International Journal of Environment and Pollution Research
Vol.9, No.2 pp.25-39, 2021
Print ISSN: 2056-7537(print),
Online ISSN: 2056-7545(online)

STUDY ON HEAVY METALS LEVELS AND SOME PHYSICOCHEMICAL PARAMETERS OF A POLLUTED CREEK ALONG THE TIN CAN ISLAND IN LAGOS

Davies, I. C., Agarin, O. J., and Onoja C. R.

Department of Fisheries, Faculty of Agriculture, University of Port Harcourt, P.M.B. 5323, Port Harcourt, Nigeria.
Department of Marine Sciences, Faculty of Science, University of Lagos, Akoka, Lagos State, Nigeria.
Department of Fisheries and aquaculture, Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

ABSTRACT: *The study was carried out to assess the level of selected metals and physico-chemical parameters of a polluted creek along the Tin Can Island in Lagos. Metals such as Cu, Fe, Zn, Pb, Cd, Mn, and Cr were analysed using Atomic Absorption Spectrophotometer. Correlations analysis was conducted to determine the spatial distribution of the metals. From the results, it was evident that accumulation of heavy metals was within the internationally acceptable standards as reported by WHO and EPA. There was significant difference (p<0.05) between the physicochemical parameter across the different stations and months. Although conductivity (11060.5±6.4), TDS (2328.33±3.04) and BOD (107±52.0) were higher than the recommended limit of these metals by WHO which could be attributed to large amount of deposited and sewage floating at the banks of the creek. However, if these levels are not checked, they may increase the potential of bioaccumulation in the aquatic organisms and inhabitants that depends on the creek for survival. Therefore, there is need for policies to conduct regular monitoring of this creek to avoid future deterioration of the creek.*

Keywords: heavy metals, physicochemical parameters, Tincan island and creek.

INTRODUCTION

Water pollution has become a global concern in recent years. This is as a result of the increased level of domestic and industrial waste materials deposition in the rivers and other aquatic bodies (Miebaka, 2017). Environmental pollution which naturally or as a result of human activities, is assuming enormous proportions, increasing considerably by the day with the advent of civilization, industrialization and urbanization (Okere *et al.*, 2020). The availability and quality of water has been impacted upon by both natural and anthropogenic sources, leading to poor water quality and productivity of the aquatic ecosystems and heavy metals are one of the sources that leads to poor water quality and productivity of aquatic ecosystems (Akankali and Davies, 2020).

These discharges may contain many potentially dangerous pollutants that include heavy metals, which ultimately find their way into surface and interstitial waters that are used by man and are natural habitats for biota (Authman *et al.*, 2015). In spite the efforts put in by government and the private sector in pollution control, the challenges seem to be intractable as the indices of pollution continue to be unabated in the society (Davies and Okonkwo, 2021).

The main objective of this study was to determine the distribution of heavy metals and some physicochemical parameters of a polluted creek from tin can island in Lagos State, Nigeria; thereby establishing a useful data base on the current pollution status of the creek. Therefore, this study will provide information on the current levels of metals in the water body and its environmental quality and health implication of the inhabitants that depend on the creek for survival thereby help environmental and law enforcement agencies to come up with a sustainable monitoring approach in the aquatic ecosystem and adjoining water bodies.

LITERATURE/THEORETICAL UNDERPINNING

The waters body around the polluted creek from tin can island in Lagos are essential viable resource for transportation, commercial and artisanal fishing activities. The recipient waters are heavily contaminated due to sand dredgers, miners and discharge of untreated sewage and other relative unregulated activities such as ships wreck and other abandoned vessels (Agarin *et al.*, 2020). These activities have impact the aquatic environment which are crucial to primary production of most some important set of organisms which are essential in maintaining balance in the ecosystem society (Akankali *et al.*, 2019). The pollution of the aquatic environment with heavy metals has become a worldwide problem in recent times because they are indestructible and most of them have toxic effects on organisms (Davies, and Okonkwo, 2021). Among environmental pollutants, metals are of particular concern, due to their potential toxic effect and ability to bioaccumulate in aquatic ecosystems (Akankali and Davies, 2020).

The presence of heavy metals in aquatic ecosystems is the result of two main sources of contamination; natural processes or natural occurring deposits and anthropogenic activities. The main sources of heavy metal pollution to life forms are invariably the result of anthropogenic activities (Akankali *et al.*, 2019). Heavy metal concentrations in aquatic ecosystems are usually monitored by measuring their concentrations in water, biota and sediments (Okoro *et al*., 2021). These heavy metals generally exist in low levels in water and attain considerable concentration in sediments and biota (Ekeanyanwu *et al.*, 2010). Heavy metals including both essential and nonessential elements have a particular significance in ecotoxicology, since they are highly persistent and all have the potential to be toxic to living organisms (Dinku, 2015). The presence of metal pollutant in fresh water is known to disturb the delicate balance of the aquatic systems. The above assertion could be said to be true as regards the study area as a result of urbanization and industrialization.

