Heavy Metals Contamination of Streams in Meme River Basin of Kogi State, Nigeria

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Abstract

This paper focuses on heavy metals contamination of streams in Meme River basin in Kogi State, Nigeria. The streams of the basin are the primary sources of domestic water supply to basin residents in both dry and wet seasons. Eighteen (18) stream water samples were collected; 8 samples from upstream and 10 from downstream sections of the basin; for characterization and analysis. The upstream section is typically rural while the downstream section is largely urbanized. Samples were collected in September 2024. The parameters used in the study consist of. Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Lead (Pb), Zinc (Zn), Hydrogen ion Concentration (pH), Turbidity (NTU) and Total Hardness. The results obtained from our laboratory analysis revealed significant contaminations and high variability in pollutant concentrations between upstream and downstream parts of the basin. The concentration values returned ranged as follows: (As) 0.23 to 3.83 mg/l (mean = 1.53 mg/l);, (Cd) 0.02 to 0.18 mg/l (mean = 0.05 mg/l);, (Cr) 0.12 to 0.69 mg/l (mean = 0.14 mg/l), (Cu) 0.03 to 0.32 mg/l (mean = 0.11 mg/l), (Fe) 0.12 to 0.85 mg/l (mean = 0.37 mg/l), (Mn) 0.01 to 0.26 mg/l (mean = 0.08 mg/l), (Ni) 0.1to 1.64 mg/l (mean = 0.45 mg/l), (Pb) 0.15 to 0.59 mg/l (mean =0.3 mg/l) (Zn) 0.01 to 0.08 mg/l (mean = 0.03 mg/l), (pH) 7.8 to 9.2 mg/l (mean = 8.82 mg/l), Turbidity (NTU) 17 to 76 mg/l(mean =29.94 mg/l) and Total Hardness 5.1 ,to 33 mg/l(mean= 8.66 mg/l). The results were compared with WHO (2011) and (NSDWQ, 2007) permissible limits for drinking water supplies. Seven parameters- Arsenic, Cadmium, Lead, Iron, Nickel, pH and Turbidity, returned elevated values above the WHO(2011) and NSDWQ(2007), permissible limits for drinking water while five parameters- Chromium, Copper, Manganese, Zinc and Total Hardness, returned low values below the WHO and NSDWQ, 200 guideline limits. The study offers strategies to prevent or reduce pollutant levels on the streams were recommended.

Key words: Heavy Metals, Contamination, Meme River Basin, Streams, Impacts, Remediation.

1.1 Background of the Study

Heavy metals constitute an ill-defined group of inorganic chemical hazards that occur in all ecosystems at varying concentrations levels (Masindi, 2016). Heavy metals occur naturally in the earth’s crust; however, anthropogenic releases can result in higher concentrations of these metals, relative to their normal background values (Adeleke and

Abegunde, 2011; Zhong, 2017). The most commonly found heavy metals include; Lead (Pb), Chromium (Cr), Arsenic (As), Zinc (Zn), Iron (Fe), Cadmium (Cd), Copper (Cu), Mercury (Hg), Nickel (Ni), Manganese (Mg) and Magnesium (Mn). Most heavy metals are phytotoxic (i/e poisonous to plants) at both low and high concentration levels (Boyd, 2015). They are generally non-biodegradable and accumulate at high concentration levels in water. In small quantities, certain heavy metals are nutritionally essential for a healthy life, but large amounts of any of them may cause acute or chronic toxicity (poisoning). Excess levels of lead, mercury, arsenic and cadmium are very poisonous to humans due to their non-degradability, persistence and bio-accumulation in the food chain (Boyd, 2015). Heavy metals are frequently released into the environment, especially by industries, where they cause serious environment pollution and degradation.

Heavy metals pollution of stream water has received and continues to receive wide spread attention from researchers across the globe, due to their harmful effects on living beings and the environment (Real et al., 2014; USEPA 2016).Elevated concentrations of heavy metals in stream water pose risks and hazards to humans and the ecosystem through direct ingestion or contact with the food chain (Olusegun *et al,* 2017). High concentrated heavy metals load in stream water threatens the environment and human life because they can accumulate in the human body tissues, causing damage to the nervous system and internal organs (Gupta et al., 2015; Akinwekomi *et al.,* 2017*;* Doabi *et al.,* 2019). Individual metals and metal compounds negatively affect peoples' vital organs, even though, in very small amounts, some are necessary to support life.

In Meme River Basin, heavy metals occur naturally, at varying concentrations levels and with relatively short residence times (Omali, 2014). The sources of heavy metal load in the basin streams include, weathered soil or rocks, uses of fertilizers, pesticides and pipes, mining and releases from industrial emissions (Kumar et al., 2019). Others sources include disposal of untreated and partially treated effluents that contain toxic metals, and the indiscriminate use of heavy metals in the production of agricultural and household goods, (Omali, 2014). Unfortunately, these streams are the major sources of water for basin residents; plants and animals inclusive. They also serve as discharge points for industrial, municipal and agricultural wastes. Basin residents use the streams for washing (see Plate 1) as well as for the movement and transportation of goods.

Plate 1: Washing activities ongoing at the shallow bank of River Meme tributary at Crusher Village
Source: Field Work, 2024

Currently, studies on the level of concentrations of heavy metals in the basin streams and on the risks stream water pollution pose to human health in the area are yet to be undertaken. The consumption of these streams water may be a source of concern if their pollutant loads exceed recommended limits. In developed parts of the world, studies on stream water assessment are frequently undertaken (Ibrahim, *et al.,* 2014); but in our study area, such studies are rare Musa *et al.,* 2014). The presence of toxic metals in the streams and their consequences on human health need to be investigated periodically; considering the increases in basin population, as well as in agricultural and industrial activities (Ajibade *et al.,* 2019). The safety of the water environment and of life in, within and around the basin is a priority, hence the need for study.

The aim of this study therefore is to examine the heavy metals contamination of streams in Meme River Basin of Kogi State, Nigeria while the specific objectives are to:

i) determine the heavy metal concentration levels in streams within the basin and to

ii) assess the health implications of such heavy metal contamination levels.

This study is essential because studies seeking to ascertain the level of concentrations of these metals in stream water in the area and the risks they pose to human health are yet to be undertaken. In many parts of the world, such studies are regularly undertaken (Ibrahim, *et al.,* 2014; Musa *et al.,* 2014); to safeguard the health of the water users. The safety of the water users and water environment, within and around the basin is a priority, hence the need for study.

1.2 The Study Area

Meme River basin is a pear shaped, 5^{th} order basin covering an area of 9,560.5km^2 and located between latitudes 7.45^0 and to 7.52^0 N and longitudes 6.38^0 and to 6.46^0 E of the Greenwich meridian (see Fig. 1). The basin has about 92, tiny, fast-flowing, high – gradient streams and lies almost entirely within in Lokoja Local Government Area of Kogi state, Nigeria.

