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CLIMATE VULNERABILITY OF A NIGERIAN TROPICAL DAM: BIOASSESSMENT OF WATER QUALITY USING MACROINVERTEBRATES IN MICHIKA, ADAMAWA STATE

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ABSTRACT

Rising environmental pollution from anthropogenic activities poses significant threats to aquatic ecosystems in Nigeria. Heavy metals persist in water and sediments, bioaccumulate, and enter food chains, while benthic macroinvertebrates serve as effective bioindicators for assessing long-term water quality. This study evaluated the climate vulnerability of the Michika mini-dam in Adamawa State by analyzing physicochemical parameters, heavy metal concentrations, and macroinvertebrate community structure. Water and sediment samples were collected biweekly over six months from three stations. Physicochemical parameters were measured using standard methods, and heavy metals (Fe, Zn, Cd, Pb, Cr, Mn, Cu) were analyzed via Atomic Absorption Spectrophotometry. Benthic macroinvertebrates were sampled using a Van Veen grab, preserved in formalin, and identified to species level. Results showed mean dissolved oxygen (DO) levels (5.51-6.31 mg/L) below FMEnv guidelines, while biochemical oxygen demand (BOD_5) levels (2.17-3.27 mg/L) exceeded acceptable limits, indicating organic pollution. Heavy metals in water were detected at levels such as Cd (0.01–0.04 mg/L), Pb (0.02–0.06 mg/L), and Fe (0.68-1.53 mg/L), particularly at Station 3, which was the most contaminated. Sediments contained higher concentrations of metals. A total of 462 macroinvertebrate individuals across 17 taxa were identified, with Diptera (Chironomidae) being the most abundant. Despite the metal contamination, biotic indices rated water quality as good to excellent, highlighting the dam's moderate pollution stress and the importance of integrated bioassessment for tropical dam management.

Keywords: Heavy Metals, Water Quality, Sediment Contamination, Benthic Macroinvertebrate Luhu Dam, Pollution Assessment, Adamawa State

INTRODUCTION

Rising levels of environmental pollution from toxic substances are increasingly concerning in Nigeria and worldwide (Fabian et al., 2022). Contaminants are regularly introduced into aquatic ecosystems due to intensified industrial activities, population growth, oil extraction, and agricultural runoff (Lima et al., 2008). Heavy metals are notable pollutants due to their harmful effects, persistence, and ability to accumulate in organisms, causing biomagnification in the food chain (Ozturk et al., 2006). Although typically found in low concentrations in aquatic systems, human activities have elevated their levels, particularly in lakes (Ntakirutimana et al., 2013). Heavy metals can enter water bodies through natural processes like rock weathering and soil erosion, as well as from human sources, including agricultural practices and waste (Abasiryu et al., 2024). Once released, they spread between water and suspended sediments.

Heavy metals do not naturally decompose and persist in aquatic environments, adhering to sediment and accumulating in lakes and rivers. These sediments are crucial for elemental cycling and can act as reservoirs for pollutants like heavy metals and pesticides, often at concentrations higher than in the water itself (Milenkovic et al., 2005). They interact with organic matter and minerals, forming harmful compounds. Under varying conditions, heavy metals may leach back into the water, indicating pollution levels (Praveena et al., 2010). Contaminated sediments pose risks to benthic organisms, which can suffer from toxic exposure and impact food availability for larger animals like fish (Abida et al., 2009).

Benthic macroinvertebrates are organisms larger than 1mm that inhabit the substrates of aquatic environments, including lakes, rivers, and streams. These bottom-dwelling species are often used in biomonitoring due to their presence in sediments, rocks, and aquatic plants (Louis et al., 2017; Sengupta and Dalwani, 2008). They are non-mobile and have a lifespan that allows for the detection of both immediate and long-term environmental changes. This makes them effective indicators of water quality, as they can reveal the impacts of various disturbances and pollutant concentrations. Indices based on macroinvertebrate assemblages have proven to be valuable measures of river health (Ogbeibu and Oribhabor, 2002; Omoigberale and Ogbeibu, 2010).

Benthic macroinvertebrates are primarily the immature stages of flying insects such as mayflies, stoneflies, caddisflies, and midge flies. They include small organisms like mites and planarians that live their entire lives in streams, as well as freshwater snails that switch between aquatic and damp terrestrial habitats. These organisms can be classified as infauna, which burrow into sediment, or epifauna, which live on the surface.

Benthic macroinvertebrates are important indicators of water quality and play a crucial role in aquatic food chains by recycling nutrients. They consume debris at the bottom of water bodies, providing food for fish and shellfish. The objectives of this study are to assess the physicochemical properties of the Dam, evaluate the heavy metals present, and determine the composition, diversity, and abundance of macrobenthic invertebrates.

