

Comparative Analysis of Concentrations of Heavy Metals in Surface Water of Nafada, Ashaka and Almakashi Corridors of River Gongola, Nigeria

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Abstract

Study on comparative analysis of heavy metals' concentrations in surface water was carried out in three selected stations: Nafada, Ashaka and Almakashi along the corridors of River Gongola in Gombe state for a period of eighteen months. The water samples were collected in triplicate from the sampling stations. Water samples were collected using sampling bottles of 250ml dipped below the water surface for water collection. Zinc, lead, copper, cadmium and manganese were determined using Atomic Absorption Spectrophotometer. The result elucidates that most of the heavy metals were found to be within the recommended ranges as compared to standard limits. The result of concentrations of heavy metals of the surface water elucidates that there was significant difference ($P > 0.05$) among the months in respect to zinc and there was no significant difference in the concentration of lead ($P < 0.05$). The concentrations follow the order ($Zn > Cd > Cu > Mn > Pb$). The higher concentration of heavy metals was found in Ashaka corridors with Zinc concentration ranging between 0.99 ± 0.01 and 0.33 ± 0.01 , Cadmium 0.88 ± 0.02 and 0.03 ± 0.00 , Copper 0.58 ± 0.02 and 0.14 ± 0.02 , Manganese 0.87 ± 0.56 and 0.17 ± 0.01 , Lead 0.28 ± 0.36 and 0.01 ± 0.01 . The waste water from the cement effluent factory in Ashaka might have impacted negatively on the water chemistry by elevating the levels of some heavy metals. Therefore, more intensive treatment of the factory effluents before discharging into the River Gongola is recommended.

Keywords: Factory Effluent, Heavy Metal, Corridors of River Gongola, Zinc, Gombe State.

Introduction

The term 'heavy metal' refers to any metal or metalloid that has relative atomic density greater than $4g/cm^3$ or $5g/cm^3$ and is toxic even at very low concentration (Saravpreet *et al.*, 2018). Heavy metals could get easily dissolved and are transported by water where they are readily taken up by aquatic biota. Due to its high toxicity, long persistence and non-biodegradable nature in the food chain, they constitute a core group of aquatic contaminants causing cellular toxicity, mutagenicity and carcinogenicity in animals; globally, aquatic environments are heavily polluted with heavy metals due to high exposure to the environment as a result of the growing urbanization and globalization in the last few decades (Authman *et al.*, 2013; Ullah *et al.*, 2017). Heavy metals in the environment are

present partly due to anthropogenic and partly due to biogenic sources, which both have undeniable consequences (Ajeagah et al., 2013). Heavy metal pollutants present in water can accumulate in aquatic organisms from water, sediments or through the food chain (Oladunjoye et al., 2021). Some heavy metals like Cu, Zn or Fe are also important for many biochemical processes in living organisms and they are essential elements for aquatic plants and animals. However, in the case of higher concentrations of those metals, they also become toxic and considered as pollutants. Heavy metals are natural constituents of the earth crust; however, unsystematic anthropogenic activities have significantly distorted their geochemical cycles and biochemical balance in the ecosystem (Singh et al., 2011). Industrial activities as well as agriculture and mining create a potential source of metal pollution in the aquatic environment (Hosseini et al., 2014). Over the past centuries, heavy metals have been discharged into rivers and estuaries as a result of rapid industrialization, urban and industrial activities in coastal areas that introduced significant quantity of trace metals into the marine environment thereby causing permanent disturbances in marine ecosystems, leading to environmental and ecological degradation constituting a potential risk to flora and fauna species, including humans particularly through food chains (Oladunjoye et al., 2021).

Statement of the Problem

Significant variety of domestic sewage, industrial discharge and agricultural waste are washed into the corridors of Nafada, Ashaka and Almakashi along River Gongola complex in Gombe state of Nigeria. The generated wastes pollute the water with a variety of pollutants (physical, chemical and biological). Such pollutants might accumulate in various organs of fishes and sediments which have been recognized as excellent bio indicator and as the ultimate sink for heavy metals that give vital information such as the source, distribution and levels of pollution. Concentration of pollutants significantly impact on the food web of the aquatic ecosystem when its level exceeds the permissible limit which in turn affects humans (Daniel et al., 2017).