Vol.9, No.2 pp.25-39, 2021
Print ISSN: 2056-7537(print),
Online ISSN: 2056-7545(online)

MATERIALS AND METHODS

Study Area

Tin Can Island is located in Lagos, Nigeria with an estimated terrain elevation of above sea level is 7metres. It lies between Latitude N 6°26'2" and Longitude E 3°21'23". It is a shallow at some point and is open all-year round through the Lagos Harbour. Sea water associated with the semi-diurnal tidal oscillation experienced in the entire Gulf of Guinea Coast, and fresh water from the adjoining wetlands are important factors that determine the hydrological conditions and hence, the plankton of the creek (Onyema *et. al.*, 2003). While freshwater inflow dilutes the water during the rains, increasing brackish/marine conditions from the harbour marks the dry season. The tidal range recorded is low (between 0.4 m and 0.9 m), and tidal effects are delayed inland in proportion to the distance from the harbour. Surrounding it is a dense rainforest vegetation preceded by littoral mangrove assemblages characterize this area especially in places with reduced anthropogenic influence around the region. This riparian mangrove community is also typified by mangrove swamps which possess mudflats, mud banks and mangrove roots which are inhabited by polychaetes, amphipods, isopods, barnacles, oysters, periwinkles, fiddler crabs, sea cucumbers, hermit crabs, crabs, mudskippers and shrimps among others. The notable macro-floral species present here include *Acrotiscum aureum. Avicennia geminanas, Cocos nucifera* (coconut tree), *Paspalum virginatum, Rhizophora racemosa* (red mangrove), *R. harrisoni,* water fern, *Laguncularia racemosa* (Linn.) Gaertn, *Phoenix reclinata*, *Raphia hookeri*, *Elaeis guineensis* and *Pinus* sp. (pine tree). Floating aquatic macrophytes include *Lemna paucicostata* (duckweed), and *Eichhornia crassipes* (Mart.) Solms (water hyacinth).

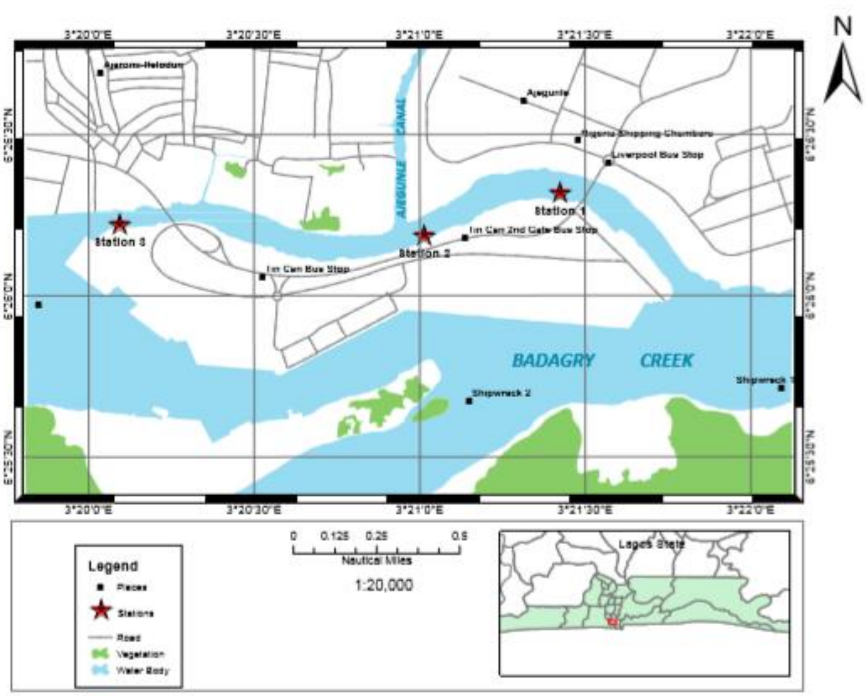

Figure 1: The Map of the study area of Tin Can Island Creek in Lagos, Nigeria.

Collection of Water Samples

The samples were taken once monthly from May-September (2020). Water samples were collected each time using 75cl plastic containers with each indicating the month of collection at the study site. Sampling was carried out between 09.00 and 12.00 hours on each sampling day. The plastic bottles were dipped into the water to collect the water samples and were taken to the laboratory for physical and chemical analysis.

Determination of Physicochemical Parameters

The Physicochemical parameters such pH, Temperature, Salinity, Conductivity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS) were measured using an in-situ Handheld Multimeter (Milwaukee Model pH600 and Laboratory Benchtop meter 860033-model). while the Dissolved Oxygen (DO) was measured using Milwaukee dissolved oxygen meter (MW 600 Model). Turbidity (NTU) was measured using a 20cm diameter Secchi disc. Biochemical Oxygen Demand (BOD) was determined by the 5-day BOD test (APHA, 2005). All the parameters were determined using the method recommended by APHA 2340C (1995) standards.

Determination of Heavy Metals in Water Sample

Metal analysis such as Copper (Cu), Iron (Fe), Zinc (Zn), Lead (Pb), Cadmium (Cd), Manganese (Mn), and Chromium Cr (mg/L) was carried out using a computer controlled Atomic Absorption Spectrophotometer (Buck Scientific 210/211 VGP Model). Sample preparation was by acid digestion, followed by filtration through a 0.45-micron membrane filter. Then aliquots of the filtrate were used to analyses for the various metals. The instrument setting and operational conditions were done in accordance with the manufacturers' specifications.

STATISTICAL ANALYSIS

Duncan (1955) Multiple Range Test was conducted to separate differences among means. The data were subjected to one-way analysis of variance (ANOVA) to test for significant differences and were considered significant at ($P<0.05$). All statistical analysis was conducted using the SPSS software version 23.

RESULTS

PHYSICOCHEMICAL PARAMETERS

Data for these Physicochemical Parameters are presented in Tables 1.

pH Value

pH value varied between low acidic and low alkaline. The lowest value (5.94) was recorded in September at Station 1, while the highest value (7.33) was recorded in July at Station 3. The mean and standard deviation is 7.10±0.32. There was significant difference ($p<0.05$).

Temperature (^{0}C)
Water temperature fluctuated slightly at all stations during the period of study. The lowest value (26 °C) was recorded in both June at Station 1 and August at Station 3, while the highest (30 °C) was recorded across varying stations in all months except August. There was significant difference ($p<0.05$) with the mean and standard deviation of 27.60±1.50.

