



Physio-Chemical and Heavy Metals Assessment of River Challawa In Relation To Effluent Discharge in Kano, Nigeria

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ABSTRACT

This study was carried out in order to assess the water quality parameters and heavy metals of River Challawa in relation to industrial effluent discharge. Four study sites were selected based on the differences in the activities being done along the river. Water samples were analyzed for quality parameters using standard methods. Physicochemical parameters analyzed were temperature, pH, electrical conductivity (EC), turbidity, total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrate and phosphate, while heavy metals assessed were cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn) and nickel (Ni). Results showed marked variations with means of Turbidity (168.03 ± 16.87 NTU), Nitrate (15.40 ± 4.61 mg/L) and Phosphate (3.67 ± 0.67 mg/L) higher than the WHO safe limits of 25 NTU, 5.0mg/L and 0.3 mg/L respectively. The selected heavy metals in water showed significant variations with means of Cd, Cr, Pb and Ni exceeding WHO guideline limits. The high concentrations of these metals observed could be attributed to the influx of effluents from tanneries, agro-allied industries and various others located in the nearby Challawa Industrial Estate which threatens the ecosystem and public health. It is, therefore, recommended that effluents from the nearby industries should be properly treated before release into the environment.

Keywords: Physico-Chemical Parameters, Heavy Metals, Water Quality, Industrial Effluent, River Challawa

INTRODUCTION

Water is the second most important resource for life to exist after air. It is a dynamic system, containing living as well as non-living components, organic, inorganic, soluble as well as insoluble substances that constitute life support systems. Changes in water quality are known to affect the equilibrium of the aquatic environment, causing it to become unfavorable for designated uses (Karthika and Dheenadayalan, 2015). Water quality is a measure of the condition of water relative to the requirements of one or more biotic species and/or to any human need or purpose (Shah, 2017).

Pollution is caused when a change in the physical, chemical, or biological condition of the environment harmfully affects the quality of human life, including other animals' lives and plants (Aliyu *et al.*, 2017; Okoye *et al.*, 2002). Pollution of surface and ground water is due to increase in industrialization, urbanization, agricultural and various human activities (Duressa *et al.*, 2019; Khan *et al.*, 2012). Most of the rivers in the urban areas of the developing countries are the receiving ends of the effluents discharged from the industries (Bajpai, 2012). Rivers serve as a source of water for human consumption as well as irrigation purposes. Due to the significance of rivers, it has become essential for the regular monitoring of the important parameters of the water (Shawai *et al.*, 2019).

Heavy metals can be found in traces in water sources and still be very toxic and impose serious health problems to humans and other ecosystems, because the toxicity level of a metal depends on factors such as the organisms which are exposed to it, its nature, its biological role and the period at which the organisms are exposed to the metal (Masindi and Muedi, 2018). Aquatic organisms can accumulate and tolerate heavy metals to a certain extent. However, when the concentration and toxicity levels of heavy metals exceed the tolerance of aquatic organisms, they will generate serious toxic effects on their related indicators and their life activities as well (Rose *et al.*, 2015). At the same time, genetic mutations or variations may take place, which will result in changes in species

diversity and survival rates. As heavy metals have the potential of eventually being transmitted to humans and other organisms through the food chain, they also cause serious threats to human health. These heavy metals are not easily eliminated after entering the human body and tend to continuously accumulate over time. Once they exceed the physiological limit of the human body, they tend to cause physiological and structural changes. These changes may lead to acute, chronic, or long-term hazardous effects (Hong *et al.*, 2020). Heavy metals may act as free radical causing damage which includes oxidative stress, aging caused by DNA damage, cardiovascular disorders, fatigue and rare autoimmune disorder, arthritis, calcification, chronic arterial rupture and other degenerative problems (Sahu *et al.*, 2007). Surface freshwater directly receives large quantities of waste water from domestic, agricultural, and industrial sources that are directly disposed in the water bodies. Indirect contamination also occurs, when contaminants dispersed in the soil are washed by the rainfall and by precipitation of air particles, which are present in the air, end up in the water through rainfall. Urban contamination, mainly from large cities, is of special concern due to the large amounts of complex mixtures of wastes, derived mostly from domestic sewage and industrial processes (Edokpayi *et al.*, 2017). Although several studies have been conducted on bioaccumulation of heavy metals and water quality of River Challawa such as studies by Sani *et al.* (2022), Shaibu and Audu (2019), Udiba (2018), Malami *et al.* (2014), continuous monitoring of the water will provide relevant updated information that will aid pollution prevention and control efforts as well as decision making. It is in that regard that this study was undertaken in order to assess the physico-chemical parameters of river Challawa.