MATERIALS AND METHODS

Area of the Study

The study site is the Michika mini dam, which is located in Michika one (1), Michika local government area of Adamawa State, as shown in Figure 1. The dam is located exactly at latitude 10.609^0 N and longitude 13.385^0 E. The Michika dam is man-made for the purpose of aquaculture, especially for recharging the ponds. It covers an estimated area of about

43,200 square meters (4.2 hectares) with an approximate depth of about 6 meters, with its drainage basin from the mountains of Wambrimi and the adjacent farm lands (Adebayo and Tukur, 1999).

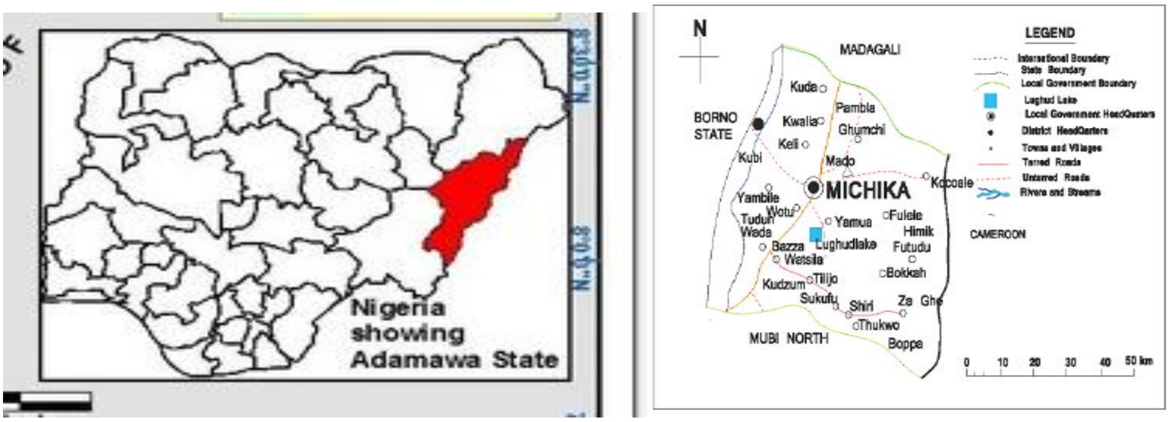

Figure 1: Map of Michika Showing the Study Area

Sampling

Three sampling stations were chosen based on the objective of the study. Samples were collected fortnightly for a period of six months between the hours of 8 am and 11 am. Sampling usually began in stations 1, 2, and 3 in that order. Sediment samples were collected from the study area using a Van Veen grab of 0.6 m2, which was lowered into the bottom of the reservoir with the aid of strong ropes attached to it, on the top of a canoe. On board, the grab was opened above a plastic bucket, and the sample was gently removed. The surface characteristics of the samples would be examined before sieving (0.5mm mesh size), then fixed in a labeled plastic container containing 10% formalin solution (Davide and Marco, 2010). The samples were transported to the laboratory of the Department of Fisheries, Adamawa State University, Mubi, for sorting

Measurement of Variables

Air and Water temperature (˚C). This was carried out in situ using a mercury-in-glass thermometer. This was done by holding the thermometer in the air for 5 minutes in order to obtain stable readings for air temperature. Water temperature was determined by immersing the thermometer in the water, and stable readings were recorded after being held for 5 minutes.

Dissolved oxygen, Hydrogen Ion Concentration (pH), Total Dissolved Solids (TDS) (Mg/L), Electric conductivity, and chloride (Mg/L) were determined using the Hech HQ2200 multi-meter. The probe was dipped into the water samples until a stable reading was obtained and recorded. Biological Oxygen Demand (BOD_5) (Mg/L) Water samples for BOD_5 were collected in amber-coloured bottles by immersing the bottle in the water and stopping it below the water surface. The bottles were completely covered in black polythene bags to prevent light penetration. The samples were incubated at 20 °C for 5 days in the laboratory. Using the procedure for dissolved oxygen, the sample was analyzed, and the reading was taken. BOD_5 was extrapolated from the equation:

$BOD_5 = DO_1 - DO_5$.

Where BOD_5 = Biological oxygen demand at day five

DO_5 = dissolved oxygen at day five

DO_1 = dissolved oxygen at day one

Sera Aqua test kids was used for the determination of Nitrite (NO_2), Nitrate (NO_3), Phosphate (PO_4) and Calcium (Ca). The manufacturer's user guide was followed

The following heavy metals: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), chromium (Cr), cadmium (Cd), and lead (Pb) were analyzed using the Atomic Absorption Spectrophotometer (AAS) Solar 969 Unicam Series model. Each metal has a hollow cathode lamp for its determination. The instrument was set up at wavelengths specific to each element to be analyzed. Distilled de-ionized water aspiration between each reading was conducted. Readings of the absorbance were obtained by observing the steady galvanometer reading in 1-2 minutes. Analysis for each sample was carried out in triplicate to get representative results. The concentration of the metals was calculated using the standard calibration plot (Beauchemin and Berman, 1989).