Significance of the Study

The rise in the incidences of heavy metal poisoning among humans have attracted the attention of researchers in identifying the sources and determining their contributions to the heavy metal burden on individuals (Daniel et al., 2017). The daily accumulation of heavy metals in the environment has increased significantly due to increasing anthropogenic activities causing pollution of aquatic water bodies. Although, metals are present naturally in trace amount in freshwaters from the weathering of rocks and soils, they become toxic when a particular level is reached (Oluowo and Sobor, 2016). Because of these toxic manifestations of heavy metals' exposure and intake, heavy metals must be monitored to maintain and sustain good health. The World Health Organization (WHO) and the Food and

Agricultural organization (FAO) have recommended some maximum limits for each of these metals in various food substances (Morais et al., 2012).

Aim and Objectives

The aim of this study is to determine the concentration of heavy metals concentrations in surface water of Nafada, Ashaka and Almakashi corridors of River Gongola of Gombe State in Nigeria through the following objectives:

1. To determine seasonal variation in the concentration of heavy metals in surface water at Nafada, Ashaka, and Almakashi corridors of River Gongola
2. To compare the concentrations of heavy metals in the water columns of the Nafada, Ashaka, and Almakashi corridors of River Gongola among themselves and in relation to standard permissible limits.

Materials and Methods

Description of the Study Area

The River Gongola is in north eastern Nigeria and the principal tributary of the River Benue. The river rises on the eastern slopes of the Jos plateau and falls to the Gongola Basin, running north-eastern into Nafada Local Government (11°00', 11°15'N and 11°15', 11°30'E), Gombe State. The river continued from Nafada in the Northeast direction to Lake Chad. It turns south from Nafada passing through the corridors of Ashaka (10°45', 11°0'N and 11°30', 11°45'E), Almakashi (10°44', 40.584'N, and 11°30', 32.574'E) and Kupto and then continued to Dadin Kowa dam in Yamal Deba Local Government of Gombe State (Figure 1).

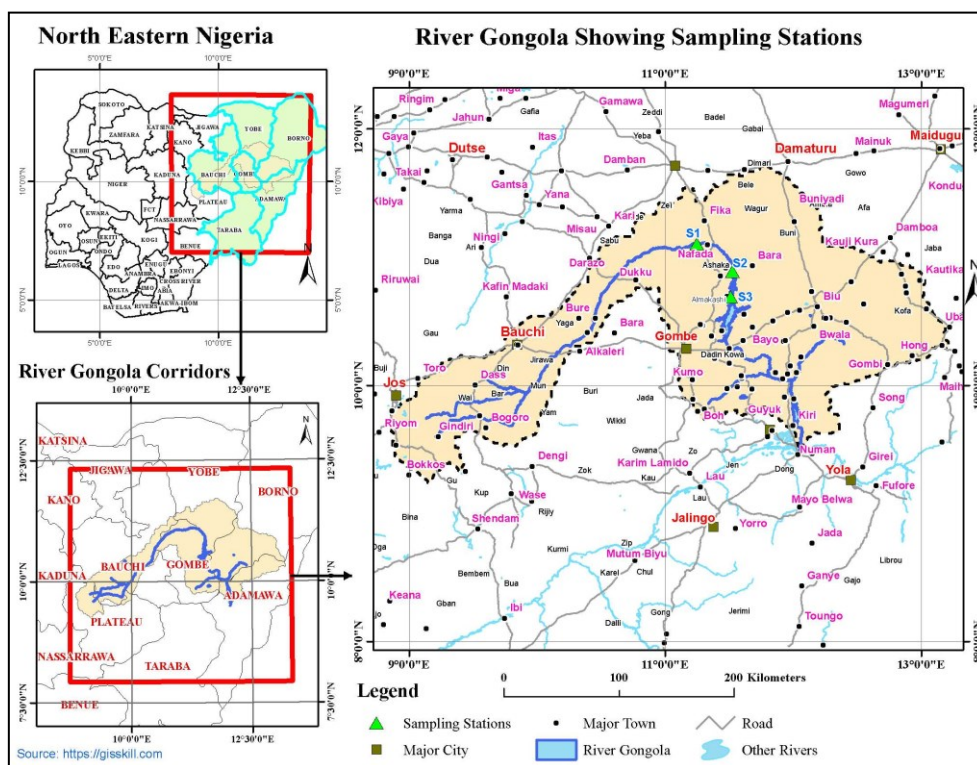


Figure 1: Study Area projected from Map of Nigeria showing River Gongola Corridors

Water Sampling

Water samples were collected for the period of 18 months from January 2020 to June 2021. The water samples were collected in triplicate from the sampling stations. Station₁ (Nafada corridor), station 2 (Ashaka corridor) and station 3 (Almakashi corridor) all along River Gongola complex in Gombe state. Water samples were collected using sampling bottles; the sampling bottles were thoroughly cleaned after washing with detergent and rinsed. It was soaked in Nitric acid for two days followed by a thorough wash with deionized distilled water. Sample bottle of 250ml were used by dipping below the water surface for the water collection.