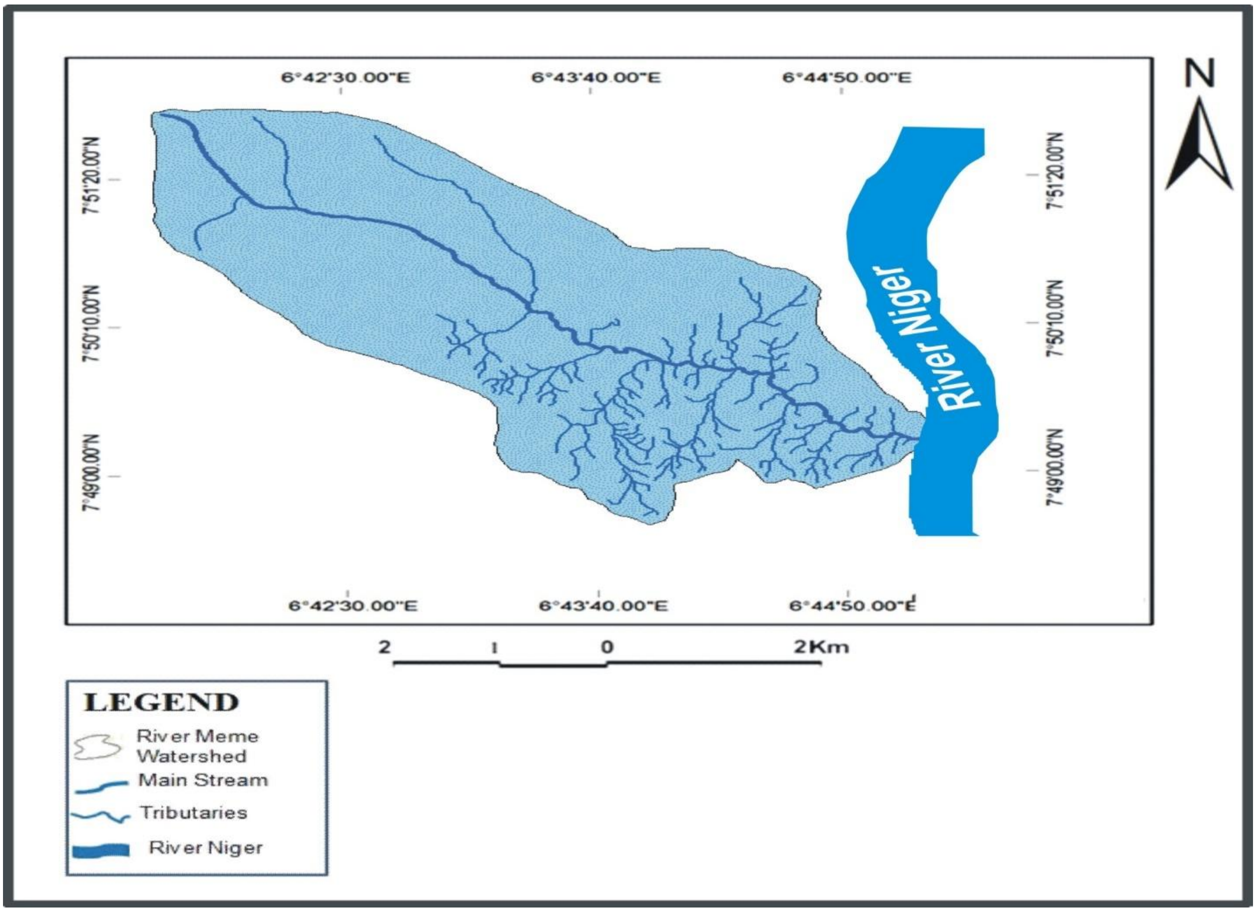

Fig. 1: Meme River Basin, showing the main stream and its numerous tributaries

Source: GIS-LAB, Federal University Lokoja, Kogi State

The Meme Basin catchment has its gauge at Lokoja, the capital city of Kogi State, in Lokoja Local Government Area of the state. The east flowing Meme River and its tributaries drain the basin.

Meme is the main and most important stream within the basin before Osara River, because of its volume and coverage Omali (2014).The geology of the basin comprise basement complex rock, migmatite and undifferentiated older granite,including porphyroblastic granite, granitic gneiss with porphyroblastic gneiss and fine-grained biotite granite (Otene *et al*, 2019). The River Meme extensive floodplain is seasonally flooded for about two to three months when River Meme overflows its bank. The fine and coarse materials (sediments) carried by floodwater are deposited in the floodplains. The soils formed on this floodplain differ in their morphological, probably due to age of sedimentation and mineralogy (UN-Water*,* 2015). The soils are characterized by dark greyish brown, greyish brown, yellow surface overlaying pinkish, grey olive yellow subsurface (Ifatmehin et al., 2012, Aloke, 2018, Otene et al., 2019). Meme river floodplain is utilized for agricultural production.

1.3 Methodology

A reconnaissance survey of the study area was first undertaken to identify the location, uses, land use activities, names of streams and flow directions within the Meme River basin. The cross-sectional research design was adopted for the study, due to the types of data and analysis required. Data used for this study were obtained from primary and secondary sources. Primary data were gathered through field observations, measurements, water samples collection and from secondary data sources.

Sampling sites along the basin streams were located 200 meters apart, in the extensive, upper, rural parts and 100 meters apart in the lower, smaller and heavily settled parts (see Fig.2). We used the grid system after Obeta, *et al.* (2019) in deterring sampling points. Once the initial sampling point around the basin gauge was chosen, the others were measured and marked off along basin streams. I8 sampling points were used for the study (see fig.2). The sample locations were not only spatially distributed but accommodated all the hydrodynamic characteristics of the basin. Nine heavy metals and 2 physico-chemical parameters were selected for the study (see Table 1). The heavy metals were selected based on their availability and ease of interpretation

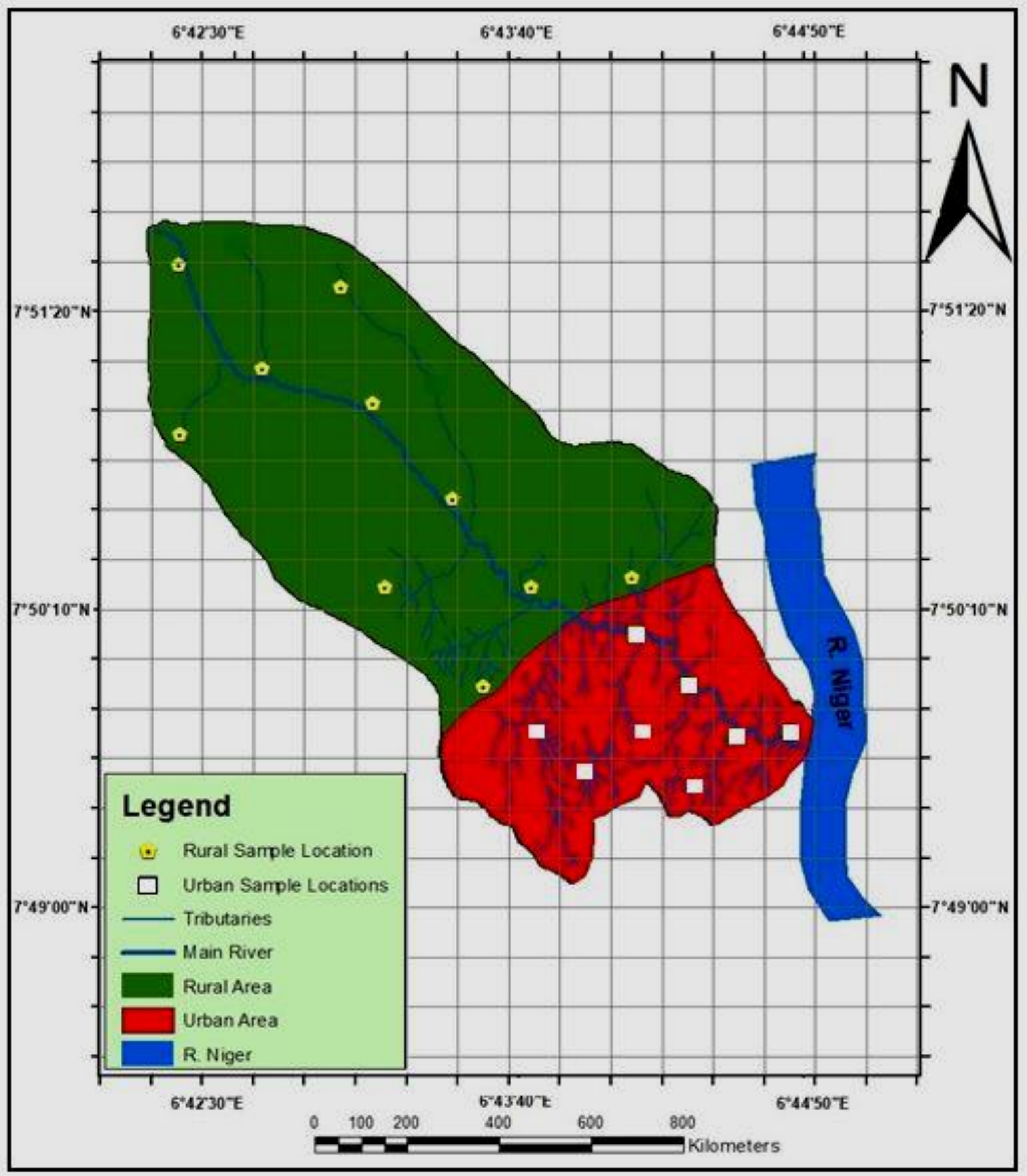

Fig. 2: Meme River watershed, showing Sample Points within the Catchment

Source: GIS-LAB, Federal University Lokoja, Kogi State

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Table 1: Heavy Metals and Physico-chemical parameters analyzed in the study

