analytical Environmental Chemistry* 12(1&2): 25-31.

Jamila, T.S. and Sule, S.Y. (2020). Assessments of ,quality index of river Getsi irrigation water in Kano Metropolis, Nigeria. *International Research Journal of Pure and Applied Chemistry,* 21(3): 8–16.

Kortei, N. K, Heymann, M.E., Essuman, E. K., Kpodo, F. M., Lokpo, A. P. T., Boadi, N. O., and Amonor, M. A. (2020) Health risk assessment and levels of toxic metals on fishes (oreochronis noliticus and Claria anguillaris) from Ankobrah and Pra basins: impact of Illegal minning activities on food safety. Toxicol Rep 7:360–369. https:// doi. org/ 10. 1016/j. toxrep. 2020. 011

Leelapongwattana, S, Bordeerat, N. K. (2020). Induction of genotoxicity and mutagenic potential of heavy metals in Thai occupational workers. *Mutat Res Genet Toxicol Environ Mutagen.*; 856-857:503231. doi: 10.1016/j. mrgentox..503231.

Meijide, F., Da Cuña, R., Prieto, J., Dorelle, L., Babay, P. and Lo Nostro, F. (2018). Effects of waterborne exposure to the antidepressant fluoxetine on swimming, shoaling and anxiety behaviours of the mosquitofish *Gambusia holbrooki*. *Ecotoxicology and Environmental Safety*, *163*, 646–655.

Moses, S., Agbaji, E., Ajibola, V. and Gimba, A. (2018). Heavy metals content in water and crops in golding mining vicinity on major dams in Zamfara State, Nigeria.

Musa, M.S. (2021). Determination of selected heavy metals in gills and livers of some catfish (*Clarias gariepinus*) from two dam reservoirs in Katsina State, Nigeria. *Dutse Journal of Pure and Applied Sciences*, Vol. 7, No. 1.

Nwani, C.D., Nwoye, V.C., Afiukwa, J.N. and Eyo, J.E. (2009). Assessment of heavy metals kconcentrations in the tissues (gills and muscles) of six commercially important fresh water fish species of Anambra River South-East, Nigeria*Asian Journal of Microbiology, Biotechnology and Environmental Sciences*, 11(1): 7–12.

Nwoko, C. I. A, Ukiwe, L N, Egereonu, U. U. and Ukachukwu, S. N. (2015) Assessment of seasonal physico-chemical parameters of Oguta Lake, *Nigeria. J. Adv. Chem.* 11:3759-3764.

Oluyemi, E.A., Adekunle, A. S., Adenuga, A. A., and Makinde. W. O. (2010) .Physico-chemical properties and heavy metal content of water sources in Ife North Local Government Area of Osun State, *Nigeria African Journal Environmental. Science Technol*ogy 4:691-697.

Prajapati, S. K., Meravi, N. and Singh, S. (2012). Phytoremediation of Chromium and Cobalt using *Pistia stratiotes. A sustainable Approach,* 2(2): 136–138.

Ramazan, S., Suleyman, A. and Fatma, D. (2011). Acute effects of Copper and lead on Some Blood Parameters on Coruh trout (Salmo coruhensis). *African Journal of Biotechnology, 10 (16): 3204 - 3209.*

Schmeller, D. S., Loyau, A., Bao, K., Brack, W., Chatzinotas, A., De Vleeschouwer, F., et al. (2018). People, pollution and pathogens – Global change impacts in mountain freshwater ecosystems. *Science of the Total Environment,* 756–763.

Singh, D., Yadav, B,. and Choudhary, S (2024. Heavy Metals in the Environment and their Toxicological Consequences on Animal Health. *Research Journal of Life Sciences,Bioinformatics,Pharmaceuticals and Chemical Sciences* 10(2) 51 DOI: 10.26479/2024.1002.02

Tahir, U., Zameer,. M, Ali,. Q, Rafique, A., Ali, S. M., and Arif, M.U. (2023),. Toxicity assessment of heavy metal (Pb) and its bioremediation by potential bacterial isolates. *Environ Monit Assess.* ;195(9):1047. doi: 10.1007/s10661-023- 11632-9

WHO (1985). World Health Organization. Toxicological evaluation of certain food additives and contaminants, Cambridge University press, Cambridge, pp. 163-219

Yahaya, T, Aisha,. N.L, Kalgo, A. S, Muhammad, N., Abubakar, M.J. and Faruk, U. M (2024). Contamination and risk assessment of heavy metals in water and fish obtained in Bunza River in Kebbi State, Nigeria. *Environmental Health Engineering and Management Journal* , 11(2), 191-199

Yasmeen K, Versiani M, Arain R, Haque Q, Khan N, Ali S, and Langha A (2010). Enhanced Metal Levels in Vegetables and Farm Soil Irrigated with Industrial Wastewater. *Journal Applied Science Environmental Management* 14:95 - 99.

Yilmaz, F. (2009). The comparison of heavy metal contaminations (Cd, Cu, Mn, Pb and Zn) in tissues of three economically important fish (*Anguillaanguilla*, *Mugilcephalus* and *Oreochromis niloticus*) inhabiting Koycegiz Lake Mugla (Turkey). *Turkish Journal of Science and Technology*, 4(1): 7-15.

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