Conductivity (µS/cm)
Conductivity fluctuated in value from May to September at all three sampling stations. The lowest conductivity value (2760.00 µS/cm) was recorded in September at Station 1, while the highest (24900.00 µS/cm) was recorded in June at Station 3. Conductivity value at Station 1 dropped slightly in June, picked up in July through August and dropped drastically in September. At Station 2, the value dropped slightly in June, picked up again in July and plunged in August through September. At Station 3, the value rose in June, plunged in July, picked up slightly in August and plunged again in September. The mean and standard deviation is 11060.5±6.44.

Salinity (‰)
There were wide variations in salinity values among the stations in May, June and August. Slight variations were recorded in the other months. The lowest value (1.50‰) was recorded in September at Station 1, while the highest value (18.40‰) was recorded in May at Station 3. The mean and standard deviation is 7.5±4.94.

Total Dissolved Solids (mg/L)
Total dissolved solids values fluctuated significantly throughout the sampling months. The value ranged between 1569.20 mg/L in September at Station 1 and 1518.9 mg/L in June at Station 2. The mean and standard deviation is 2328.33±3.04.

Total Suspended Solids (mg/L)
Similar values (30 mg/L) were recorded in September at both Stations 1 and 2. There were considerable variations in the TSS values recorded across the stations for each month especially May, June, July and August. Values ranged between 1.00 mg/L in June at Station 3 and 48.00 mg/L in June at Station 1. The mean and standard deviation is 14.81±13.15.

Turbidity (NTU)
There was slight variation in the turbidity value across the three stations throughout the five months. The lowest value (2.72 NTU) was recorded in May at Station 1, while the highest value (39.20 NTU) was recorded in September at Station 1. The mean and standard deviation is 13.95±11.42.

Dissolved Oxygen (mg/L)
DO values showed variation in value from May to September at all three stations. The lowest DO value (0.36 mg/L) was recorded in September at station 1, while the highest (5.12 mg/L) was recorded in June at station 3. DO value dropped sharply in June at Station 1, picked up in both July and August, remaining steady, and then, dropped sharply again in September. There was a slight

drop in value in June at Station 2. It rose slightly in July and remained steady through August with a sudden drop in September. It recorded a sharp rise in June at Station 3, remained steady with a gradual drop in August through September. The mean and standard deviation is 3.90±1.41.

Biochemical Oxygen Demand (mg/L)

BOD_5 value fluctuated across the stations in the five months under investigation. The lowest BOD_5 value (3.00 mg/L) was recorded in September at station 2, while the highest value (211 mg/L) was recorded in September at station 1. At Station 1, the value rose steeply in July, dropped slightly in August, and then, rose sharply in September. On the other hand, Station 2 experienced the sharpest drop in value in September, while Station 3 experienced a steady decline in value across all the months. The mean and standard deviation is 107±52.0

Table 1: Mean values for Physicochemical parameters of the Tin Can Island Creek between May- September (2020) in comparison with standards.

Parameters	Mean ±S. D.	WHO (2011)	EPA (2011)
pH	7.10±0.32	6.5-8.5	6.5-8.5
Temperature (^{o}C)	27.60±1.50	27.8/30	27.8-30
Conductivity (µS/cm)	11060.5±6.4	400	200-1000
Salinity (ppt, at 25°C)	7.50±4.94	-	-
TDS (mg/L)	2328.33±3.04.	2000	1000-2000
TSS (mg/L)	14.81±13.15	500-1000	30
Turbidity (NTU)	13.85±11.4	1.5	-
DO (mg/L)	3.90±1.41	3-5	7.5
BOD (mg/L)	107±52.0.	4	5-7

HEAVY METALS

Data for the heavy metals (Cu, Fe, Zn, Pb, Cd, Mn, and Cr) are presented in Tables 2, Figures 2-3.

Lead (mg/L)

Lead varied slightly across all three stations during the study period. Lead value ranged between 0.0004 mg/L and 0.0013 mg/L. The lowest value (0.0004 mg/L) was recorded in May at Station 3 and the highest value (0.0013 mg/L) was recorded in September at Station 1. The mean and standard deviation is 0.0007±0.0003. There was significant difference ($p<0.05$) in the concentrations across the various months.

Chromium (mg/L)

Chromium value varied slightly across all three stations during the study period. Chromium value ranged between 0.0005 mg/L and 0.0026 mg/L. The lowest value (0.0005 mg/L) was recorded in June at Station 1 and the highest value (0.0026 mg/L) was recorded in September at Station 3. The mean and standard deviation is 0.0014±0.0007. There was significant difference ($p<0.05$) in the concentrations across the various months.

Copper (mg/L)
Copper value <0.0016 mg/L in all stations during the sampling period. The mean and standard deviation is 0.0008±0.0003. There was no significant difference (p>0.05) in the concentrations across the various months.

Iron (mg/L)
Iron value ranged between 0.016 mg/L and 0.233 mg/L. The lowest value (0.016 mg/L) was recorded in May at Station 1 and the highest value (0.233 mg/L) was recorded in June at Station 2. The mean and standard deviation is 0.07±-.03. There was significant difference (p<0.05) in the concentrations across the various months.

Zinc (mg/L)
Zinc value ranged between 0.005 mg/L and 0.126 mg/L. The lowest value (0.005 mg/L) was recorded in May at Station 3 and the highest value (0.126 mg/L) was recorded in June at Station 1. The mean and standard deviation is 0.07±0.05. There was significant difference (p<0.05) in the concentrations across the various months.