MATERIALS AND METHODS

Study Area

Challawa River is located in Yandanko village in the Challawa Industrial Estate ($11^{\circ} 45' 42''$ N, longitude $8^{\circ} 46' 17''$ E)

in Kumbotso Local Government Area of Kano state. Kano is located in the northern part of Nigeria covering an area extending between latitudes $12^{\circ} 40'$ and $10^{\circ} 30'$ and longitudes of $7^{\circ} 40'$ and $9^{\circ} 40'$ (Uzairu *et al.*, 2014).

Four (4) sampling sites were selected for this research, each sampling site is comprised of three sampling points; and sites chosen were based on the different activities in the areas.

Site A: This site is near the point at which the Kano State Water Works draws its raw water to the treatment plants for

purification. At this station, few human activities such as sand dredging and fishing take place.

Sites B and C

This site receives raw effluent from Challawa Industrial Area and is discharged into the river. They comprise mainly food, textile, agro-allied, plastics and tannery industries.

Site D

This site is at Tamburawa along Zaria Road where the river forms a confluence with River Kano. Activities such as sand dredging, farming, and fishing take place in the area.

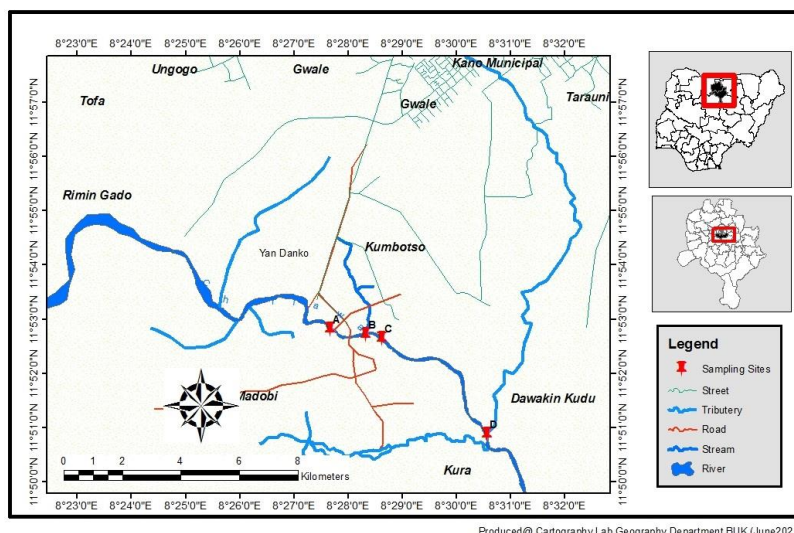


Figure 1: Map of River Challawa showing the Sampling Sites (Cartography Lab, Dept of Geography, 2021)

Sample Collection

All the samples for this research work were collected monthly between July 2021 and June 2022.

Water Sampling

Water samples were collected in 1L sterile polyethene plastic bottles by dipping the bottles about 20cm below the water surface and filling them to the brim. Samples were stored in ice box, transported to the laboratory and refrigerated at about 4°C prior to analysis as adopted by Indabawa (2012).

Physico- Chemical Analysis

All physico-chemical parameters were determined using standard methods and instruments. Temperature, pH, dissolved oxygen and turbidity were measured in-situ. All reagents used were of analytical grade quality.

Determination of Heavy Metals

Water samples were digested prior to heavy metal analysis according to procedures adopted by Uddin *et al.* (2016). Atomic Absorption Spectrophotometer (Agilent Technologies model 200 series AA) was used to determine the levels of heavy metals in digested water samples according to manufacturer's instructions.

Data Analysis

Results were presented as means \pm SD. One-Way analysis of variance (ANOVA) with Post-Hoc test was used to determine significance in physico-chemical parameters and heavy metals. Independent student t-test was used to determine the seasonal variation in all parameters. All statistical analyses were conducted using R statistical software (Version 4.0.1).

RESULTS AND DISCUSSION

The physicochemical parameters of River Challawa showed marked variations. The water temperature indicated a mean \pm SD value of $27.82 \pm 0.07^{\circ}\text{C}$; the pH values ranged from 5.78-7.98 with a mean \pm SD value of 7.32 ± 0.07 ; Turbidity fluctuated with mean \pm SD value of 168.08 ± 1.41 NTU. The Electrical Conductivity ranged from 129-503 $\mu\text{S}/\text{cm}$ with a mean \pm SD of 298.15 ± 8.84 $\mu\text{S}/\text{cm}$. Total Dissolved Solids has a peak value of 416 mg/L which was recorded in the month of December while the least value of 87 mg/L was recorded in the month of August, the mean \pm SD was 220.20 ± 7.72 mg/L. The Dissolved Oxygen values of the water ranged from 4.33 - 6.99 mg/L; with the mean \pm SD of 5.52 ± 0.04 mg/L. Biochemical Oxygen Demand revealed monthly variation with mean \pm SD value of 27.69 ± 0.26 mg/L. Nitrate indicated mean \pm SD values of 15.40 ± 0.38 mg/L during the period of study and the mean \pm SD value of Phosphate was 3.67 ± 0.06 mg/L as shown in table 1.