Determination of Heavy Metals in Water Sample

The water samples were digested as follows: A water sample of 100cm³ was transferred into a beaker and 5ml concentrated HNO₃ was added. The beaker with the content was placed on a hot plate and evaporated down to about 20cm³. The beaker was cooled and another 5ml concentrated HNO₃ was added. The beaker was covered with watch glass and returned to the hot plate. The heating continued and then small portion of HNO₃ was added until the solution appeared light colour and clear the beaker wall; then watch glass was washed with distilled water and the sample was filtered to remove some insoluble materials that can clog the atomizer. The volume was adjusted to 100cm³ with distilled water (Radojevic & Bashkin, 1999). Dissolved concentrations of heavy metals in the water samples (Zinc, lead, copper, cadmium and manganese) were determined using Atomic Absorption Spectrophotometer (AAS) Model VGP 210 as described in the manufacturer's instruction manual.

Table 1: Acceptable ranges of Heavy Metals in Drinking Water

Heavy Metals	Maximum Concentration (WHO)	Maximum Concentration (NAFDAC)
Zinc (Zn)	5 mg/l	5 mg/l
Arsenic (As)	0.01 mg/l	0.0 mg/l
Magnesium (Mg)	50 mg/l	30 mg/l
Calcium (Ca)	50 mg/l	50 mg/l
Cadmium (Cd)	0.003 mg/l	0.0 mg/l
Lead (Pb)	0.01 mg/l	0.0 mg/l
Silver (Ar)	0.0 mg/l	0.0 mg/l
Mercury (Hg)	0.001 mg/l	0.0 mg/l

Source: Lavanya et al. (2021)

The determined values of heavy metals will be compared to the maximum tolerable limit for drinking water as in Table 1. There are different standards but the most commonly used standards worldwide are World Health Organization (WHO) and National Agency for Food and Drugs Administration and Control (NAFDAC) of Nigeria (Lavanya et al., 2021).

Results

The results of monthly variations of surface water heavy metals in Nafada station is presented in Table 2 as follows:

Table 2: Monthly Variations of Concentrations of Heavy Metals in Surface Water at Nafada Station

Months & Year	Heavy Metals				
2020	Zinc	Lead	Copper	Cadmium	Manganese
January	0.46±0.01 ^{fg}	0.02±0.01 ^b	0.21±0.01 ^g	0.30±0.01 ^e	0.23±0.01 ^b
February	0.47±0.02 ^{fg}	0.01±0.01 ^b	0.20±0.01 ^g	0.21±0.02 ^f	0.20±0.01 ^b
March	0.53±0.02 ^e	0.04±0.01 ^b	0.28±0.01 ^f	0.35±0.01 ^d	0.26±0.01 ^b
April	0.52±0.02 ^e	0.02±0.01 ^b	0.29±0.01 ^{ef}	0.13±0.02 ^h	0.33±0.00 ^b
May	0.63±0.02 ^c	0.04±0.01 ^b	0.32±0.01 ^{cde}	0.56±0.02 ^a	0.27±0.01 ^b
June	0.61±0.01 ^c	0.02±0.01 ^b	0.30±0.02 ^{ef}	0.30±0.01 ^e	0.32±0.01 ^b
July	0.57±0.01 ^d	0.00±0.00 ^b	0.14±0.02 ^h	0.46±0.01 ^c	0.15±0.01 ^b
August	0.33±0.01 ^j	0.02±0.01 ^b	0.16±0.01 ^h	0.23±0.00 ^f	0.17±0.01 ^b
September	0.42±0.02 ⁱ	0.06±0.01 ^{ab}	0.40±0.01 ^b	0.23±0.02 ^f	0.23±0.01 ^b
October	0.43±0.01 ^{hi}	0.15±0.21 ^a	0.46±0.01 ^a	0.47±0.01 ^c	0.37±0.01 ^b
November	0.47±0.01 ^{fg}	0.02±0.00 ^b	0.48±0.02 ^a	0.16±0.01 ^g	0.26±0.02 ^b
December	0.45±0.01 ^{ghi}	0.07±0.02 ^{ab}	0.40±0.01 ^b	0.45±0.03 ^c	0.86±0.01 ^b
2021					
January	0.71±0.02 ^{hi}	0.02±0.00 ^b	0.31±0.02 ^{def}	0.03±0.00 ⁱ	0.21±0.01 ^b
February	0.44±0.03 ^{ghi}	0.04±0.01 ^b	0.32±0.02 ^{cde}	0.06±0.00 ⁱ	0.25±0.02 ^b
March	0.50±0.01 ^{ef}	0.04±0.01 ^b	0.33±0.01 ^{cd}	0.52±0.03 ^b	0.87±0.56 ^a
April	0.60±0.02 ^{cd}	0.06±0.01 ^{ab}	0.35±0.02 ^c	0.14±0.01 ^{gh}	0.30±0.01 ^b
May	0.81±0.02 ^a	0.05±0.01 ^b	0.41±0.02 ^b	0.56±0.02 ^d	0.39±0.00 ^b
June	0.71±0.02 ^b	0.04±0.01 ^b	0.31±0.01 ^{def}	0.37±0.02 ^d	0.26±0.01 ^b
Mean	0.52	0.04	0.31	0.29	0.83
Stand. Dev	0.11	0.05	0.09	0.15	0.90
P < 0.05	0.000	0.349	0.000	0.000	0.473