S/No	Heavy Metal	Chemical Formula	Unit of Measurement	WHO (2011) Max. Limits	Analytical Instrument/Method
1.	Arsenic	As	Mg/l	10	Atomic Absorption Spectrophotometer
2.	Cadmium	Cd	Mg/l	3	Atomic Absorption Spectrophotometer
3.	Chromium	Cr	Mg/l	50	Atomic Absorption Spectrophotometer
4.	Copper	Cu	Mg/l	2.0	Atomic Absorption Spectrophotometer
5.	Iron	Fe	Mg/l	0.2	Atomic Absorption Spectrophotometer
6.	Lead	Pb	Mg/l	10	Atomic Absorption Spectrophotometer
7.	Manganese	Mn	Mg/l	0.4	Atomic Absorption Spectrophotometer
8.	Nickel	Ni	Mg/l	20	Atomic Absorption Spectrophotometer
9.	Zinc	Zn	Mg/l	3	Atomic Absorption Spectrophotometer
10.	Total Hardness		Mg/l	300	Atomic Absorption Spectrophotometer
11.	Turbidity	(NTU)	Mg/l	5.0	Atomic Absorption Spectrophotometer
12.	pH		Mg/l	7.0-8.5	Atomic Absorption Spectrophotometer

Sample locations were geo-referenced using global positioning reference system (GPS). Water samples were collected with plastic bottles measuring 500 milliliters while Mercury thermometer was used to determine the temperature of the samples in-situ, while pH meter (HANNA) was used to measure the pH of the samples on-site. Ice pack insulated container was used to carry samples and to maintain inert temperature condition for stabilization of parameters before transportation for chemical analysis. Prior to the sampling, plastic bottles, caps and scissors were sterilized to decontaminate them (Okafor, *et al*., 2021). The sample collection field work program was divided into two phases; the first samples were taken in the morning between 7 am to 11 am, while the second samples were taken in the afternoon between 1 pm to 3 pm. At each sampling location, samples were collected at the region of good mixing in the river channel and stored in a clean 500mil plastic bottle. Each plastic bottle was rinsed three times with water before sample collection. Plastic bottles were opened and held at the lower part, submerged diagonally to a depth of about 20cm, and 3m away from the streams' bank with the mouth facing slightly upward to ensure that water entering the sample bottles had no contact with the hand. Water samples were filled with water to the brim so that no air was trapped inside. The plastic bottles were corked immediately after collection. Caps of the plastic bottles were properly sealed with masking tape to ensure that none of the samples was tampered. They were properly tagged and labeled with a marker, and they bore information such as (i) name of the stream, (ii) location of collection, (iii) name of the community, (iv) date of collection and (v) time of collection. Water Quality Analysis was done at the Energy Center, of the University of Nigeria, Nsukka. This laboratory was chosen because it is accredited. Distances between samples location along the navigable section of Meme River were measured through the use of Android phone install with Distance Measuring app inside the Canoe/boats; whiles distances between samples location at the upper, rugged and un-navigable section of Meme River were measured using 50 meter tape with the help of the employed research assistant. The stream channels environments, sampling sites and economic activities along the stream channels were careful observed

Results and Discussion

The results of the concentration values returned by the analyzed parameters in the stream water samples are summarized in table 2 below.

Table 2: Physico-Chemical characteristics and Heavy Metals Contents of Water Samples from Meme River Basin

**EXCEEDED WHO (2011)   **EXCEEDED BOTH WHO (2011) and NSDWQ (2007)*

	SAMPLE LOCATIONS																					
Parameters (Mg/L)	SL1	SL2	SL3	SL4	SL5	SL6	SL7	SL8	SL9	SL10	SL11	SL12	SL13	SL14	SL15	SL16	SL17	SL18	Mean	Max	(NSDWQ 2007) Allowable Limits	WHO Allowable Limit
Arsenic	0.23**	1.80**	1.80**	0.68**	1.58**	0.45**	0	2.26**	0.90**	0	2.93**	1.13**	1.58**	3.38**	0.45**	3.83**	2.71**	1.80**	1.53	3.83	0.01	0.01
Cadmium	0.07**	0.02**	0.04**	0.18**	0	0.11**	0	0	0	0	0.04**	0	0.04**	0.04**	0.11**	0.11**	0.14**	0.04**	0.05	0.18	0.003	0.003
Chromium	0.23	0.23	0	0	0	0.12	0.12	0.23	0.12	0.12	0.23	0.12	0	0.12	0.69*	0.12	0.12	0	0.14	0.69	0.5	0.5
Copper	0.23	0	0.19	0.13	0.06	0.19	0.13	0.03	0.06	0.09	0.06	0.06	0.03	0.19	0.19	0.32	0.06	0	0.11	0.32	1.0	0.5
Iron	0.12	0.49**	0.12	0	0.37**	0.12	0	0.24	0	0.49**	0.24	0.85**	0.49**	0.24	0.61**	0.61**	0.73**	0.85**	0.37	0.85	0.3	0.3
Lead	0.15**	0.59**	0.45**	0.45**	0.15**	0.59**	0.15**	0.59**	0.15**	0	0	0.29**	0.59**	0.15**	0.59**	0.29**	0.29**	0	0.30	0.59	0.01	0.01
Manganese	0.03	0.06	0	0	0.01	0.16	0.19	0.03	0.03	0.13	0.06	0.06	0.26	0	0	0.19	0	0.16	0.08	0.26	0.2	0.4
Nickel	0.41**	0.20**	0.20**	1.13**	0	0	0.20**	1.43**	0.20**	0.10**	0.20**	0.61**	0.31**	0.10**	0.41**	0.61**	0.31**	1.64**	0.45	1.64	0.02	0.02
Zinc	0.01	0.06	0.03	0.01	0.08	0.04	0.01	0.01	0.05	0.03	0.04	0.02	0.01	0	0.03	0	0.05	0.04	0.03	0.08	3.0	5.0
Total Hardness	6.0	6.1	5.9	5.9	11.5	5.5	5.4	5.7	5.4	5.3	14.5	33.0	5.2	5.1	5.3	5.2	12.5	12.3	8.66	33	150	300
Turbidity (NTU)	50**	76**	29**	24**	17**	25**	22**	23**	22**	24**	22**	25**	22**	43**	39**	22**	32**	22**	29.94	76	5.0	5.0
pH	8.8**	8.8**	9.0**	9.0**	9.0**	9.2**	7.8	8.9**	8.9**	8.8**	8.8**	9.0**	9.0**	9.0**	9.2**	7.8	8.9**	8.9**	8.82	9.2	7.0-8.5	7.0-8.5

Source: Field Work, 2024

Table 2 summarizes the results of the analysis of physico-chemical characteristics and heavy metals contents in water samples from Meme River Basin. As Table 2 shows, the concentration levels of the analyzed pollutants varied widely among the sample locations. The average concentrations levels of most the parameters were higher than both the WHO (2011) and NSDWQ (2007) guideline values for drinking water supplies. For instance, Turbidity and pH, returned elevated values that were higher than WHO (2011) and NSDWQ (2007) guideline values at almost all the sample locations (see table 2). The details of the loading patterns are discussed parameter by parameter below.

Arsenic

The concentration levels of Arsenic in the stream water samples returned at all the sampled locations were summarized in figure 3. As shown in Fig 3, the values of Arsenic ranged from 0.23 mg/l at SL1 to 3.83 mg/l at SL16 with a mean value of 1.53 mg/l.