Mean concentrations of heavy metals in water, sediment and mussels across sites and seasons were presented in tables 2-9. Mean levels of Cd (0.088 ± 0.01 mg/L), Cr (0.457 ± 0.10 mg/L), Pb (0.127 ± 0.08 mg/L) and Ni (0.101 ± 0.10 mg/L) in water have exceeded the WHO (2018) guideline limits of 0.003 mg/L, 0.05 mg/L, 0.01 mg/L and 0.07 mg/L respectively. Cu and Mn were found within guideline limits. Highest concentrations of all metals in water, sediment and mussels were recorded in site B, while Site D recorded the least concentrations in heavy metals as illustrated in figures 2-7.

Table 1: Mean (±SD) Variations of Physico chemical Parameters across Sites and Seasons

Parameters	Sites				Seasons	
	A	B	C	D	Wet	Dry
Temp (°C)	27.69±0.78 ^{ab}	27.66±0.84 ^b	27.84±0.66 ^{ab}	28.07±0.88 ^a	27.81±0.81 ^a	27.81±0.80 ^a
pH	7.66± 0.11 ^b	5.98± 0.11 ^c	7.84± 0.09 ^a	7.79± 0.08 ^a	7.33±0.80 ^a	7.31±0.77 ^a
EC (µs/cm)	271.77±30.15 ^b	456.16±28.26 ^a	260.77±69.30 ^b	203.88±49.54 ^c	294.50±104.51 ^a	300.76±107.65 ^a
TDS (mg/L)	195.66±36.38 ^b	362.63±37.08 ^a	192.61±43.20 ^b	137.88±35.89 ^c	225.21±94.81 ^a	217.98±90.17 ^a
Turbidity (NTU)	165.27± 9.38 ^c	185.72± 10.73 ^a	172.50± 12.72 ^b	148.83± 8.28 ^d	173.88± 18.71 ^a	163.94± 14.14 ^b
DO (mg/L)	5.64± 0.28 ^a	5.30± 0.50 ^b	5.51± 0.39 ^a	5.61± 0.46 ^a	5.20± 0.43 ^b	5.74± 0.27 ^a
BOD (mg/L)	26.64± 1.97 ^c	30.32± 3.53 ^a	28.68± 2.02 ^b	25.10± 1.37 ^d	28.60± 4.01 ^a	27.03± 1.92 ^b
NO ₃ (mg/L)	13.38± 3.80 ^c	21.85± 2.77 ^a	14.8± 1.04 ^b	11.51± 0.87 ^d	17.14± 4.95 ^a	14.15± 3.92 ^b
PO ₄ (mg/L)	3.21± 0.57 ^c	4.51± 0.48 ^a	3.50± 0.40 ^b	3.46± 0.33 ^b	3.54± 0.80 ^a	3.76± 0.55 ^a

Keywords: Temp- temperature, EC- electrical conductivity, TDS- total dissolved solids, DO- dissolved oxygen, BOD- biochemical oxygen demand, NO₃- nitrate-nitrogen, PO₄- phosphate-phosphorus

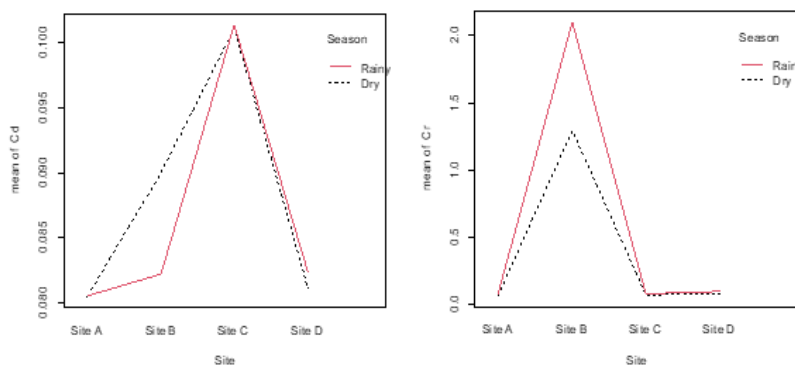


Figure 2 and 3: Interactive Chart showing Mean Concentrations of Cadmium and Chromium (mg/L) in Water across Sites and Seasons

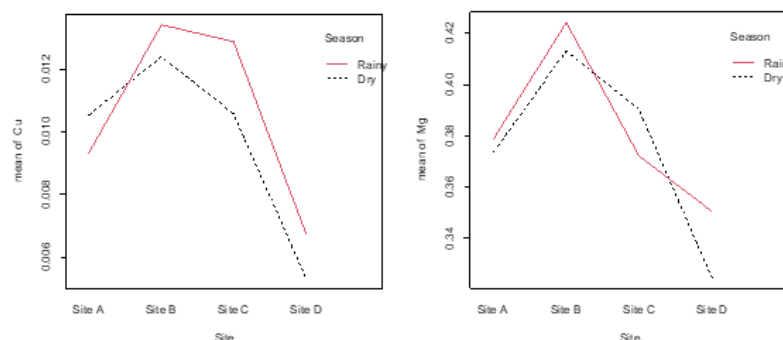


Figure 3 and 4: Interactive Chart showing Mean Concentrations of Copper and Manganese (mg/L) in Water across Sites and Seasons