Identification of benthic macroinvertebrates

The preserved benthic macroinvertebrates were identified in the laboratory following the keys provided by Macan (1959), Quigley (1977), Gerber and Gabriel (2002) and Voshell (2002).

Data Analysis

The values of data obtained were subjected to analysis of variance (ANOVA), mean, and standard deviation. Biological indices such as Shannon and Weiner index (H1); Margalef's index (d); Simpson's diversity index (1-D), and Pielou's Evenness (J') were used to analyse the data.

Shannon- Weiner diversity index (H^1) = $-\sum[(ni/N)\times\ln(ni/N)]$.

Margalef value is the measure of species richness. It is expressed as $d= S-1/\ln N$.

Pielou's index: Measures how evenly the species are distributed in a sample community. It is expressed as: $J = H^1/$ Hmax.

Simpson dominance index (D) = $\sum(n/N)^2$.

RESULTS AND DISCUSSION

Table 1: Physical and Chemical Parameters of Surface Water Of Michika Dam

Parameters	Station 1	Station 2	Station 3		Standard FMEnv. Permissible Limit	WHO Permissible Limit
	$\bar{X} \pm S.E$ (Min-Max)	$\bar{X} \pm S.E$ (Min-Max)	$\bar{X} \pm S.E$ (Min-Max)	p-Value		
D O (mg/l)	5.51 ± 0.159 (5.00-6.20)	6.31 ± 0.216 (5.50-7.50)	**5.59±0.271** **(4.40-7.10)**	**$P > 0.05$**	7.5	-
B O D_5 (mg/l)	2.66 ± 0.221^{AB} (1.60-3.80)	2.17 ± 0.256^{A} (1.40-3.80)	3.27 ± 0.268^{B} (1.90-4.40)	$P < 0.05$	0	-
pH	7.73 ± 0.088 (7.22-8.30)	7.45 ± 0.111 (7.81-8.10)	7.50 ± 0.119 (7.0-8.33)	$P > 0.05$	6.5 - 8.5	6.5 – 8.5
Conductivity (µS/cm)	93.7 ± 12.86 (50.10-161.30)	85.49 ± 12.93 (40.70-155.50)	109.86 ± 18.82 (39.30-219.80)	$P > 0.05$	-	-
TSS (mg/l)	6.37 ± 0.729 (2.40-9.40)	5.53 ± 1.292 (1.20-13.20)	9.72 ± 1.449 (4.60-17.80)	$P > 0.05$	0	500-1500
TDS (mg/l)	46.3 ± 6.261 (24.20-80.60)	42.22 ± 6.229 (21.40-77.50)	54.6 ± 9.096 (19.50-108.40)	$P > 0.05$	500	500
Air temp. (˚C)	28.6 ± 0.729^{AB} (24.00-32.00)	28.8 ± 0.465^{AB} (26.00-30.00)	28.2 ± 0.760^{A} (24.00-30.00)	$P > 0.05$	-	-
H_2O temp (˚C)	26.0 ± 0.577^{A} (22.00-28.00)	27.1 ± 0.539^{AB} (24.00-29.00)	27.4 ± 0.412^{AB} (25.00-29.00)	$P < 0.05$	20-33	-

NOTE: $p<0.01$ – Highly Significant Difference; $p<0.05$ – Significant Difference; $p>0.05$ – No Significant Difference; Similar Superscripts Row-wise – No Significant Difference using Duncan Multiple Range Tests (DMRT)
Where X = Mean, SE = Standard Error, Min. = Minimum value, and Max. = Maximum value

Table 2: Nutrient Parameters of the Surface Water of Michika Dam

Parameters	Station 1	Station 1	Station 1		Standard FMEnv. Permissible Limit	WHO Permissible Limit
	$\bar{X} \pm S.E$ (Min-Max	$\bar{X} \pm S.E$ (Min-Max	$\bar{X} \pm S.E$ (Min-Max)	p-Value		
Chloride (mg/l)	29.96 ± 3.39 (16.20-46.40)	25.79 ± 2.249 (17.70-35.90)	39.47 ± 6.602 (18.60-78.40)	$P > 0.05$	250	200 – 600
Nitrate (mg/l)	2.36 ± 0.405 (0.68-5.13)	1.90 ± 0.352 (0.90-3.91)	3.32 ± 0.701 (0.84-7.02)	$P > 0.05$	10	45
Phosphate (mg/l)	1.17 ± 0.109 (0.57-1.74)	0.91 ± 0.133 (0.57-1.74)	1.79 ± 0.406 (0.35-4.27)	$P > 0.05$	3	-
Calcium (mg/l)	1.89 ± 0.281 (0.94-3.88)	1.73 ± 0.119 (1.22-2.22)	2.65 ± 0.408 (1.19-4.25)	$P > 0.05$	-	-
Magnesium (mg/l)	0.60 ± 0.055 (0.33-0.85)	0.53 ± 0.048 (0.35-0.80)	0.79 ± 0.105 (0.37-1.18)	$P > 0.05$	-	0.1
Nitrite (mg/l)	0.031 ± 0.006^{AB} (0.01-0.07)	0.018 ± 0.003^{A} (0.01-0.03)	0.07 ± 0.0136^{C} (0.01-0.12)	$P < 0.01$	1	10