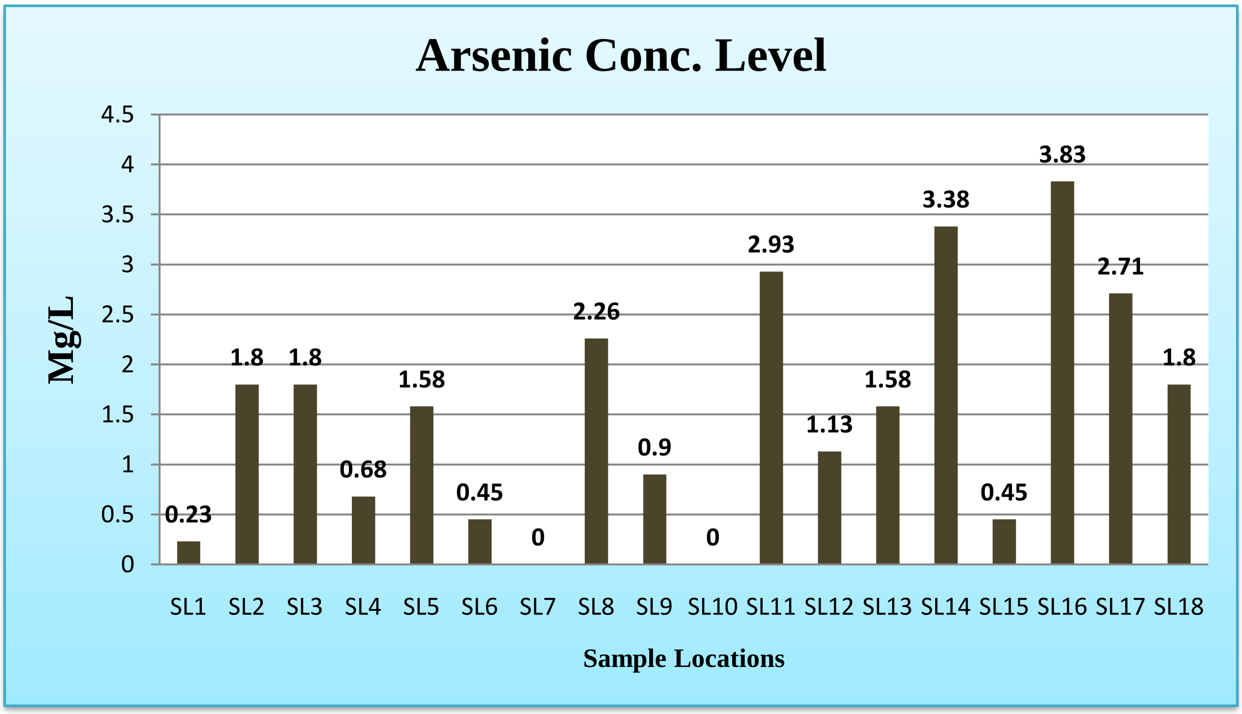

Fig. 3: Concentration values of Arsenic in all sampled locations

Source: Field Work, 2021

Arsenic concentrations in all the sampled locations were higher than the WHO (2011) and the NSDWQ (2007) permissible limits, except at two sample locations (SL7 and SL10) where Arsenic deposition was not detected. The concentrations patterns of Arsenic at the sampled locations were relatively inconsistent with the highest values of 3.83 mg/l and 3.38 mg/l at SL16 and SL14, and lowest concentration values of 0.23 mg/l and 0.45 mg/l obtained from SL1 and SL6 & SL15; respectively. The high concentrations of Arsenic in all the sampled locations may suggest excessive use and application of Arsenic compounds in industries located within and around the study area (Ying *et al*., 2017). The high values obtained at the downstream part of the basin were probably due to volatile and increase in effluents discharged from the industries located in the area.

Cadmium

The loading pattern of Cadmium in the stream water samples in all the sampled locations are shown in figure 4. As shown in Fig 4, the values of Cadmium ranged from 0.02 mg/l at SL2 to 0.18 mg/l at SL4 with a mean value of 0.05 mg/l.

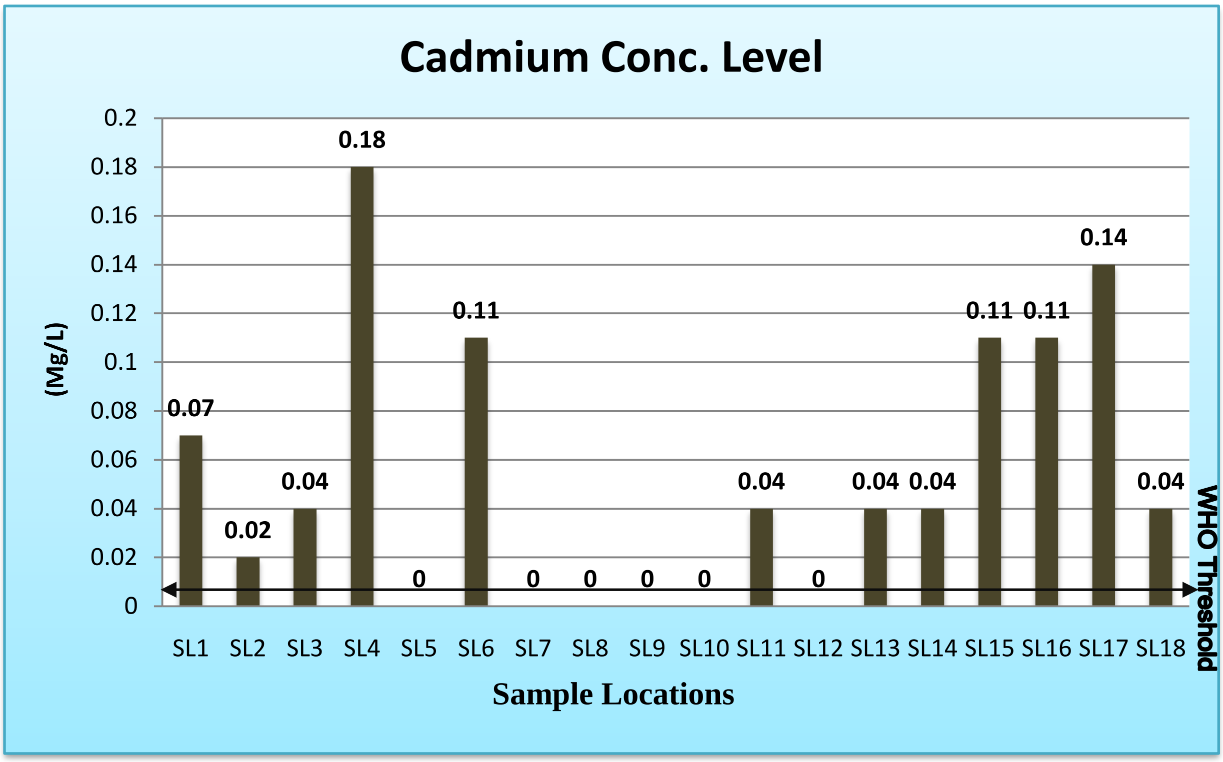

Fig. 4: Concentration values of Cadmium in all sampled locations

Source: Field Work, 2021

Cadmium concentrations in 11 sampled locations were higher than the WHO (2011) and the NSDWQ (2007) permissible limits. This pollutant was not detected in 6 sampled locations (SLs 5,7,8,9, 10 and 12); SL2 returned a low value of just 0.02 mg/l. The highest values of 0.18 mg/l and 0.14 mg/l were returned at SL4 and SL17, while lowest concentration values of 0.02 mg/l and 0.04 mg/l obtained were from SL2 and SL3,11,13,14 & SL18; respectively. The high concentrations values returned at SL4 and SL17 may be attributed to the use of Cd. compounds in domestic chores, crop fertilization and paint industries located within and around the study area.

Chromium

The details of the loading pattern of Chromium in the stream water samples are shown in figure 5. The values of Chromium ranged from 0.12 mg/l at SLs 6, 7, 9, 10, 12, 14, 16, 17 to 0.69 mg/l at SL15 with a mean value of 0.14 mg/l.