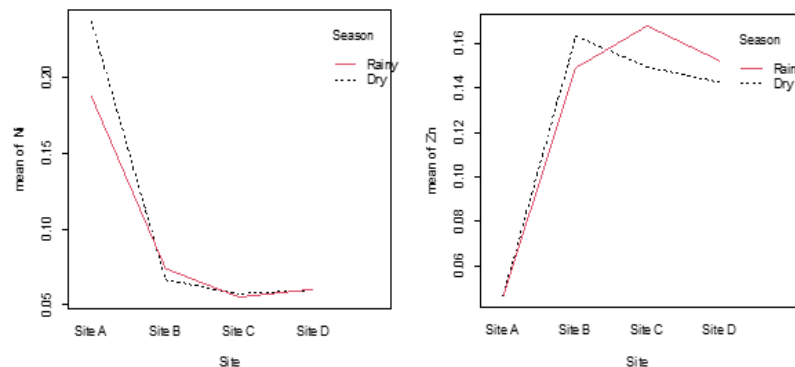


Figure 5 and 6: Interactive Chart showing Mean Concentrations of Nickel and Lead (mg/L) in Water across Sites and Seasons

Discussion

The mean results obtained for temperature in the surface water samples of Challawa River in the four sites sampled ranged between 26.65 ± 0.12 and 28.40 ± 0.33 °C. The mean value of temperature was 27.82 ± 0.41 °C. The values recorded for temperature from the river were within the permissible limits of temperature in the aquatic space acceptable by WHO which falls between 28.5- 32 °C. The results obtained were higher than those obtained from the Isiodu River during dredging in Niger Delta, Nigeria which fell between 5.81 and 13.20 °C (Iyama & Edori, 2013). However, it was similar to those reported by Iyama and Edori (2014) at the Imonite River which was in the temperature ranges of 24.94 - 26.70 °C and by Udiba *et al.* (2018) from Challawa surface water (27.56 - 28.23 °C). Results obtained from this study was slightly below those obtained by Edori *et al.* (2021) from a study in Whuo stream in Rivers (30.00 ± 0.42 - 30.26 ± 0.83 °C). These values also coincide with those obtained from Kubanni Reservoir by Jelili (2020) and Ewim *et al.* (2022) from water samples of Borno State.

As reported by Udiba *et al.* (2018), the significantly lower temperature recorded at site D when compared to the other three river stations from the point source downstream suggest that effluent from tanneries around Challawa industrial area have significant influence on the quality of Challawa River. Increased water temperature lowers the amount of dissolved oxygen available for the aquatic life present and promotes excessive growth of aquatic plants and algae. This coincides with findings of this study where temperature and dissolved oxygen possesses a significant negative correlation. Also, the toxicity of pollutants tends to intensify with an increase in temperature (Udiba *et al.*, 2018).

The level of temperature of any water body has direct or indirect impact on the organisms' biological effects or conditions. At a time when a change is detected in the temperature of any water body, there is also a resultant change in the physicochemical characteristics of the water that is subsequent on the physiological adaptation of organisms within the system (Edori & Nna, 2018). In addition to that, the assessment of the ecological factors or conditions of both biological and non-biological organisms to fit into the environment is dependent on temperature. This is due to the fact that temperature has direct bearing on the normal lifestyle and behavioral characteristics in an aquatic ecosystem (Palamuleni & Akoth, 2015). In addition, the level of gases dissolved in the water body such as oxygen, might be either harmful or vital for migration, reproduction, growth and even death of water dwelling animals and plants (Patil *et al.*, 2012). The mean monthly results obtained for pH from the surface water samples of River Challawa in the four sampling sites ranged between 5.86 ± 0.22 in September and 7.91 ± 0.31 in May. The mean value obtained for pH was 7.32 ± 0.90 . Some observed values of pH were slightly lower than the acceptable limit required for drinking water by WHO which ranged from 6.5 to 8.5. The values obtained in this study were in the same range with that obtained by Iyama and Edori, (2013); Udiba *et al.* (2018) and Edori *et al.*, (2021) from the Isiodu River, River Challawa and Whuo stream respectively. However, results obtained from this study were higher than those obtained by Edori and Nna (2018) from different locations of the New Calabar River (3.43 ± 0.24 and 5.06 ± 1.42); Ewim *et al.*, (2022) from water samples of Borno State (4.96 - 7.38) and Braga *et al.* (2022) from Maranhao Amazon, Brazil (5.73 - 6.01). Mean pH values ranging from 7.21 ± 0.02 - 10.46 ± 0.01 and 7.23 - 7.65 have previously been reported for different sampling points along Challawa River by Wakawa *et al.* (2008) and Udiba *et al.* (2018) respectively.