Cadmium (mg/L)
Cadmium value ranged between 0.0004 mg/L and 0.0009 mg/L. The lowest value (0.0004 mg/L) was constant in June at Station 3 and in July at Station 3, while the highest value (0.0009 mg/L) was constant in May at Station 2, June at Station 1 as well as July at Station 1. The mean and standard deviation is 0.0007±0.0002. There was significant difference (p<0.05) in the concentrations of the metals across the various months.

Manganese (mg/L)
Manganese value ranged between 0.01 mg/L and 0.07 mg/L. The lowest value (0.01 mg/L) was constant in July at Station 3 while the highest and in May at Station 1. The mean and standard deviation is 0.048±0.0002. There was significant difference (p<0.05) in the concentrations across the various months.

Table 2. Monthly Variation in the Heavy Metals Concentrations in Surface Water of Tin Can Island Creek (May- September) in comparison with standards.

Months	**Zn** (mg/L)	**Fe** (mg/L)	**Mn**(mg/L)	**Cu** (mg/L)	**Cd** (mg/L)	**Pb** (mg/L)	**Cr** (mg/L)
May	0.07±0.03[a]	0.13±0.06[b]	0.06±0.04[a]	0.0014±0.0[a]	0.0005±0.0[b]	0.0009±0.0[b]	0.0015±0.0[bc]
June	0.07±0.03[a]	0.07±0.03[c]	0.05±0.02[a]	0.0014±0.0[a]	0.0008±0.0[b]	0.0009±0.0[b]	0.0013±0.0[c]
July	0.04±0.03[b]	0.51±0.30[a]	0.03±0.01[b]	0.0014±0.0[a]	0.0007±0.0[b]	0.0036±0.0[a]	0.0008±0.0[d]
Aug	0.07±0.03[a]	0.15±0.02[b]	0.05±0.04[a]	0.0014±0.0[a]	0.0028±0.0[a]	0.0008±0.0[b]	0.0016±0.0[b]
Sept	0.07±-.03[a]	0.17±0.03[b]	0.05±0.03[a]	0.0014±0.0[a]	0.0025±0.0[a]	0.0008±0.0[b]	0.0018±0.0[a]
WHO 2011	30	0.1	0.05	2.0	0.01	0.01	0.05
EPA 2017	30.0	0.5	0.02	3.0	0.5	2.0	0.05
DPR 2002	50-3000	20	-	35/20	0.03-0.3	2-20	-
NIS 2007	3.0	-	-	1.0	0.003	0.01	-

*At p>0.05
*With same superscript there is no significant difference.
*With different superscript there is a significant difference
*Nigeria Industrial Standard (Council, 2007).
*Environmental Protection Agency (EPA) (2017)
*World Health Organization (WHO). (2011).
*Department of Petroleum Resources (DPR) (2002).

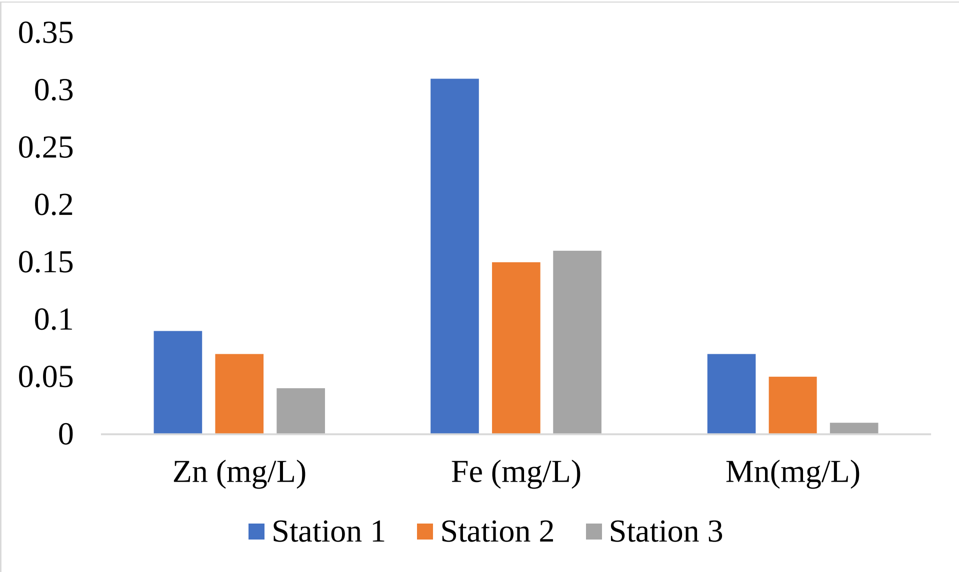

Figure 2: Showing the variation in concentrations of Zn, Fe and Mn across the Stations during the study

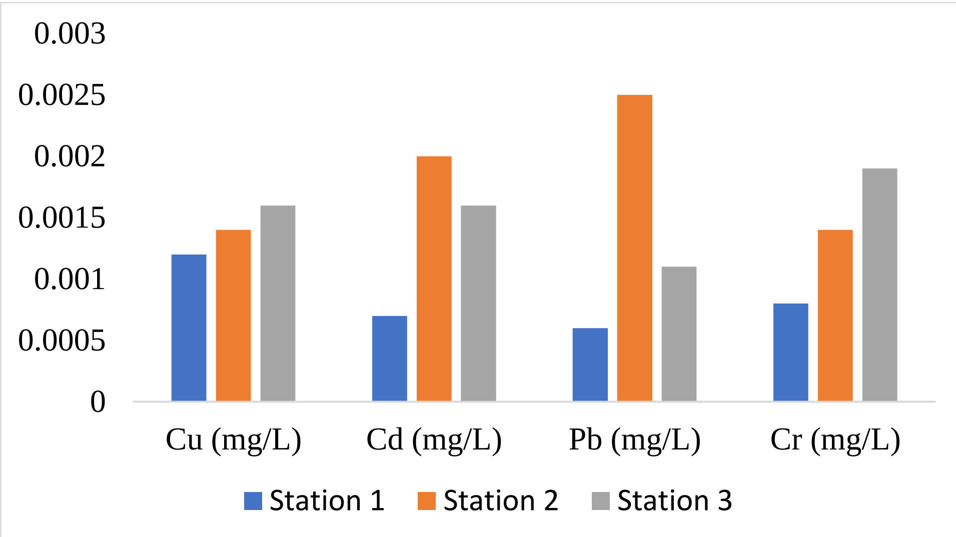

Figure 3: Showing the variation in concentrations of Cu, Cd, Pb and Cr across the Stations