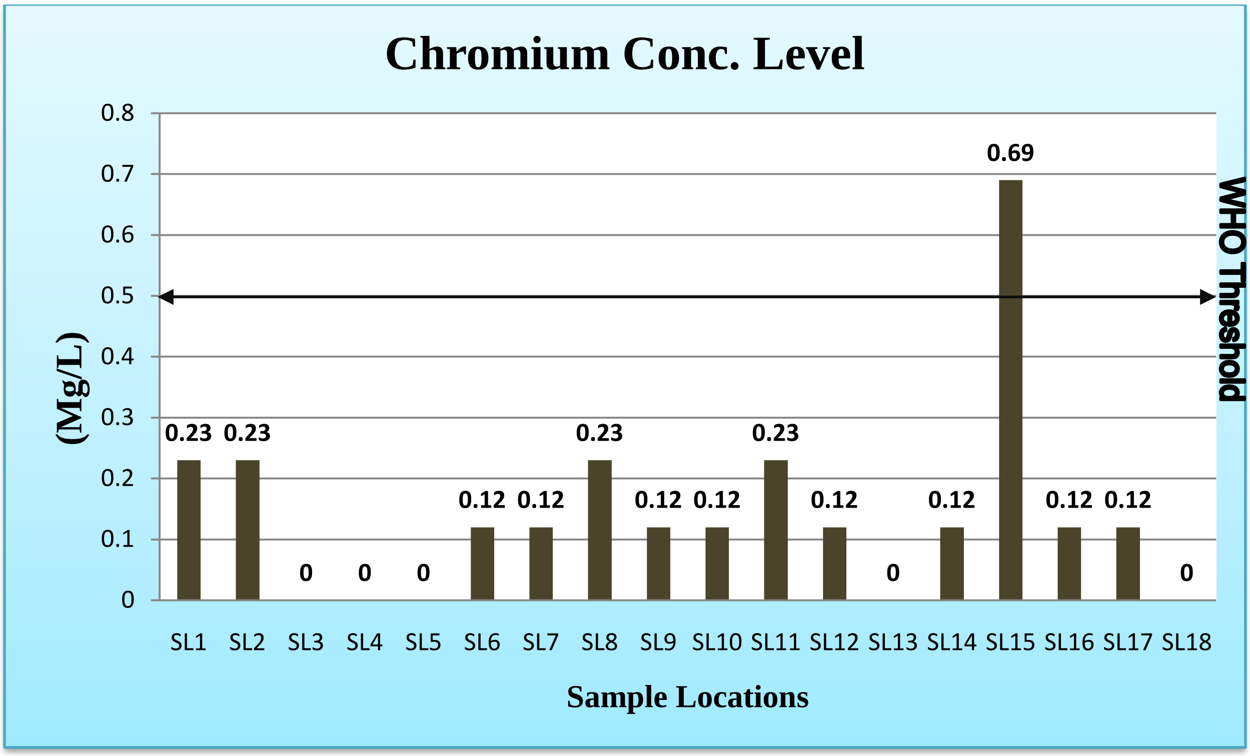

Fig. 5: Chromium concentration values in all sampled locations

Source: Field Work, 2021

Chromium concentrations in all the sampled locations were lower than permissible limits of WHO (2011) and the NSDWQ (2007), with the exception of SL15 which had a value of 0.69 mg/l .This relatively high returned value at this location may probably be due to the discharge of industrial effluent and application of chemical fertilizer in crop farming around the study area. The concentrations patterns of Cr are relatively regular with the highest values of 0.69 mg/l at SL15, and lowest concentration values of 0.12 mg/l and 0.23 mg/l obtained in SL6, 7, 9, 10, 12, 14, 16, 17 and SL1, 2, 8 & SL11; respectively. The low concentrations of Chromium in most of the sampled locations may probably be due to the low use and application of Chromium compounds in the study area, (Plummer et al., 2018). The high value retuned at SL15 could probably result runoff and effluents discharge from agricultural fields near that particular sample location.

Copper

The details of the loading pattern of Copper in the stream water sampled are shown in figure 6. The values of Copper ranged from 0.03 mg/l at SL8 and SL 13 to 0.32 mg/l at SL16 with a mean value of 0.11 mg/l.

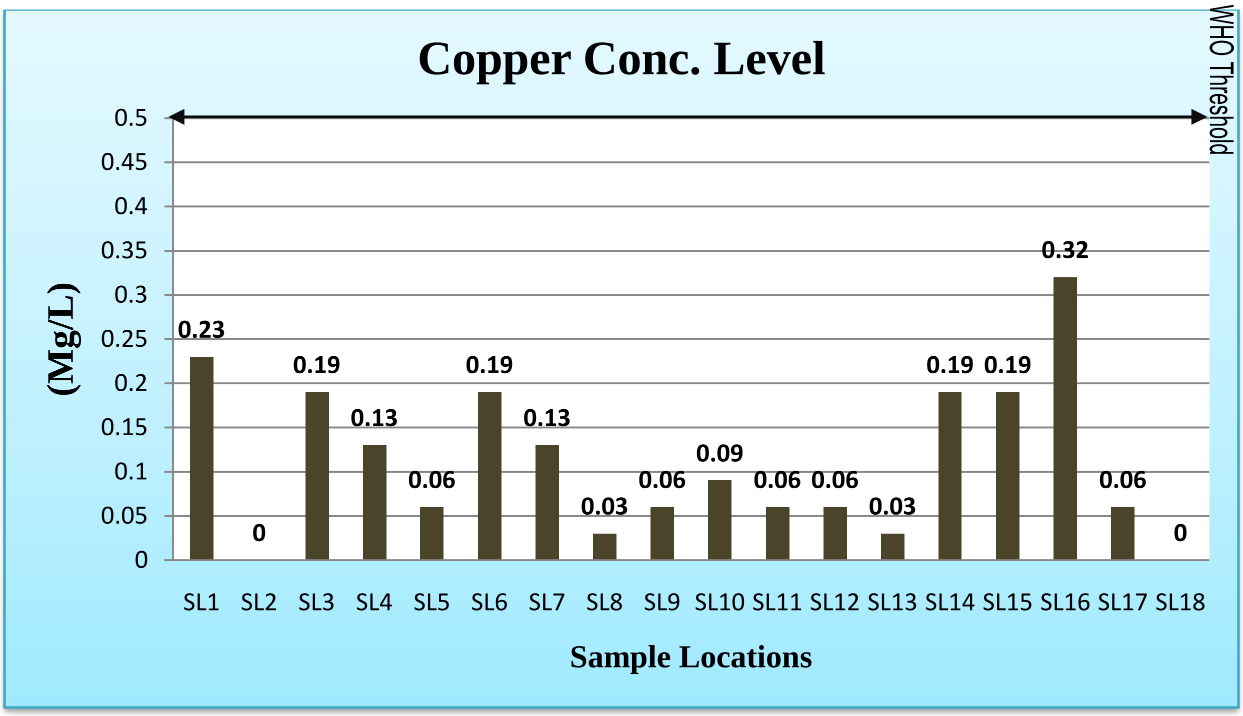

Fig. 6: Concentration values of Copper in all sampled locations
Source: Field Work, 2021

Copper concentration in all the sampled locations were below the permissible limits of WHO (2011) and the NSDWQ (2007), This relatively low values at all the locations could be attributed to the limited discharge of copper-rich waste water from mines and effluents in and around the sampled locations. The concentrations patterns of Cu. exhibits an irregular pattern with the highest values of 0.32 mg/l and 0.23 mg/l at SL16 and SL1, and lowest concentration values of 0.03 mg/l and 0.06 mg/l obtained at SL8, SL13 and SL5 & SL17; respectively. Copper deposit was not detected in SL2 and SL18. The low concentrations of Copper in all the 18 sampled locations also suggest low utilization of Copper element or compounds materials, such as plumbing, alloys, wood preservative, leather and fabrics and pharmaceutical products in the study area.

Iron

The values of Iron in the stream water samples collected from the basin are shown in figure 7. The values of Iron ranged from 0.12 mg/l at SLs 1, 3 and SL6 to 0.85 mg/l at SL12 and SL18 with a mean value of 0.37 mg/l.