Means with the same alphabet down the column are not statistically significant at $P < 0.05$.

The results elucidated that there is significant difference ($P < 0.05$) among the months in respect to zinc, copper and cadmium concentrations, while there is no significant difference ($P > 0.05$) among the months in respect to lead and manganese concentrations.

Table 3 elucidates the results of monthly variations of surface water heavy metals in Ashaka station that there is significant difference ($P < 0.05$) among the months in respect to zinc, copper, cadmium and manganese concentrations while there is no significant difference ($P > 0.05$) among the months in respect to lead concentration.

Table 3: Monthly Variations of Concentrations of Heavy Metals in Surface Water at Ashaka Station

Months	Heavy Metals				
2020	Zinc	Lead	Copper	Cadmium	Manganese
January	0.54±0.04 ^j	0.02±0.00 ^b	0.22±0.01 ^j	0.27±0.01 ^g	0.26±0.01 ^{hi}
February	0.61±0.02 ^{hi}	0.05±0.01 ^b	0.26±0.01 ⁱ	0.16±0.01 ^k	0.34±0.01 ^e
March	0.70±0.02 ^{ef}	0.06±0.01 ^b	0.38±0.01 ^g	0.51±0.00 ^d	0.34±0.02 ^e
April	0.80±0.01 ^c	0.28±0.36 ^a	0.47±0.02 ^c	0.88±0.02 ^a	0.46±0.01 ^a
May	0.99±0.01 ^a	0.06±0.01 ^b	0.58±0.02 ^a	0.75±0.00 ^b	0.43±0.01 ^{ab}
June	0.79±0.02 ^c	0.04±0.00 ^b	0.27±0.03 ⁱ	0.58±0.01 ^c	0.40±0.02 ^{cd}
July	0.64±0.02 ^{gh}	0.00±0.00 ^b	0.23±0.01 ^j	0.46±0.02 ^e	0.30±0.02 ^{fg}
August	0.51±0.03 ^j	0.02±0.00 ^b	0.21±0.01 ^j	0.23±0.01 ^h	0.25±0.02 ⁱ
September	0.59±0.02 ⁱ	0.01±0.01 ^b	0.42±0.01 ^{de}	0.22±0.01 ^{hi}	0.25±0.01 ⁱ
October	0.53±0.04 ^j	0.02±0.01 ^b	0.57±0.01 ^a	0.50±0.01 ^d	0.29±0.01 ^{fg}
November	0.60±0.01 ^{hi}	0.05±0.04 ^b	0.50±0.01 ^b	0.20±0.01 ^{ij}	0.31±0.01 ^{efg}
December	0.59±0.02 ⁱ	0.03±0.01 ^b	0.43±0.02 ^d	0.31±0.01 ^f	0.28±0.01 ^{gh}
2021					
January	0.60±0.01 ^{hi}	0.02±0.02 ^b	0.39±0.01 ^{fg}	0.18±0.01 ^{jk}	0.37±0.01 ^d
February	0.67±0.01 ^{fg}	0.04±0.01 ^b	0.30±0.01 ^h	0.14±0.01 ^l	0.42±0.01 ^{bc}
March	0.74±0.02 ^{de}	0.06±0.01 ^b	0.43±0.01 ^{de}	0.33±0.01 ^f	0.45±0.01 ^{ab}
April	0.86±0.01 ^b	0.05±0.02 ^b	0.42±0.01 ^{ef}	0.16±0.01 ^k	0.46±0.01 ^a
May	0.97±0.02 ^a	0.06±0.01 ^b	0.40±0.01 ^{efg}	0.32±0.01 ^f	0.45±0.01 ^{ab}
June	0.78±0.02 ^{cd}	0.05±0.00 ^b	0.40±0.02 ^{efg}	0.51±0.01 ^d	0.32±0.02 ^{ef}
Mean	0.69	0.05	0.38	0.37	0.35
Stand. Dev	0.14	0.09	0.11	0.21	0.07
P < 0.05	0.000	0.198	0.000	0.000	0.000