LINEAR RELATIONSHIP BETWEEN THE METALS AND THE MONTHS

Data for the linear relationship between the heavy metals (Cu, Fe, Zn, Pb, Cd, Mn, and Cr) and the months are presented in Figures 4 to 7.

There was a positive relationship between the months and the concentration of iron (Fe) ($y = 0.0663x + 0.0077$) although Zinc (Zn) ($y = -0.018x + 0.0993$) and Manganese (Mn) ($y = -0.018x + 0.0993$) recorded a negative relationship with the months (Figure 4).

Figure 5 shows the linear regression graph of the association between the months and copper (Cu), cadmium (Cd), lead (Pb) and chromium (Cr). Cd ($y = 0.0006x - 0.0003$) and Cr ($y = 9E-05x + 0.0011$) recorded a positive relationship with the months while Cu ($y = -3E-19x + 0.0014$) and Pb ($y = -3E-05x + 0.0015$) had negative associations with the months (Figure 5)

The relationship between the stations and the heavy metal concentration are reported in Figure 6. Iron (Fe) recorded a positive relationship ($y = 0.096x + 0.0147$) with the stations while Zinc (Zn) ($y = -0.009x + 0.086$) and lead (Pb) ($y = -0.037x + 0.1193$) both recorded negative relationships with the stations as seen in (Figure 6).

Chromium, cadmium, copper and lead also had positive associations with the stations with linear regression equations of $y = 0.0005x + 0.0003$, $y = 0.0005x + 0.0005$, $y = 0.0002x + 0.001$ and $y = 0.0003x + 0.0009$ respectively (Figure 7).

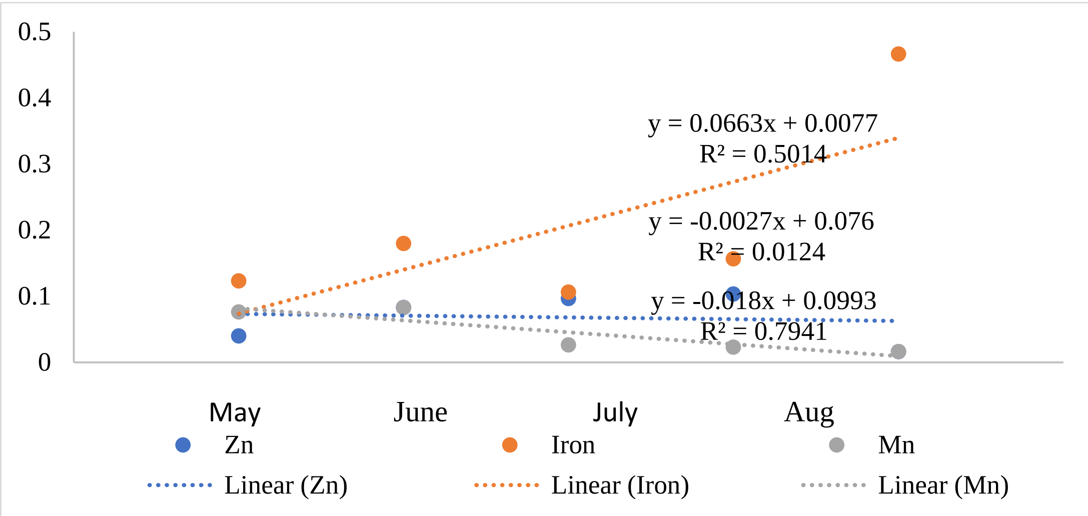

Figure 4: The relationship between the months and the heavy metal (Zn, Fe and Mn)

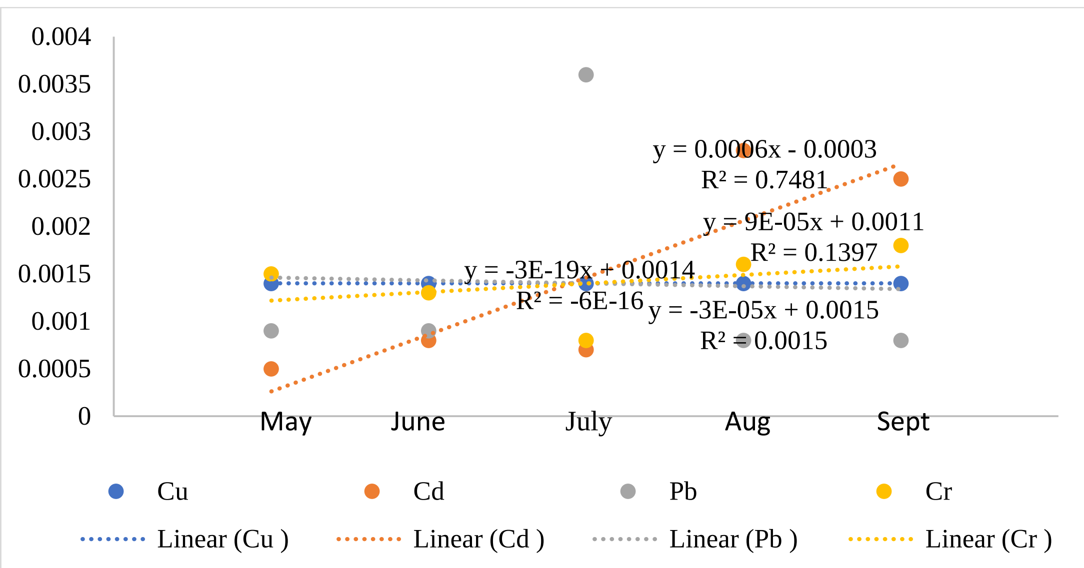

Figure 5: Shows the relationship between the months and heavy metal (Cu, Cd, Pb and Cr)