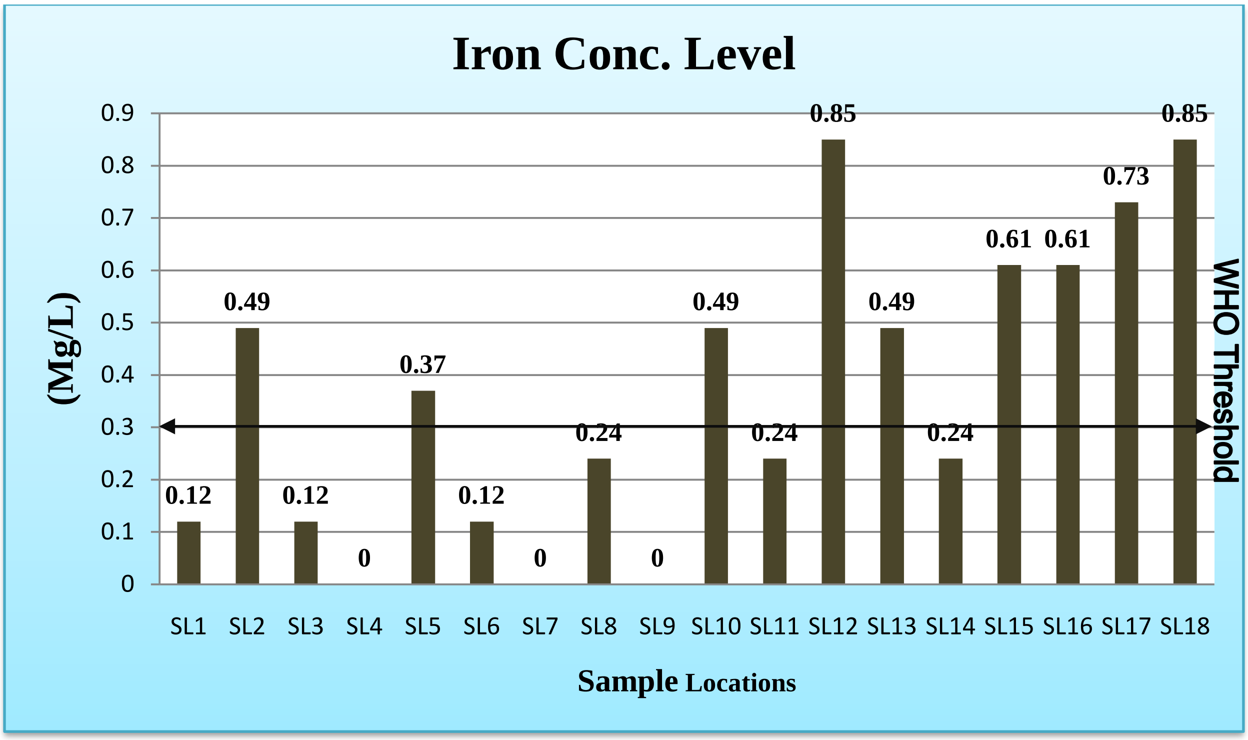

Fig. 7: Concentration values of Iron in all sampled locations
Source: Field Work, 2021

Iron concentrations in 9 sampled locations were higher than the permissible limits of WHO (2011) and the NSDWQ (2007), but lower in 6 sampled locations. This pollutant was not detected in samples analyzed in SLs 4, 7 and 9 (see Fig. 15). Iron concentration in all the sampled points were averagely higher/below the permissible limits of WHO (2011) and the NSDWQ (2007), indicating moderately to balanced Iron concentration in the study area. The concentrations patterns of Fe are relatively regular, with the highest values of 0.85 mg/l and 0.73 mg/l at SLs 12, 18 and SL17 and lowest concentration values of 0.12 mg/l and 0.24 mg/l returned in SLs 1, 3 & SL6 and SLs 8, 11 & SL14 respectively. The average concentrations of Iron in the 18 sampled locations suggest high runoff discharge along the natural flow path, which readily oxidized iron pyrites (FeS^2) that are common in cretaceous sedimentary regions or washed down Iron element or compounds to the basin. It could also be attributed to the geological make-up of the river basin bed and the adjoining rock type within the basin (Kordas et al., 2018).

Lead

The details of the loading pattern of Lead in the stream water samples are shown in figure 8, the values of Lead ranged from 0.15 mg/l at SLs 1, 5, 7, 9 and SL14 to 0.59 mg/l at SLs 2, 6, 8, 13 and SL15 with a mean value of 0.3 mg/l.

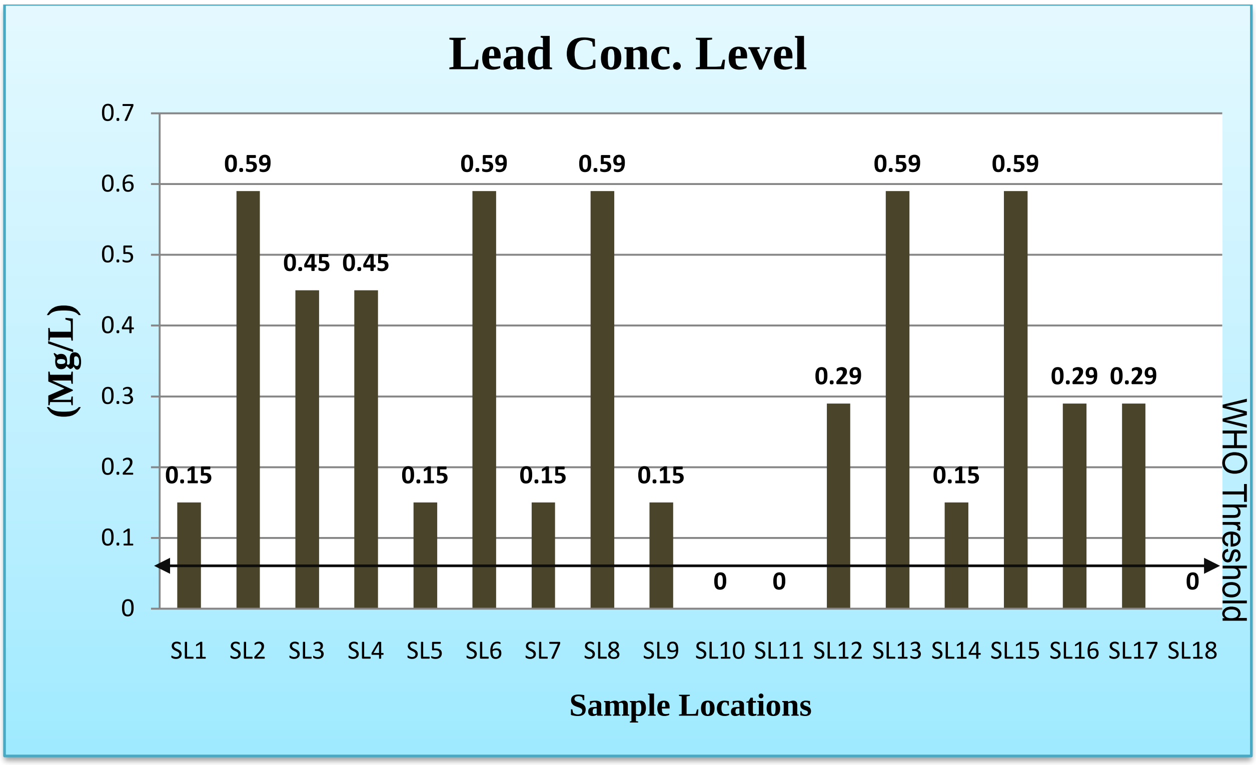

Fig. 8: Concentration values of Lead in all sampled locations
Source: Field Work, 2021

As seen in table 2, Lead concentrations in almost all the sampled locations were higher than permissible limits of WHO (2011) and the NSDWQ (2007). Lead was not detected in samples analyzed in SLs 10, 11 and 18 as (seeing in Fig. 16) above. The concentrations patterns of Lead are relatively regular in the sample locations, with the highest values of 0.59 mg/l and 0.45 mg/l at SLs 2, 6, 8, 13, 15 & SLs 3, 4, and lowest recorded concentration values of 0.15 mg/l and 0.29 mg/l returned at SLs 1, 5, 7, 9, 14 & SLs 12, 16, 17; respectively. The high concentration values of Lead in all the sampled locations, suggested that there is high contamination of Lead element in the Meme basin, which may have resulted from the extensive use of Leaded materials in pipes, cable, alloy and industries, printing, pigments and fuels, as they finds their ways into stream water in the study area (Boskabady et al, 2018).

Manganese

The loading pattern of Manganese in the stream water samples are shown in figure 9. As shown in Fig 9, the values of Manganese ranged from 0.01 mg/l at SL5 to 0.26 mg/l at SL13 with a mean value of 0.08 mg/l.