NOTE: $p<0.01$ – Highly Significant Difference; $p<0.05$ – Significant Difference; $p>0.05$ – No Significant Difference; Similar Superscripts Row-wise – No Significant Difference using Duncan Multiple Range Tests (DMRT)
Where X = Mean, SE = Standard Error, Min. = Minimum value, and Max. = Maximum

The basis of water quality monitoring is to obtain information that will be useful in the management of water resources in the country. It is useful in management, control, and investigation of pollution cases, classification of water resources, and collection of baseline data, water quality surveillance, and forecasting water quality. Water quality assessment is frequently based on the monitoring of the physical, chemical, and biological parameters due to natural occurrences and anthropogenic activities, to develop strategies for the protection of fresh water resources from pollution (Ekiye *et al.*, 2010).

Physical and Chemical Characteristics

The physical and chemical characteristics of the studied area showed variations. In this study, Air temperature showed distinct variations across the three stations, with the mean monthly values higher in the dry season (November to January) than in the rainy season months (August to October). This condition is distinctive in tropical weather.

Surface water temperatures were higher in the dry season than in the rainy season, likely due to increased chemical reactions and biological activity, which are influenced by temperature (Apoorva et al., 2025). There was minimal variation in water temperature across stations, following the air temperature pattern typical of Nigerian waters. Influencing factors include turbidity, vegetation cover, runoff, and heat exchange with air (Edokpayi et al., 2010; Ogbeibu et al., 2012). Water temperature significantly differed ($p < 0.05$), with Station 1 recording the lowest mean (26.0°C), while Stations 2 and 3 measured between 27.1-27.4°C, all within the FMEnv recommended range (20-33°C). The slight increases at Stations 2 and 3 may indicate shallower depths or reduced shade. While temperatures are acceptable, variations could impact metabolic rates and species distribution.

Dissolved Oxygen (DO) analysis measures the amount of O_2 in water, crucial for the metabolism of aerobic aquatic organisms (Wetzel, 2023). DO levels in the study ranged from 4.40-7.50 mg/L, with mean values of 5.51-6.31 mg/L, showing no significant differences among stations ($p > 0.05$). All stations had mean DO below the FMEnv limit of 7.5 mg/L, indicating moderate oxygen depletion likely due to organic decay or limited re-aeration. Station 2 had the highest mean DO (6.31 mg/L), suggesting better oxygenation, possibly from wave action or photosynthesis. These results align with Shweta et al. (2013).

The Biochemical Oxygen Demand (BOD5) measures the amount of biodegradable organic material in water. Results, expressed in mg/L, indicate the level of pollution in surface and groundwater. Significant variation was observed, with Station 3 having the highest mean BOD5 (3.27 mg/L), followed by Station 1 (2.66 mg/L) and Station 2 (2.17 mg/L). All values exceed the FMEnv limit of 0 mg/L, indicating organic contamination from sources like domestic runoff and agricultural discharge, with Station 3 being the most affected.

The mean pH ranged from 7.45 to 7.73, within the FMEnv and WHO standards (6.5-8.5), with no significant differences among stations. This slightly alkaline nature is typical for tropical surface waters and poses no immediate concerns for aquatic life or human use. High pH levels can affect disinfection efficacy and may give water a bitter taste. Generally, natural water bodies should maintain a pH between 6.5 and 8.5.

Electrical conductivity (EC) indicates how well an aqueous solution conducts electricity, influenced by ion presence, concentration, mobility, and temperature. In the study, EC values ranged from 39.30 to 219.80 µS/cm, with an average of 85.49-109.86 µS/cm, showing low dissolved ionic content. Natural water's dissolved solids include carbonates, chlorides, sulfates, and minerals, originating from rock and soil weathering.

Total Dissolved Solids (TDS) ranged from 42.22-54.60 mg/L, well below the 500 mg/L limit set by FMEnv and WHO, with no significant differences among stations ($p > 0.05$). This low TDS indicates dilute freshwater, suitable for domestic and agricultural use, posing minimal salinity risk and supporting aquatic habitats. TDS in drinking water can stem from natural sources, sewage, agricultural activities, industrial runoff, and water treatment chemicals. Total Suspended Solids also remained within recommended limits for drinking.