Means with the same alphabet down the column are not statistically significant at P < 0.05.

The results of monthly variations of surface water heavy metals in Almakashi station as presented in Table 4 elucidated that there was statistical significant difference (P< 0.05) among the months in respect to zinc, lead, copper, cadmium and manganese concentrations.

Table 4: Monthly Variations of Concentrations of Heavy Metals in Surface Water at Almakashi Station

Months & Year	Heavy Metals				
2020	Zinc	Lead	Copper	Cadmium	Manganese
January	0.49±0.02 ^{ef}	0.05±0.01 ^{bc}	0.22±0.02 ^{gh}	0.29±0.01 ^{gh}	0.25±0.02 ^e
February	0.46±0.02 ^{fg}	0.03±0.01 ^{cde}	0.24±0.01 ^{efgh}	0.14±0.02 ^{jk}	0.24±0.01 ^e
March	0.60±0.02 ^c	0.05±0.01 ^{bc}	0.29±0.01 ^{defg}	0.40±0.02 ^e	0.31±0.02 ^c
April	0.79±0.01 ^a	0.02±0.00 ^{def}	0.31±0.02 ^{def}	0.16±0.01 ^j	0.30±0.01 ^c
May	0.78±0.03 ^a	0.05±0.01 ^{bc}	0.46±0.01 ^a	0.46±0.01 ^d	0.29±0.01 ^{cd}
June	0.49±0.02 ^{ef}	0.01±0.01 ^{ef}	0.23±0.17 ^{fgh}	0.44±0.02 ^d	0.24±0.01 ^e
July	0.39±0.01 ⁱ	0.08±0.01 ^a	0.30±0.01 ^{defg}	0.58±0.01 ^b	0.19±0.01 ^f
August	0.50±0.01 ^e	0.07±0.01 ^{ab}	0.18±0.02 ^h	0.21±0.02 ⁱ	0.17±0.01 ^f
September	0.50±0.02 ^e	0.00±0.00 ^f	0.35±0.11 ^{bcd}	0.34±0.01 ^f	0.32±0.01 ^c
October	0.56±0.01 ^d	0.01±0.00 ^{ef}	0.40±0.01 ^{abc}	0.47±0.01 ^d	0.26±0.02 ^{de}
November	0.41±0.02 ^{hi}	0.07±0.01 ^{ab}	0.36±0.01 ^{bcd}	0.32±0.01 ^g	0.44±0.02 ^a
December	0.44±0.01 ^{gh}	0.04±0.01 ^{cd}	0.32±0.01 ^{cde}	0.37±0.01 ^f	0.41±0.01 ^{ab}
2021					
January	0.48±0.02 ^{ef}	0.01±0.01 ^{ef}	0.29±0.01 ^{defg}	0.40±0.02 ^e	0.42±0.02 ^{ab}
February	0.47±0.01 ^{efg}	0.04±0.01 ^{bc}	0.29±0.01 ^{defg}	0.27±0.02 ^h	0.39±0.01 ^b
March	0.73±0.02 ^b	0.06±0.01 ^{bc}	0.35±0.01 ^{bcd}	0.84±0.01 ^a	0.43±0.00 ^a
April	0.62±0.03 ^c	0.05±0.01 ^{bc}	0.39±0.00 ^{abc}	0.13±0.02 ^k	0.39±0.01 ^b
May	0.60±0.01 ^c	0.07±0.01 ^{ab}	0.41±0.02 ^{ab}	0.50±0.01 ^c	0.44±0.02 ^a
June	0.50±0.02 ^e	0.04±0.01 ^{bc}	0.33±0.01 ^{bcd}	0.51±0.01 ^c	0.32±0.01 ^c
Mean	0.54	0.04	0.32	0.38	0.32
Stand. Dev	0.11	0.02	0.07	0.17	0.08
P < 0.05	0.000	0.000	0.000	0.000	0.000