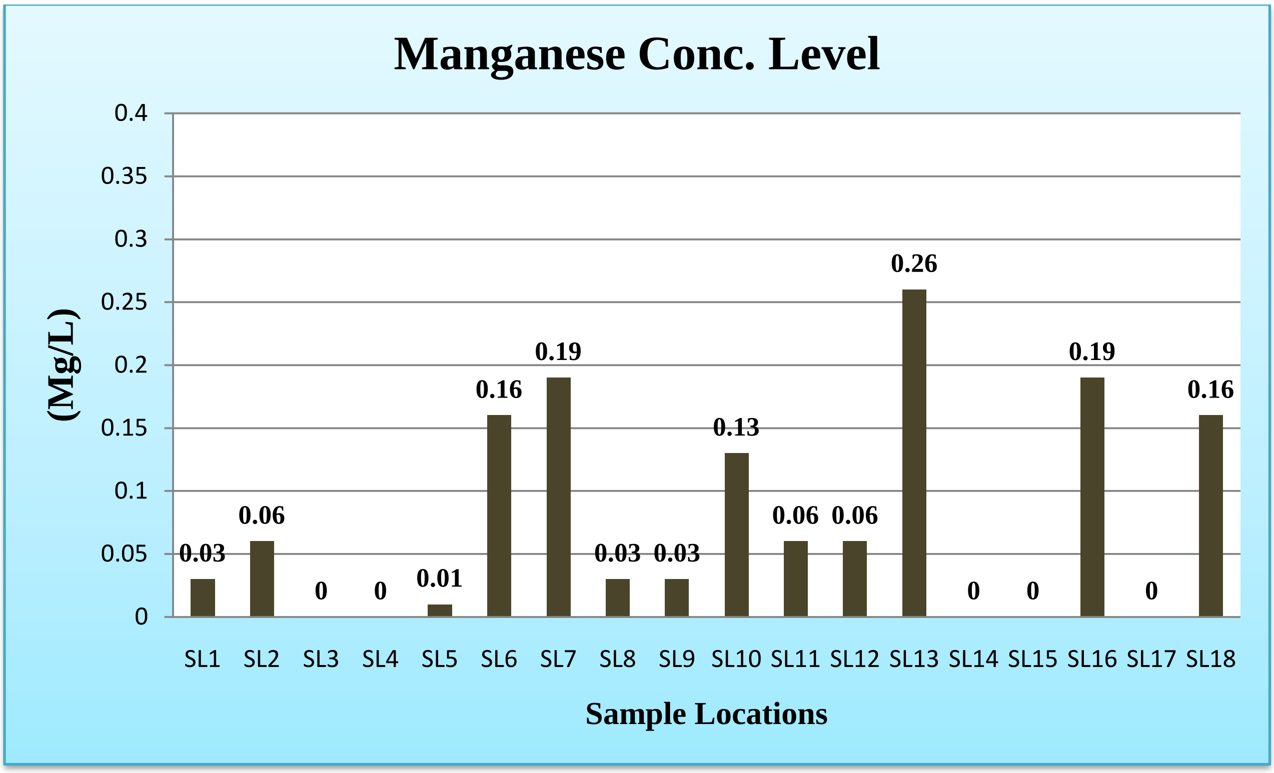

Fig. 9: Concentration values of Manganese in all sampled locations
Source: Field Work, 2021

Figure 9 shows details of Manganese concentration in all the sampled locations were below the permissible limits of WHO (2011) and the NSDWQ (2007). The concentrations patterns of Manganese exhibits an irregular pattern with the highest values of 0.26 mg/l and 0.19 mg/l at SL13 and SLs 7 & 16, and lowest concentration values of 0.01 mg/l and 0.03 mg/l returned in SL5 and SLs 1, 8 & SL9 respectively. Manganese was not detected in samples analyzed in SLs SL3, 4, 14, 15 & SL17. The general low concentrations of Manganese in all the 18 sampled locations could be attributed to the low to lack releases of industrial discharge, landfill and soil leaching and underground injection of Manganese in the form of potassium permanganate in the study area.

Nickel

The loading pattern of values of Nickel in the stream water sampled is shown in figure 10. The values of Nickel ranged from 0.1 mg/l at SL10 & SL14 to 1.64 mg/l at SL18 with a mean value of 0.45 mg/l.

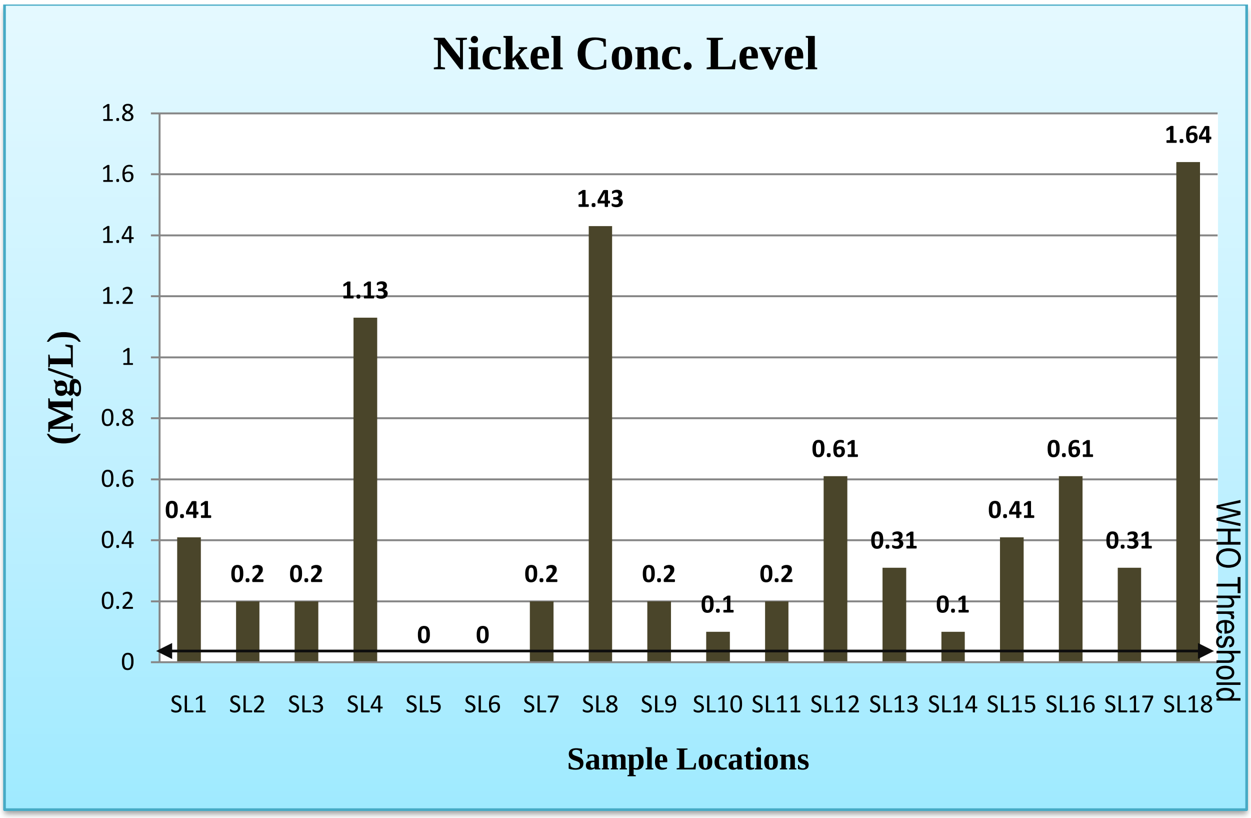

Fig. 10: Concentration values of Nickel in all sampled locations

Source: Field Work, 2021

As seeing in Fig. 10 above, Nickel concentrations in all the sampled points were higher than the permissible limits of WHO (2011) and the NSDWQ (2007), whereas Nickel deposition was not detected in SL5 and SL6 respectively. The general elevated level of Ni in the study area shows high Nickel contamination in the Meme basin. The concentrations patterns of Nickel were irregular, with the highest values of 1.64 mg/l and 1.43 mg/l at SL18 & SL8 and lowest concentration values of 0.1 mg/l and 0.2 mg/l returned at SL10 & SL14 and SLs 2, 3, 7, 9 & SL11; respectively. The high concentration values of Nickel in all the sampled locations shows high contamination of Nickel element in the Meme basin, which results from the widely-used Nickel elements and compounds in various industries and consumer products, including open waste dumpsite, domestic cleaning products and fungicides, which are of major contributors of nickel contaminations in the study area, (Jadhav et al., 2015).

Zinc

The loading pattern of Zinc in the stream water is shown in figure 11. The values of Zinc ranged from 0.01 mg/l at SLs 1, 4, 7, 8 & SL13 to 0.08 mg/l at SL5 with a mean value of 0.03 mg/l.