Excess chloride in inland waters is an indicator of pollution, with sources including sodium, potassium, and calcium salts. This study found chloride concentrations ranging from 16.20 to 78.40 mg/L, with mean values between 25.79 and 39.47 mg/L, showing no significant differences among stations ($p > 0.05$). All values were below the FMEnv (250 mg/L) and WHO (200–600 mg/L) limits, indicating low pollution levels. Station 3 had the highest mean (39.47 mg/L) and widest range (18.60-78.40 mg/L), suggesting localized influence but still within safe limits. These findings align with the seasonal patterns observed in conductivity values (Aschalew, 2015).

Nitrate concentration is influenced by nitrifying bacteria and dissolved oxygen levels. Nitrate and phosphate, natural in water, indicate organic pollution (Eneji et al., 2011), originating from plant residue, sewage, and fertilizers. These nutrient levels vary seasonally in African rivers due to surface runoff and flooding (Georgescu et al., 2011). In this study, nitrate levels ranged from 0.68-7.02 mg/L, with means of 1.90-3.32 mg/L, showing no significant spatial differences ($p > 0.05$). All values were below FMEnv (10 mg/L) and WHO (45 mg/L) standards, indicating minimal pollution, which protects against eutrophication and low methaemoglobinemia risk. Station 3 had the highest mean (3.32 mg/L) and maximum (7.02 mg/L), likely due to localized organic matter decomposition or fertilizer runoff, but still at safe levels.

Phosphate is a key nutrient limiting productivity (Ekeh and Sikoki, 2003) and enters water primarily from domestic sewage, detergents, and fertilizers. The decreased phosphate levels, compared to other aquatic systems, may be due to microbial uptake, sediment adsorption, and water currents (Anyanwu, 2012). Research by Omoigberale and Ogbeibu (2007) found phosphate levels in the Osse River ranging from 0.28 mg/L to 3.52 mg/L, while Anyanwu (2012) reported 0.10 mg/L to 1.44 mg/L. Overall, concentrations ranged from 0.35-4.27 mg/L, averaging 0.91-1.79 mg/L, with no significant differences among sampling stations ($p > 0.05$). Although most levels were below the FMEnv limit of 3 mg/L, Station 3 exceeded this with 4.27 mg/L. While average levels are acceptable, the higher value at Station 3 indicates a need for attention, and the lack of significant variation suggests uniform inputs likely from agricultural or domestic sources.

Magnesium is linked with calcium in water, being crucial for chlorophyll growth and limiting phytoplankton growth. A decrease in magnesium can reduce phytoplankton populations. Calcium levels in natural water vary by rock type, with low concentrations helping to reduce pipe corrosion. Magnesium hardness, especially with sulphate, can have a laxative effect on those unaccustomed to it (Manto, 1999). In this study, Calcium and Magnesium levels adhered to WHO standards (2017). Calcium ranged from 0.94-4.25 mg/L (mean: 1.73-2.65 mg/L), indicating soft water with no significant differences ($p > 0.05$). Low calcium may affect certain aquatic life. Station 3 displayed higher levels, suggesting increased ionic input. Magnesium levels ranged from 0.33-1.18 mg/L (mean: 0.53-0.79 mg/L), with no significant differences ($p > 0.05$), and these low levels are non-toxic and beneficial.

Table 3: Mean Variation of Heavy Metals in the Surface Water of Michika Dam

Parameters	Station 1 $\bar{X} \pm S.E$ (Min-Max)	Station 2 $\bar{X} \pm S.E$ (Min-Max)	Station 3 $\bar{X} \pm S.E$ (Min-Max)	p-Value	Standard FMEnv. Permissible Limit	WHO Permissible Limit
Iron (mg/l)	0.96±0.14 (0.34-1.57)	0.68±0.121 (0.25-1.44)	1.53±0.353 (0.33-3.83)	$P > 0.05$	1	0.3
Zinc (mg/l)	0.34±0.06 (0.1-0.62)	0.20±0.034 (0.09-0.41)	0.51±0.112 (0.13-1.06)	$P > 0.05$	5	5.0
Cadmium (mg/l)	0.02±0.005^{AB} (0.00-0.04)	0.01±0.003^{A} (0.00-0.02)	0.04±0.011^{B} (0.01-0.09)	$P < 0.05$	0.01	0.005
Lead (mg/l)	0.03±0.006 (0.00-0.06)	0.02±0.008 (0.00-0.07)	0.06±0.0167 (0.01-0.17)	$P > 0.05$	0.05	0.01
Chromium (mg/l)	0.027±0.005 (0.01-0.05)	0.020±0.005 (0.00-0.05)	0.04±0.009 (0.01-0.09)	$P > 0.05$	0.05	0.05
Manganese (mg/l)	0.087±0.022^{A} (0.03-0.24)	0.057±0.014^{A} (0.01-0.14)	0.166±0.061^{A} (0.04-0.63)	$P > 0.05$	0.05-0.5	-
Copper (mg/l)	0.04±0.008 (0.01-0.09)	0.027±0.008 (0.01-0.08)	0.07±0.019 (0.02-0.19)	$P > 0.05$	0.1	0.05 – 1.5