Acidic water increases the rate of corrosion of metallic materials, pipes, cement walls and plumbing materials, but alkaline water is a revelation that the water is disinfected and suitable for use (Rahmanian *et al.*, 2015; Edori & Kpee, 2016). The acidic nature of the water in the river may be due to the prevailing domestic and industrial activities which has led to the deposition of metallic materials in the river within the sampled locations. When the pH values of water are on the extreme, it affects the taste and sweetness of the water. The efficiency and effectiveness of biochemical reactions within any water body hinges on pH as reported by Edori, Iyama and Awari (2021).

The mean value obtained for electrical conductivity in the surface water of River Challawa was 298 ± 109.06 $\mu\text{S}/\text{cm}$. The values reported for electrical conductivity in this work were within the permissible limits of electrical conductivity by WHO in any aquatic environment. The values reported for conductivity in this study were quite higher in comparison to that from Edori and Nna (2018) which ranged between 11.60 ± 2.68 and 15.61 ± 3.01 $\mu\text{S}/\text{cm}$; Abdar (2013) in Morna Lake, Shirala, India and those detected by Sharma and Walia (2017) in Satluj River, Himachal Pradesh, India. The high level of the conductivity observed in the river may be due to run-off of industrial waste according to Verma *et al.* (2012).

The mean value obtained for total dissolved solids from River Challawa was 222 ± 93 mg/L which varied from 87 - 416 mg/L. The values obtained were within the permissible value of 1000 mg/L by WHO for potable water. The total dissolved solids reported in this study were far lower than that which was observed by Edori *et al.*, (2019) in the water samples of the Silver River in Bayelsa State which ranged from 13,050 to 13,500 mg/L. The values in this work were also lower than that obtained and observed in the upper reaches of Orashi River (Davies *et al.*, 2018) and a stretch of the New Calabar River (Dienye & Woke, 2014). Meays and Nordin (2013) reported that conductivity is the measure of electricity conducting ions (both anions and cations such as ions of hydrogen, nitrates, phosphates, sodium, chlorides) in a water system. Sigler and Bauder (2015) reported that total dissolved solids, basically is the sum of all minerals dissolved in the water system. These include carbonate, bicarbonate, chloride, fluoride, sulphate, phosphate, nitrate, calcium, magnesium, sodium, and potassium, but other ions dissolved in the water could also contribute to the total dissolved solids observed. Meays and Nordin (2013), added that, compounds of soil organic matter such as humic and or fulvic acids are also vital components of total dissolved solids. Positive correlation was observed between total dissolved solids and electrical conductivity; this was also reported by Dike *et al.* in River Jakara (2013) and Safana (2018) from River Ginzo.

The results obtained for turbidity in the water samples of River Challawa in the four sites sampled varied from 133 – 208 NTU. The mean value obtained for turbidity was 168 ± 14.9 NTU. The values recorded for turbidity in this study were higher than the WHO value of 10 NTU for drinking water and for other domestic use. Turbidity is the extent to which a water body is clear or opaque. The values recorded for turbidity in this research was found to be higher in value than those reported by Edori and Nna (2018) in the New Calabar; and that obtained by Yapo *et al.*, (2012) in a river in Abidjan City and Edori *et al.* (2022) from Whuo stream in Rivers. This could be attributed to the discharge of waste and urban run-off which creates large number of organic materials and hence increased the turbidity of River Challawa according to Indabawa (2010). Kinuthia *et al.* (2020) also reported turbidity levels between 160.33 – 544.67NTU in a study from open drainage channels in Kenya which indicates the presence

of suspended solids in the water bodies. The level in which particles are suspended or dissolved in any given aquatic system contributes to the high turbidity of that aquatic environment. The high values of turbidity observed from the river might have originated from high level of chemicals and effluents discharged into the river through drainages from Challawa Industrial Area. High turbidity levels in a water body hinders the effective penetration of light into greater depth and hampers the photosynthetic activities and destroys or decreases normal aquatic life and upsets the value and appearance of surface water (Gupta and Singh, 2011). The level in which microorganisms, phytoplankton and zooplankton occur in the aquatic system increases the level of water turbidity (Edori & Kpee, 2016; Edori & Nna, 2018; Edori *et al.*, 2022).