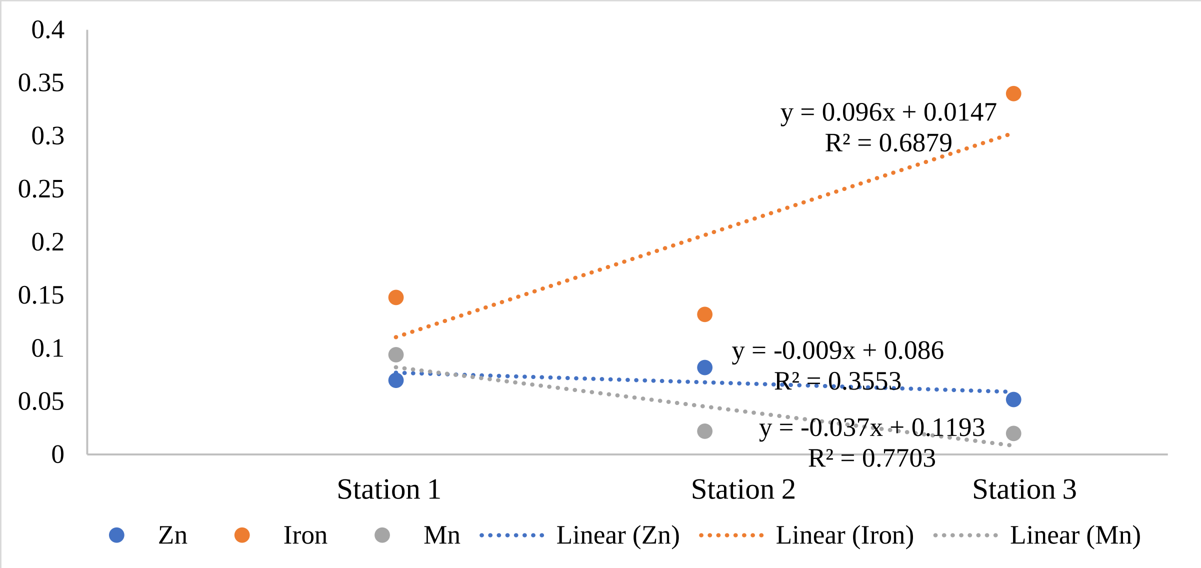

Figure 6: The relationship between the various stations and the heavy metal (Zn, Fe and Mn)

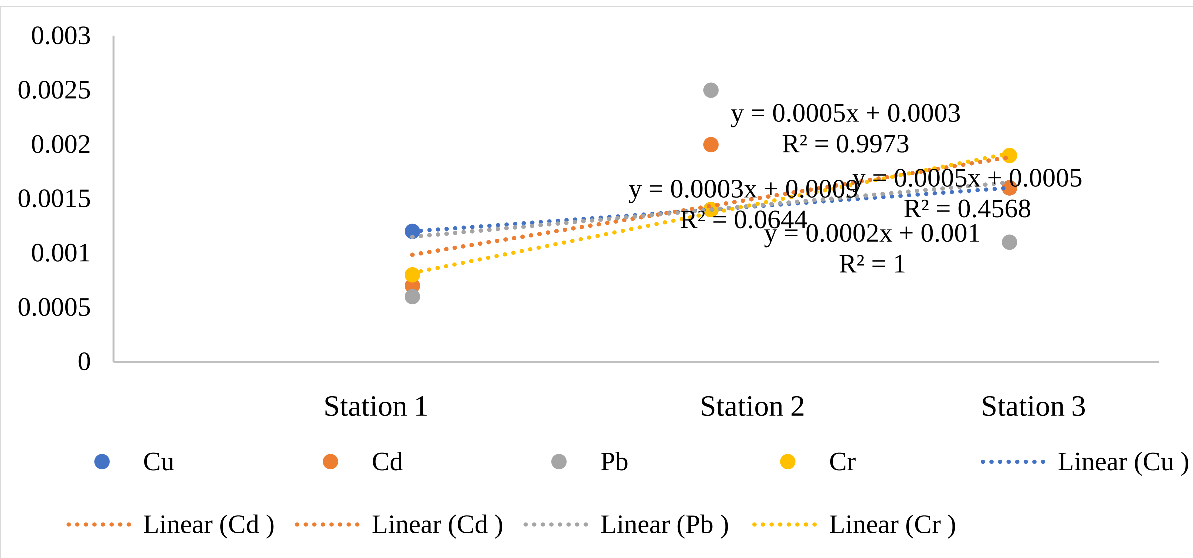

Figure 7: The relationship between the various stations and the heavy metal (Cu, Cd, Pb and Cr)

DISCUSSION

The variations in the physicochemical parameters as seen in Table 1. The results show that the water parameters fluctuated slightly across all the stations during the period of study. pH, Temperature, Salinity, Total Dissolved Solids, Total Suspended Solids and Turbidity were all within the World Health Organization (WHO, 2003) and Environmental Protection Agency (EPA,