NOTE: $p<0.01$ – Highly Significant Difference; $p<0.05$ – Significant Difference; $p>0.05$ – No Significant Difference; Similar Superscripts Row-wise – No Significant Difference using Duncan Multiple Range Tests (DMRT)
Where X = Mean, SE = Standard Error, Min. = Minimum value, and Max. = Maximum val

Table 4: Heavy Metals in Sediments of Michika Dam

Parameters	Station 1 $\bar{X} \pm S.E$(Min-Max)	Station 2 $\bar{X} \pm S.E$(Min-Max)	Station 3 $\bar{X} \pm S.E$(Min-Max)	p-value
Iron (mg/kg)	208.09±19.69 (111.30-286.90)	188.3±26.86 (119.30-392.00)	283.4±37.47 (110.90-444.50)	$P > 0.05$
Copper (mg/kg)	6.29±0.955 (1.22-9.93)	3.99±1.193 (0.86-10.60)	8.69±1.517 (1.91-15.60)	$P > 0.05$
Cadmium (mg/kg)	4.05±0.789^{A} (0.35-8.34)	1.99±0.560^{A} (0.73-5.43)	8.98±2.304^{B} (0.32-18.00)	$P < 0.05$
Zinc (mg/kg)	33.54±2.467^{AB} (23.90-44.80)	26.41±5.435^{A} (8.71-55.4)	48.6±7.103^{B} (16.00-79.60)	$P < 0.05$
Chromium (mg/kg)	4.30±0.615^{A} (0.74-6.58)	2.53±0.821^{A} (0.62-7.59)	8.76±1.705^{B} (1.41-15.50)	$P < 0.01$
Lead (mg/kg)	4.66±0.819 (0.60-9.30)	2.16±0.741 (0.00-6.52)	8.95±2.149 (0.84-19.40)	$P < 0.05$
Manganese (mg/kg)	21.16±1.853 (12.30-30.30)	16.88±3.411 (8.24-37.20)	30.83±4.008 (12.40-49.10)	$P > 0.05$

NOTE: $p<0.01$ – Highly Significant Difference; $p<0.05$ – Significant Difference; $p>0.05$ – No Significant Difference; Similar Superscripts Row-wise – No Significant Difference using Duncan Multiple Range Tests (DMRT)
Where X = Mean, SE = Standard Error, Min. = Minimum value, and Max. = Maximum value.

Five heavy metals showed no significant differences ($P > 0.05$) across the three stations, except for Cadmium (Cd) and Manganese, which were significantly different ($P < 0.01$ and 0.05, respectively). Station 3 had the highest mean concentrations: Fe (1.5289 mg/l), Cu (0.0679 mg/l), Cd (0.0437 mg/l), Zn (0.5100 mg/l), Cr (0.0404 mg/l), Pb (0.0556 mg/l), and Mn (0.1656 mg/l). Station 2 had the lowest for all metals. The water samples showed a seasonal variation in heavy metal concentrations. Station 1 had mean values of Fe > Zn > Mn > Cu > Pb > Cr > Cd, with Cadmium, Lead, and Iron exceeding permissible limits from the Federal Ministry of Environment, while Zinc and Chromium were within limits. Heavy metal concentrations are generally greater during periods when the inflow of water is low, during drought months, because the decrease in water volume decreases dilution effects, and the decrease in suspended sediment concentration decreases the metal scavenging process (Chiarelli *et al.*, 2011).

Results showed that heavy metal values in water are comparatively lower than corresponding values in the sediment, an observation reported by Bashir *et al.* (2013). In the sediment, the highest mean concentration for all heavy metals studied was found at Station 3. Fe (283.4111mg/l), Cu (8.6900mg/l), Cd (8.9800mg/l), Zn (48.5778), Cr (8.7611mg/l), Pb (8.9522mg/l), and Mn (30.8333mg/l). The lowest mean concentration for all the metals was found in Station 2. Fe (188.3444mg/l), Cu (3.9944mg/l), Cd (1.9933mg/l), Zn (26.4122mg/l), Cr (2.5300mg/l), Pb (2.1567mg/l), and Mn (16.8767mg/l).

Sediment samples from Station 1 had the second-highest mean values (Fe > Zn > Mn > Cu > Pb > Cr > Cd). At Station 3, increased levels of Pb, Mn, Zn, and Fe were likely due to runoff from bush burning and agricultural activities. Perera (2017) noted that gasoline and fossil fuel combustion contribute to urban lead levels, which can reach aquatic environments through runoff. Table 3 shows no significant differences for Fe, Cu, and Mn ($P > 0.05$), while Zn, Pb, and Cd varied significantly ($P < 0.05$), and Cr displayed a very significant difference ($P < 0.01$). Lead and cadmium pose health risks, including renal failure from contaminated water, with exposure occurring via inhalation of dust or consumption of contaminated fish.