Results of DO from this study were lower than the WHO (2018) recommended limits of at least 5mg/L in water. A study by Odiba (2017) also shows DO of 3.9 mg/L in wet season which increase to 4.7 mg/L in dry season. A study by Ewim *et al.* (2022) also showed values similar to the present study (3.70 - 7.60 mg/L). The lower values could be attributed to breakdown of organic matter by aerobic microbes. This agreed with the research findings of Dike *et al.* (2013) in River Jakara and Oniye *et al.* (2002) in Zaria dam. The highest dissolved oxygen concentration was observed in January which coincided with lower surface water temperature. This observation could be attributed to the seasonal changes in air temperature resulting from the North-East trade winds (Harmattan) which is typical of the season. These findings are in agreement with the Devangee *et al.* (2013), Magami *et al.* (2014) and Jabbi (2018) in their studies on Kankariya, Vastrapur, Malav, and Chandola Lake, India, Shagari and Yardantsi Reservoirs respectively. Meays and Nordin (2013) reported that the important factors that control the dynamics in surface water dissolved oxygen concentration include; temperature, atmospheric pressure, photosynthetic activities of algae, cyanobacteria and aquatic macrophytes. The highest dissolved oxygen concentrations recorded in January coincided with minimum temperature observed. Increase in DO compared with the high temperature recorded in this study show that the site with low values of DO have high values of temperature (28.26 °C) which is in line with the findings of Akinbile and Yusoff (2011); Ewim *et al.*, (2022). Low dissolved oxygen in effluent when discharged into rivers has adverse effects on aquatic biota as less oxygen will be available for aquatic life as reported by Shaibu and Audu (2018).

BOD values ranged from 22.5 mg/L in May to 39.77 mg/L in August with a mean value of 27.69 ± 0.26 mg/L. The high values could be attributed to presence of organic waste in the environment which initiates various microbial activities, hence creating high biochemical oxygen demand (Dike *et al.*, 2013). Similar observations were made by Akan *et al.* (2013) in Jakara waste water, Indabawa (2010), Dike *et al.* (2013) in River Jakara and Safana (2018) in River Ginzo. Biodegradation activities initiated by microorganisms that often increases biochemical oxygen demand decreases dissolved oxygen, hence the negative correlation (Dike *et al.*, 2013). The highest value recorded was during the wet season (39.77 mg/L) while the lowest value recorded was 22.5 mg/L during the dry season. This finding is supported by Essien-Ibok *et al.* (2010) in Mbo River; due to the increased input of organic matter into waste channels.

Nitrate ranged between 9.89 mg/L and 25.39 mg/L with a mean value of 15.40 ± 4.35 mg/L. The mean value obtained was higher than the 10 mg/L accepted for nitrates in water for drinking and other domestic purposes by WHO. The reason

could be due to excessive influx of farmlands where fertilizers are used to boost up crop production according to Safana (2018). The level of nitrates recorded in this investigation were higher than those reported by Etim *et al.* (2013) in the Qua Iboe River in Akwa Ibom, and Sikoki and Anyanwu (2013) in Onu-Iyi-Ukwu Stream in Niger Delta, Nigeria. Low level of dissolved oxygen decreases the efficient conversion of ammonia to nitrite and then to nitrate, that leads to an increased level and quantity of ammonia and nitrite in the aquatic systems, and thereafter producing higher level toxicity to the water environment (Suthar *et al.*, 2009).

The values of Phosphate ranged between 2.31 mg/L (October) and 5.73 mg/L (December) with the mean value found at 3.67 ± 0.58 mg/L. The mean value is within the WHO safe limit of 5mg/L for phosphate in water. This also coincides with findings of Shaibu and Audu (2019) from tannery effluents of Challawa industrial area. Highest concentration obtained was in the dry season while the lowest was in the wet season. This could be as a result of decrease in water volume, intensive agricultural activities and use of pesticides to dry season crops around the river according to Ibrahim (2009).

The mean level of cadmium in water recorded was 0.088 ± 0.01 mg/L. This value has exceeded the maximum permissible limit of 0.003 mg/L for water set by the WHO. This is similar to the result obtained by Akinpelu and Kuforiji (2013) in River Owo and Akan *et al.* (2013) in Jakara waste channel. This may be due to the discharge of industrial effluents, urban and agricultural run-offs and other relevant occupational activities such as steel making, welding, electroplating etc. (Vilia-Elena, 2006, Cheang *et al.*, 2021). According to USEPA (2010) and WHO (2011), chronic toxicity of Cd in children includes damages of respiratory, renal, skeletal and cardiovascular systems as well as development of cancers of the lungs, kidneys, prostate and stomach. Exposure of people to Cd include, eating contaminated food, smoking cigarettes, and working in cadmium-contaminated work places and in primary metal industries. A study carried out in Iran reported that the level of Cd was higher than the maximum permissible limit (MPL) in canned fish samples, and this was due to discharge of heavy metal rich pollutants into aquatic ecosystems (Sobhanardakani, 2017).