2011) maximum permissible limits. Conductivity and Total Dissolved Solids exceeded the World Health Organization (WHO, 2003) and Environmental Protection Agency (EPA, 2011) maximum permissible levels for domestic use. The increase in conductivity and Total Dissolved Solids values could be related to increase in phytoplankton and macrophyte population leading to increase in the uptake of nutrients. It was observed that there was an increase in conductivity as salinity increased at the study sites. Similar observation was also observed by Adesalu *et al.* (2010).

pH value varied between low acidic and low alkaline during the study. This could be probably due to the stirring effect of the incoming flood from the rivers that converged towards the creek resulting in the mixing of the poorly alkaline or acidic bottom water with alkaline surface water to reduce pH in the creek (Kumar and Bahadur, 2009). The Biochemical Oxygen Demand value fluctuated across the stations in the five months during this study investigation. from 3.00 to 211 mg/L. The value rose steeply in July, dropped slightly in August, and then, rose sharply in September. port Seasonal water quality variations in a river affected by acid mine drainage decreased at the rate of 0.018% across the months this was in line with Olıas *et al.* (2004) who report same level of Seasonal water quality variations in a river which may have been affected by acid mine drainage. This fluctuation affected the distribution of different heavy metals around the creek. Although, most of the physicochemical parameters were very suitable for phytoplankton distribution and growth. This could also be attributed to why there were high nutrient loads in creek which could have led to the presence of large numbers of *Microcystis aeruginosa* in the creek. This observation is supported by the findings of Adakole *et al.* (2000), which attributed effective distribution and abundance of phytoplankton species as related to slight variation in physicochemical parameters. There were significantly different in the physico-chemical parameters across the station during the sampling period.

The metal concentrations in the Tin Can Island Creek are summarized in Table 2. The order of abundance of elements in the different stations are Fe > Zn > Mn > Cu > Cr > Pb > Cd in station 1, Fe > Zn > Mn > Pb> Cd > Cr > Cu in station 2 and Fe > Zn > Mn > Cu > Cr > Cd > Pb in station 3. Iron is the fourth most abundant element in the earth’s crust and is considered as a main factor determining the adsorption capacity (Huang *et al.,* 2021). Iron was found to be more abundant throughout the study with a positive relationship with the months shows an increase in the level of iron across the months. This agrees with Nakabayashi *et al.* (2002) who reported same Variation in iron (III) solubility and iron concentration in the northwestern North Pacific Ocean. Meanwhile. These variations observed were within the acceptable lime of Nigeria Industrial Standard (Council, 2007), Environmental Protection Agency (EPA) (2011), World Health Organization (WHO) (2011) and Department of Petroleum Resources (DPR) (2002). Fe is not a hazardous element here because the highest concentration (0.07 mg/l) did not exceeded the limit established by Nigeria Industrial Standard (NIS, 2007), Environmental Protection Agency (EPA, 2011), World Health Organization (WHO, 2011) and Department of Petroleum Resources (DPR, 2002).

The highest concentration of Fe was observed at during the study was not significantly different (P>0.05) from May to September. These values were lower than those reported for Ngada River and Cross River (Ayotunde, Offem, and Akan *et al.* 2010). Low concentrations of Zn, Mn, Cu, Cr, Pb and Cd are consistent with previous results in Niger Delta (Adeleye *et al.*, 2011). Similarly, low levels of these metals are in agreement with previous findings for the Niger Delta by Otitoju and Otitoju (2013); Vincent-Akpu and Mmom (2012); Ideriah, DavidOmeiema, and Ogbonna (2012); Issa *et al.* (2011). The reason for the low values have been affirmed to the high energy of current and the volume of water that ensures proper flushing of the creek system (Akankali and Davies, 2020).

The complex hydrodynamic and chemical properties of a particular river is peculiar to the behavior and concentrations of each metal which makes it difficult to compare concentrations from one river to another. Nevertheless, the variations in the concentrations of these metals in the Tin Can Island Creek could be attributed to the impact of the activities carried out in that area such as sand mining, domestic waste and inflow of effluents from the surrounding industries in the creek (Davies and Okonkwo, 2021). Consequently, the concentration of these metals in Nigerian coastal waters, fauna and sediment are of great concern, warranting the need for periodic sampling and analyses of both water and water resources in around the creeks in order to monitor the pollution and productivity status of the marine ecosystem and compare the data with international standards (Abbas *et al.*, 2016).

CONCLUSION

It could be concluded that the Creek along the Tin Can Island is less polluted. This was evident as the accumulation of heavy metals were within the internationally acceptable standards as reported by WHO and EPA. This implies that the concentrations of the metals analysed in this study were not high enough to suggest serious contamination in the surface water of the Tin Can Island Creek. However, if these levels are not checked, they may increase the potential of bioaccumulation in the aquatic organisms and inhabitants that depends on the creek for survival. It is therefore recommended that the various anthropogenic activities that constitute the sources of effluents and solid wastes introducing pollutants into the Tin Can Island Creek be adequately monitored, controlled and completely prevented where possible. Additionally, there should be continuous bio-monitoring of aquatic resources in the Creek, particularly those that constitute a source of human food.

REFERENCE

Abbas, A., Al-Amer, A. M., Laoui, T., Al-Marri, M. J., Nasser, M. S., Khraisheh, M., & Atieh, M. A. (2016). Heavy metal removal from aqueous solution by advanced carbon nanotubes: critical review of adsorption applications. *Separation and Purification Technology*, *157*, 141-161.