Older homes may contain lead pipes, which can contaminate drinking water and pose serious health risks, especially to children. Lead exposure can cause permanent damage to the central nervous system, brain, and kidneys, leading to behavioral issues, high blood pressure, hearing difficulties, and reproductive problems. Cadmium is a toxic trace element found in rocks, coal, and petroleum, and can contaminate water sources, particularly in acidic conditions. It accumulates in the body, especially in the kidneys, without any essential health benefits. Copper, while essential for life, can also pose health risks when present in drinking water due to corrosion of pipes. Prolonged exposure can lead to anemia, liver cirrhosis, and kidney damage. In children, high levels can cause diarrhea, while insufficient intake leads to anemia and growth issues.

Chromium is used in metal alloys and as a pigment in various materials, including paints and rubber. The electroplating process can emit harmful substances such as chromic acid and chromium trioxide, which may damage skin and lungs. Chromium dust is linked to lung cancer, while exposure to chromic acid can cause dermatitis and skin ulcers. Long-term exposure may lead to kidney and liver damage and affect the circulatory and nervous systems. Additionally, chromium can accumulate in aquatic life, increasing risks for consumers of contaminated fish.

Table 5: Abundance and Distribution of Benthic macro-invertebrates at the Study Stations in Michika Dam

	Station 1	**Station 2**	**Station 3**
Organism			
Nais sp	8	5	4
Eiseniella tetradra	6	4	4
Agraylea Sp.	0	13	4
Siphlonura Sp	1	2	3
Cloeon simplex	5	2	2
Baetis sp	8	4	0
P. pectoralis	4	16	5
D. vertifolis	6	0	1
Dubiraphia sp	0	29	9
Ablabesmyla sp	9	0	9
C. fractilobus	29	10	9
Pentaneura sp	49	82	15
Cardiocladius Sp	0	2	1
Tendipes tentans	4	1	0
Culex Sp.	10	12	5
Oxygaster curtisil	5	3	1
Aeshna sp	4	1	0
Lestes sp	10	0	6
Enallagma sp	4	8	9
O. hupensis	0	7	12
TOTAL	162	201	99

Table 6: Diversity Indices of Benthic Macro-invertebrates at the Study Stations in Michika Dam

	Station 1	**Station 2**	**Station 3**
Taxa	16	17	17
No of individuals	162	201	99
Margalef's Index	2.94	3.02	3.48
General diversity	2.32	2.09	2.59
Evenness	0.84	0.74	0.91
Dominance	0.141	0.209	0.077

Table 7: Biotic Indices for Assessment of the Water Quality in the Three Stations

Stations	**Simple biotic index**	**Ephemeroptera index**	**Trichoptera index**
1	Good (20)	Good (14)	Poor (0)
2	Excellent (23)	Good (8)	Good (13)
3	Good (19)	Good (5)	Moderate (4)

Species composition, abundance, and distribution of aquatic macroinvertebrates are influenced by many factors, including the physicochemical, geomorphic, and biotic factors of the aquatic ecosystem. Ibemenuga and Inyang 2006 asserted that water quality, predation intensity, and food supply were the major factors governing the abundance and distribution of macroinvertebrate fauna in aquatic environments.

The water physicochemical quality created a less homogeneous environment within the water body, which influenced the number of colonizing taxa (Ezekiel *et al,* 2011). The significant changes in the water quality parameters reported here are the obvious reflection of alterations in the water continuum due to various anthropogenic activities, and these have a direct influence on the structure of macrobenthic invertebrate communities.

Among the four main taxa—Ephemeroptera, Odonata, Coleoptera, and Diptera—Diptera was the most abundant, consistent with past studies (Townsend, 1983; Sharma et al., 1993; Ogbeibu and Oribhabor, 2002; Babasolo and Emmanuel, 2019). Their dominance is due to adaptations, food availability, and high reproductive rates (Mbah and Vijime, 1989). Chironomid larvae are common in aquatic benthic communities and often replace other invertebrates in altered streams. Main observed dipteran taxa included Ablabesma, C. fractilobus, and Pentaneura (Ogbeibu, 2001). Chironomidae showed a negative correlation with Hydroptilidae and dissolved oxygen levels, and a positive correlation with Coenagriidae, suggesting that increases in Hydroptilidae may reduce Chironomidae abundance.