From the results of this study, higher levels of Cadmium were observed in site B than the other sites (0.101 ± 0.01 mg/L). This could be because it's the point where effluent from the industrial area is being discharged into the river and hence it receives more pollutants. Similarly, sites A and D had lower mean values of Cd (both 0.08 ± 0.00 mg/L). This is due to the fact that it is the upstream of the river located before the point where effluents are being discharged into the river and had less anthropogenic impact. This agrees with the findings of Sani *et al.* (2022) with levels of Cd in water ranging from 0.273 ± 0.0282 - 0.61 ± 0.54 mg/L from River Challawa. Drinking or use of water from River Challawa for domestic purposes thus poses serious toxicological risk with respect to cadmium intoxication according to Udiba *et al.* (2018).

Musa and Imam (2021) found concentration of heavy metals in the body of fish higher than those in the water body, this is as a result of the ability of fish to bioaccumulate metals above the concentration in water. This agrees with the work of Adaka *et al.*, (2017) stating that heavy metals in the body organs of *Citharus citharus*, *T. zillii* and *Heterotis niloticus* from Oguta lake gave a higher concentration than in water. Concentrations of chromium in water observed in this study has exceeded the maximum permissible limits of 0.05 mg/L set by the WHO with site B having the highest mean value (1.62 ± 0.86 mg/L). Significant differences were observed

between the study sites which could be as a result of more industrial influence observed in site B. Similar results were reported by Musa and Imam (2021) from Hadejia-Nguru wetland with values exceeding recommended limits. Cr could gain entrance into the aquatic ecosystem through effluents discharged from dyes, leather tanneries, textiles, fertilizers etc and mussels bioaccumulate it through ingestion or by uptake through their gills. Chromium is widely used in metallurgy, electroplating, and in the manufacturing of paints, pigments, preservatives, pulp and papers among others according to Kinuthia *et al.* (2020). Higher range of 3.33 - 5.79 mg/L was also reported by Bernard and Ogunleye (2015). Values of 5.56 mg/L and 7.21 mg/L were reported by Bhatnagar *et al.* (2013) and Deepali (2010) respectively. The higher values of chromium may be attributed to large amount of chromium salt (chromium sulphate) used in tannery tanning operations (Modal *et al.*, 2005; USEPA, 2010;). At high concentration and long term exposure, chromium can cause cancer (IARC, 2012). Higher concentration ranging from 0.213 to 0.924 mg/L was reported for River challawa, Kano, Nigeria (Dan'Azumi and Bichi, 2010) and 0.33 to 1.56 mg/L for River Warri, Niger Delta, Nigeria (Owamah, 2013). Chromium concentration ranging from 0.0365 mg/l – 0.0865 mg/l was reported for surface water around Gboko abattoir (Ubwa *et al.*, 2013) and $1.55 \pm 0.13 - 2.43 \pm 0.07$ mg/L was reported from Challawa surface water (Udiba *et al.*, 2018). A mean value of 2.08 ± 1.27 mg/l was reported for lower river Niger drainage in North central Nigeria (Olatunji & Osinbajo, 2012).

Mean chromium concentration in sediment reported was 1.176 ± 0.35 mg/kg. Site B had the highest concentration of chromium in sediment (2.51 ± 0.94 mg/kg) which differs significantly with other sites. This could be as a result of frequent discharge of effluents from tannery and textile industries from the industrial area which keeps accumulating deep beneath the river bed over time.

Cu concentration in water ranged between 0.005 ± 0.003 and 0.012 ± 0.007 mg/L with a mean of 0.10 ± 0.005 mg/L which is below the maximum permissible limits of 1.0 mg/L in water. According to Padrihah *et al.* (2018), presence of copper in water or an aquatic environment occurs through several pathways including mining activities, the discharge of industrial and agricultural waste and runoff from mineral deposits. Uzairu *et al.* (2014) opined that though widely distributed and being an essential element, acute toxicity of Cu results in hypotension, coma, and death. From research, Cu has been known to participate in the ecosystem from many sources like household tools, wood and metal manufacturing, pesticides applications, fertilizers, and septic tanks waste. According to a study by Akan *et al.* (2007), results of Cu in river Challawa were above the WHO limit of 0.05 mg/L for drinking water. The concentration of copper content was 5 to 10 times above the permissible limits, indicating possible pollution.

Levels of Pb in water ranged between 0.046 ± 0.024 and 0.157 ± 0.083 mg/L. The mean value of 0.127 ± 0.06 mg/L has exceeded the maximum permissible limits of 0.01 mg/L for consumption. Another study of lead concentrations in tannery effluents of River Challawa was found above WHO (2008) limit of 0.01 mg/L with a range of 0.6250 - 0.8501 mg/L. A range of 0.67 -3.10 mg/L was also reported from the same study area (Bernard & Ogunleye, 2015). The concentration of Pb found in river Challawa might be as a result of anthropogenic discharge of Pb containing wastes from industries including used items such as pipes and petrol (Akan *et al.*, 2007; Sani *et al.*, 2022). Household waste suspected of containing lead are batteries, children's toys, washed paint,