Adakole, J. A. (2000). The effects of domestic, agricultural and industrial effluents on the water quality and biota of Bindare stream, Zaria-Nigeria. *Department of Biological Sciences, Ahmadu Bello University, Zaria, Nigeria, Ph. D Thesis, (Pg. 256).*

Adeleye A.O., Shelle R.O.D., and Akinnigbagbe A.E., (2011), Pollutant dynamics and distribution of sediments north of Lagos Lagoon ecosystem, Nature and Science, 9 (5): 1316

Adesalu, T., Bagbe, M., & Keyede, D. (2010). Hydrochemistry and phytoplankton composition of two tidal creeks in South-Western Nigeria. *Revista de biologia tropical*, *58*(3), 827-840.

Agarin O. J., Davies, I. C. And Akankali J. A. (2020). Effect of Water Quality on the Distribution of Phytoplankton in Tin Can Island Creek of the Lagos Lagoon, Nigeria. *International Journal of Agriculture and Earth Science.* 6(1): 59-76.

Akan, J. C., Abdulrahman, F. I., Sodipo, O. A., Ochanya, A. E., & Askira, Y. K. (2010). Heavy metals in sediments from river Ngada, Maiduguri Metropolis, Borno state, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*, *2*(9), 131-140.

Akankali, J.A. and Davies, I.C. (2020). Analysis of heavy metals concentration in different media of Iwofe Creek, Niger Delta, Nigeria; *International Journal of Scientific and Research Publications,* 10(04): 2250-3153.

Akankali J.A., *Davies I.C. and Kpaniku, N. (2019). Assessment of heavy metals concentrations in the upper reaches of Bonny River, Niger delta, Nigeria. African *Journal of Agriculture Technology and Environment,* 8(1): 62-73.

Authman, M. M., Zaki, M. S., Khallaf, E. A., & Abbas, H. H. (2015). Use of fish as bio-indicator of the effects of heavy metals pollution. *Journal of Aquaculture Research & Development*, *6*(4), 1-13.

Ayotunde, E. O., Offem, B. O., Ikpi, G. U., Ochang, S. N., & Ada, F. B. (2011). Influence of seasons on water quality, abundance of fish and plankton species of Ikwori Lake, South-Eastern Nigeria. *Fisheries and Aquaculture Journal*, *13*, 1-18.

Camusso, M., Vigano, L and Baistrini, R. (1995). Bioaccumulation of trace metals in rainbow trout. *Ecotoxicology and Environmental Safety*, 31: 133 – 141.

Council, S. G. (2007). Nigerian Industrial Standard NIS 554: 2007.

Davies, I. C**.** and Okonkwo, S. E. (2021). Analyses of Some Heavy Metal and Nutrients of Water Samples from Ajegunle Creek in Lagos. International Journal of Environment and Pollution Research.Vol.9, No.1 pp.7-26.

Davies, I. C. and Okonkwo, S. E. (2021). Analyses of Some Heavy Metal and Nutrients of Water Samples from Ajegunle Creek in Lagos. *International Journal of Environment and Pollution Research*.Vol.9, No.1 pp.7-26.

DPR. 2002. Pesticide Chemistry Database. Environmental Monitoring Branch, California Department of Pesticide Regulation. 2002.

Dinku, D. E. (2015). *Assessment Of The Levels Of Heavy Metals In Sediments, Water And Fish From The Weija Dam* (Doctoral dissertation, University of Ghana).

Ekeanyanwu, C. R., Ogbuinyi, C. A., & Etienajirhevwe, O. F. (2010). Trace metals distribution in fish tissues, bottom sediments and water from Okumeshi River in Delta State,

Environmental Protection Agency (EPA) (2011) Drinking Water Contaminants-Standards and Regulations. EPA 822-F-18-001, Office of Water U.S. Environmental Protection Agency, Washington DC.

Huang, J., Jones, A., Waite, T. D., Chen, Y., Huang, X., Rosso, K. M., ... & Zhang, H. (2021). Fe (II) Redox Chemistry in the Environment. *Chemical Reviews*.

Kumar, A., & Bahadur, Y. (2009). Physico-Chemical Studies on the Pollution Potential of River Kosi at Rampur(India). *World Journal of Agricultural Sciences*, *5*(1), 1-4. Olıas *et al.* (2004)

Nakabayashi, S., Kuma, K., Sasaoka, K., Saitoh, S., Mochizuki, M., Shiga, N., & Kusakabe, M. (2002). Variation in iron (III) solubility and iron concentration in the northwestern North Pacific Ocean. *Limnology and oceanography*, *47*(3), 885-892.

Okoro C.U. and Onyena, A. P., Nwosu, A.O., Chukwueloka, H.E., Eyo, V. (2021). Assessment of Physicochemical and Heavy Metal Concentrations of Surface Water Creeks Adjoining Lagos Lagoon Nigeria. International Journal of Maritime and Interdisciplinary Research, 2.

Olıas, M., Nieto, J. M., Sarmiento, A. M., Cerón, J. C., & Cánovas, C. R. (2004). Seasonal water quality variations in a river affected by acid mine drainage: The Odiel River (South West Spain). *Science of the total environment*, *333*(1-3), 267-281.

Otitoju, O., & Otitoju, G. T. O. (2013). Heavy metal concentrations in water, sediment and periwinkle (Tympanotonus fuscastus) samples harvested from the Niger Delta region of Nigeria. *African Journal of Environmental Science and Technology*, *7*(5), 245-248.

World Health Organization (2011). Guidelines for drinking-water quality. *WHO chronicle*, *38*(4), 104-108.
Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *3*(3).

Vincent-Akpu, I. F., & Mmom, T. C. (2012). Trace metals in water, fish and sediments from Elechi Creek, Port Harcourt, River State, Nigeria.Ideriah, DavidOmeiema, and Ogbonna (2012); Issa *et al.* (2011