The ecological requirements of different taxa influenced the distribution and abundance of dipterans. Pentaneura sp. was more abundant at station 2, likely due to its preference for high oxygen and shallow water rather than the substratum (Ogbeibu, 2001). Petr (1972) noted their presence in well-oxygenated shallow zones of Lake Volta, attributing their abundance to a rich food supply rather than just substratum or oxygen levels. Pentaneura larvae are predators found near aquatic plant roots, where larvae prey like oligochaetes and chironomid are abundant (McLachlan, 1969). Their high density at stations 1 and 2 supports this observation.

Ephemeropterans were found at nearly all sampling sites, with the lowest diversity at station 3. Their distribution was influenced by specific environmental conditions. These insects thrive in clean aquatic systems and contribute significantly to secondary production (Williams and Feltmate 1992; Olomukoro and Ezemonye, 2006). Interestingly, minimal organic pollution can sometimes enhance certain species' abundance while harming others. Key taxa identified include Baetis tricaudatum and Cloeon sp., commonly reported in various Nigerian waters (Ogbeibu and Oribhabor 2002; Olomukoro and Ezemonye 2006). A negative correlation between Baetidae and BOD5 suggests poor performance in polluted waters or low oxygen environments. The low population of siphlonurids is attributed to slight alkalinity and hydrogen ion concentration. Anisoptera and Zygoptera show good abundance, with O. curtilis and Lestes sp. being the main Odonata taxa found. Comparatively, Enallagma sp. was the only species common with previous studies (Ekelemu et al. 1999). Additionally, the biotope included significant annelid taxa such as Eiseniella tetrahedral and Nais spp. Also prominent at stations 2 and 3 is *Oncomelania hupensis,* which is the only species of gastropod obtained in this study.

Diversity results from spatial and temporal community changes (Ogbeibu and Oribhabor, 2002). The Shannon-Wiener index measures richness and abundance distribution, indicating taxa and individual counts. It reflects overall diversity (H’) and Evenness (E). Study stations showed varied H’. Station 3’s high diversity indicates ecological heterogeneity, supported by high evenness and low dominance. Conversely, stations 2 and 3’s low evenness and high dominance suggest lower heterogeneity. Variations in diversity are also shown by Margalef’s Index for species richness.

The assemblages and distribution of the benthic macroinvertebrates frequently change in response to pollution stress in predictable ways. This is the basis for the development of biological criteria to evaluate anthropogenic influences (Boyle and Fraleigh, 2003). Gray (1989) summarized the responses into three distinct categories: reduced diversity, increased domination by a single or group of opportunistic species, and reduced individual size. The first two were shown by the macrobenthic data in stations 1 and 2. Overall diversity is influenced by various spatial and temporal changes (Ogbeibu and Oribhabor, 2002). The Shannon-Wiener index measures relative abundance, reflecting both the number of taxa and individuals, and is expressed as general diversity (H’). Diversity varied across study stations, with higher levels at stations 3 and 2 due to their ecological heterogeneity. High evenness and dominance indices indicate greater diversity (Olomukoro and Eloghosa, 2009). Variations in general diversity are also seen in Margalef’s Index for species richness. Margalef’s Index (d)Taxa richness index was highest in station 3 (3.48). This was followed by station 2 with a value of 3.02. The lowest taxon richness was at station 1 (2.94). Simpson’s dominance index in the three stations studied shows that station 2 had the highest value of 0.209, followed by station 1(0.141). Station 3 was the least recorded, having 0.077.

Water quality was assessed at all stations using a biotic index, Ephemeroptera, and Trichoptera indices. The simple biotic index rated stations 3 and 1 as good (19 and 20 points) and station 2 as excellent (23 points). The Ephemeroptera index showed all stations 1, 2, and 3 as good (14, 8, and 5 points, respectively). However, the Trichoptera index rated station 1 as poor (0 points) while stations 2 and 3 were good (13 and 4 points, respectively). These indices reflect the river's quality at the sampled intervals during the study.

The variations in the diversity indices calculated for the various biotopes are shown in Table 7. Taxa richness was highest at stations 3 and 2 with 17 taxa each, then station 1had the lowest value recorded at 16. General diversity (H’) showed that at the biotope, station 3 had the highest value, followed by stations 1 and 2 in decreasing order of value. At the biotope, station 3 had the highest Evenness index (E); this was followed by station 1, then station 2 in order of their decreasing values.

CONCLUSION

Despite evident heavy metal contamination and organic pollution, Michika Dam maintains a functionally diverse macroinvertebrate community, with Station 3 exhibiting the highest species diversity (H' =2.59) and evenness (0.91). The research supports the use of benthic macroinvertebrates as reliable bioindicators for long-term water quality assessment in tropical dam ecosystems. Nonetheless, high concentrations of cadmium, lead, and iron present potential risks to aquatic life and human health via food chain transfer. It is advisable to implement regular monitoring, pollution control initiatives, and raise public awareness to prevent further deterioration of this dam, which supports local aquaculture and water needs.

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