Means with the same alphabet down the column are not statistically significant at $P < 0.05$

However, the higher concentrations of heavy metals were found in Ashaka corridor with Zinc concentration ranging between 0.99 ± 0.01 in the month of May, 2020 and 0.33 ± 0.01 in the month of August at Nafada; Cadmium high concentrations were detected at Ashaka 0.88 ± 0.02 in the month of April, 2020 (Table 3) and low concentration of 0.03 ± 0.00 at Nafada in the month of January, 2021 (Table 2), Copper high concentrations were detected at Ashaka (0.58 ± 0.02) in the month of May, 2020 and low concentration at Nafada (0.14 ± 0.02) in the month of July, 2020. Manganese high concentration was detected at Nafada (0.87 ± 0.56) in the month of March, 2021 and low concentration still at Nafada (0.17 ± 0.01) in the month of August, 2020. In the month of April and September, 2020 the concentrations of Lead were 0.28 ± 0.36 and 0.01 ± 0.01 being highest and lowest respectively at Ashaka station (Table 3).

Discussions

Heavy metals are classified as specific pollutants, and their effects on the environment is characterized by high toxicity, bioaccumulation, biomagnification and participation in biogeochemical cycles (Amić & Tadić, 2018). The general high and broad concentration variations of Zn are likely associated with the forms of agricultural practices, domestic waste that are released into the River (Hati et al., 2008); however, Zn values in this studied sites did not exceed the limit of 5mg/l recommended by WHO and NAFDAC (Table 1) while Cd and Pb were mostly beyond the recommended limits of 0.003mg/l and 0.001mg/l respectively. This study has established that heavy metal concentration levels in surface water typically follow the order Zn > Cd > Cu > Mn > Pb while Gwasko (2012) reported an order of Fe > Cu > Cr > Mn > Zn > Ni > Pb > Cd and Barbara (2006) has established that heavy metal concentration levels in fish in the order of Fe > Zn > Pb > Cu > Cd > Hg and the reason for this might have been drawn from the natural abundance of the metals however, strict conformity to this order are not usually observed from most studies.

The observed high metal concentrations in Ashaka can be attributed to the effluent discharges and dust from the cement factory occurring in and around the area. The lowest metal concentration found at Nafada corridor may be due to dilution in the area. The River Gongola is the major source of water for domestic activities such as washing and playing along the banks of the river as compared to other areas sampled. This might have contributed to the washing away of the top sediments and thereby reduced accumulation of metals. Generally, there is a significant difference in heavy metal concentrations in the months (November, December, January, February, March and April) of dry season compared with excessive washing of the surface soil during the wet season which could also account for the lower concentrations in the wet season. The waste water from the cement effluent factory Ashaka (Station 2) impacted negatively on the water chemistry by elevating the levels of some heavy metals (Zn, Cd, Cu, Mn, and Pb).

Conclusion

The study site is enriched and contaminated with Cd, Cu, Mn, and Pb beyond the recommended limits by WHO and NAFDAC which is an indication of the anthropogenic and industrial activities in the study sites. Generally, the mean concentrations of the heavy metals were higher in the months of dry season than the months of wet season. The study provides baseline data that can be used in future to evaluate differences within and across specific geographical areas. This database could be used to evaluate and interpret future results from the region, or to identify places with disturbing trends in pollution levels.

Recommendations

Based on the findings of the study the following recommendations are made:

1. The factory effluents should be more intensively treated before discharging into the River Gongola.

2. Remediation programme should be embarked upon in order to curtail the excessive values of contaminations of Cd, Cu, Mn, and Pb.
3. Preserve existing trees, plant new trees, shrubs and cover crops like grasses on hills and near streams to reduce land run-off.

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