and plastic food or beverage packaging (Lamondo, 2020). Eshmat *et al.* (2014) also reported that the contamination of lead (Pb) in Ngenboh waters was caused by the disposal of resident waste originating from organic and non-organic materials. Budiastuti *et al.* (2016) and Ismawati *et al.* (2021) also argue that household waste has a significant role in the presence of lead in waters. A range of 0.011 - 0.033 ppm of lead was reported in a study by Kinuthia *et al.* (2020) in waste water from Kenya open drainages. Lead affects central nervous system, particularly in children and also damages liver, kidney and the immune system. At higher concentration, lead may result in metallic poisoning which can possibly cause cancer in humans (Bakare- Odunola, 2005). Lead content of River Challawa observed in a study by Udiba *et al.* (2018) was found to be higher when compared to World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) of 0.01 mg/l for portable water which is similar to the findings of this study. Dan'azumi and Bichi (2010) reported concentrations ranging from 0.095 to 0.084 mg/L for River challawa and 0.039 - 0.256 mg/L for streams that receive effluents from different categories of industries in Nakawa - Ntinda Industrial area of Kampala, Uganda (Udiba *et al.*, 2014; Walakira and Okot-Okumu, 2011). Oronsaye *et al.* (2010) reported a lower range of 0.05 to 0.07 mg/L for Ikpoba river dam, Benin City, Nigeria. Lead exposure in young children has been linked to learning disabilities. Lead affects both the male and female reproductive systems. In men, when blood lead levels exceed 40 µg/dl, sperm count is reduced and changes occur in volume of sperm, their motility, and their morphology. A pregnant woman's elevated blood lead level can lead to miscarriage, prematurity, low birth weight, and problems with development during childhood (Bellinger, 2005). Kidney damage occurs with exposure to high levels of lead. In acute poisoning, typical neurological signs are pain, muscle weakness, paraesthesia, and, rarely, symptoms associated with encephalitis (Pearce, 2007).

Mn concentration in water ranged between 0.335 ± 0.11 and 0.417 ± 0.09 mg/L with a mean of 0.378 ± 0.10 mg/L. Highest concentration of Mn was observed in site B with the least value reported in site D which could be as a result of industrial discharge. These values are within the permissible limits of 0.4 mg/L. Udiba *et al.* (2014) reported $0.24 + 0.05$ mg/L as concentration of Mn in water from Challawa dam which is within the permissible limits of WHO. According to Atanasov *et al.* (2013), levels of Mn from Tundzha River ranged from 0.021 mg/L to 0.186mg/L which could be explained by the fact that wastewater from settlements, industrial enterprises, agricultural activities and probably by mining in the region of Tvarditsa town flow into it. All this could lead to an increase in its concentration. After discharge into the dam, the water is diluted and stays for a long time where part of the Mn is absorbed by sediment and thus its concentration in water decreases. In a study conducted by Waziri, Zakaria and Audu (2015), mean concentrations of Manganese in Challawa Gorge dam sediment were higher than in the water samples. This may be due to the deposition of sediment on the surface of water via aerial transport or directly supplied from the catchments through the weathering of rocks and other processes such as forest grazing lands, urban construction sites and other sources of erosion and runoff washed away from the land into water bodies.

Ni in water ranged between 0.056 ± 0.006 and 0.216 ± 0.129 mg/L with a mean of 0.10 ± 0.04 mg/L. This value has exceeded the WHO maximum permissible limits of 0.07 mg/L for consumption. Other values reported in literatures were 0.05 mg/L, 0.68 mg/L and 0.85 mg/L by Sahu *et al.*

(2007), Bhatnagar *et al.* (2013) and Amanial (2015) respectively. There was no significant difference in the levels of nickel in all the sites. Kinuthia *et al.* (2020) reported values of 0.004 mg/L which was within WHO permissible limits. Shaibu and Audu (2019) reported that nickel concentrations in all the tannery effluents of River Challawa were below the WHO permissible limit of 1.0 mg/L with a range 0.0029 - 0.0144 mg/L. The presence of nickel in tannery effluent may be attributed to chemicals used in the tanning and post tanning processing of leather (UNIDO, 2005). At high concentration, nickel may cause damage to DNA and cell structures (Monika *et al.*, 2011).

CONCLUSION

Results of physico-chemical and heavy metal analysis indicate that industrial effluent has an impact on these water quality parameters. The study therefore concludes that river Challawa is contaminated, most likely, from anthropogenic sources, a key suspect being the discharge of effluents from industrial area located within the catchment area which drains directly into the river. This could pose deleterious effect on aquatic organisms and public health. It is, therefore, recommended that all direct and indirect discharges of effluents into the river should be ceased. Also, all effluents should be properly treated in accordance with the best practices before being discharged into the River. These measures will, ultimately, safeguard environmental quality and public health.

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