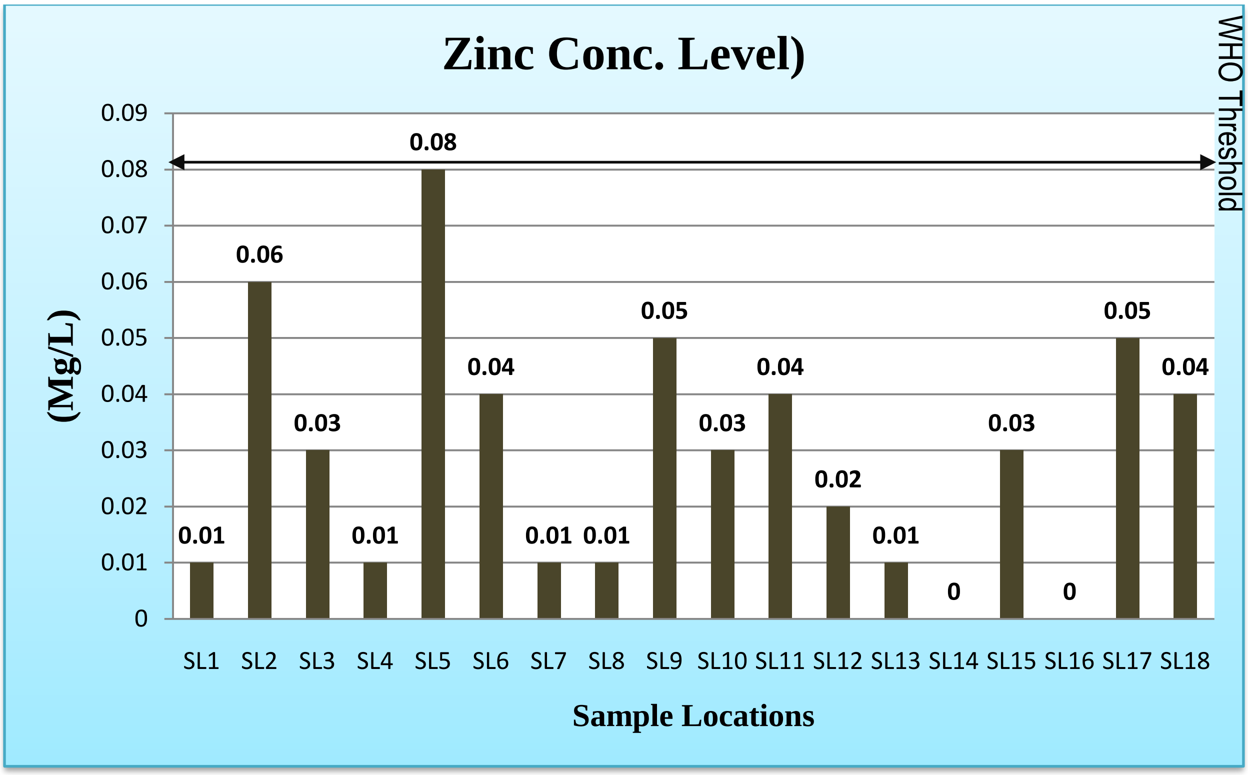

Fig. 11: Concentration values Zinc in all sampled locations

Source: Field Work, 2021

Zinc concentration in all the sampled points were below the permissible limits of WHO (2011) and the NSDWQ (2007). Zinc concentration was not detected in sample locations SL14 and SL16 respectively. The concentrations patterns of Zinc are irregular in their spread, with the highest values of 0.08 mg/l and 0.06 mg/l at SL4 & SL2 and lowest concentration values of 0.01 mg/l and 0.02 mg/l returned at SLs 1, 4, 7, 8 & SL13 and SL12; respectively. The general low concentrations of Zinc in all the 18 sampled locations could be attributed to the low releases of Zinc chloride, sulphide and zinc elements in agricultural field and domestic Zinc content materials in household materials in the study area.

Potential Hydrogen (pH)

The details of the loading pattern of Potential Hydrogen (pH) in the stream water samples are shown in figure 12. The values of Potential Hydrogen (pH) ranged from 7.8 mg/l at SL7 & SL16 to 9.2 mg/l at SL6 & SL15 with a mean value of 8.82 mg/l.

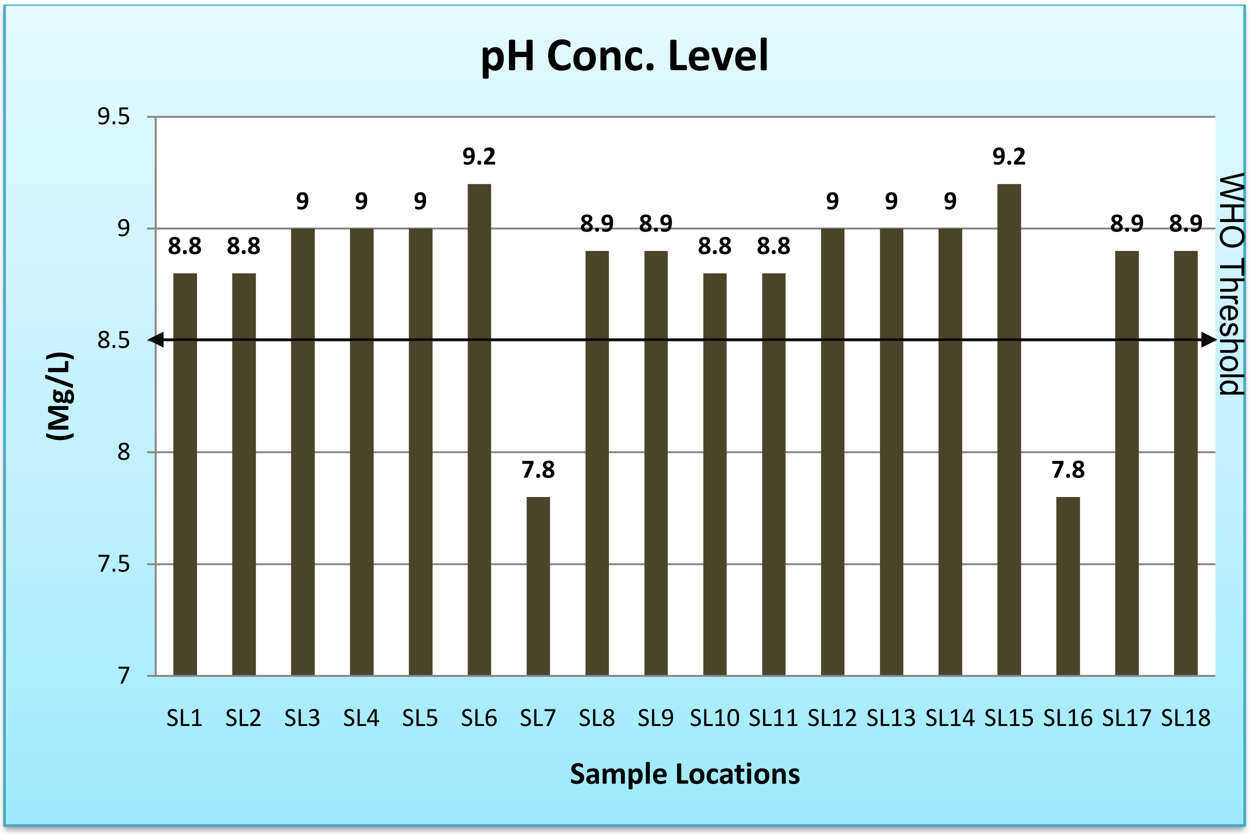

Fig.12: Concentration values of pH in all sampled locations
Source: Field Work, 2021

As indicated in Figure 12, Potential Hydrogen (pH) concentrations in all the sampled locations were higher than the permissible limits of WHO (2011) and the NSDWQ (2007), with the exception of SL7 and SL16 which recorded values are below the WHO permissible limits respectively. The concentrations patterns of pH are relatively regular with the highest values of 9.2 mg/l and 9.0 mg/l at SLs 6, 15 & SLs 3, 4, 5, 12, 13 & SL14 and lowest concentration values of 7.8 mg/l and 8.8 mg/l returned at SL7 & SL16 and SLs 1, 2, 10 & SL11 respectively. The high concentration values of pH in all the sampling locations shows that there is high alkalinity or salty concentration of the waters in the Meme basin, which results from chemical elements and compounds used for agricultural fertilizer, such as Pesticides, fungicides, herbicides, NPK fertilizers etc., and various detergent utilized for household and domestic washing in and around the river, and also chemical element from dumpsite in the Meme River banks that leach down the soil horizons, and subsequently flow into the river system through lateral flow into the river basin around the study areas, (Thakur et al., 2019).

Turbidity (NTU)

Figure 13, summaries the details of the loading pattern of Turbidity in the stream water samples. The values of Turbidity ranged from 17 mg/l at SL5 to 76 mg/l at SL2 with a mean value of 29.94 mg/l.

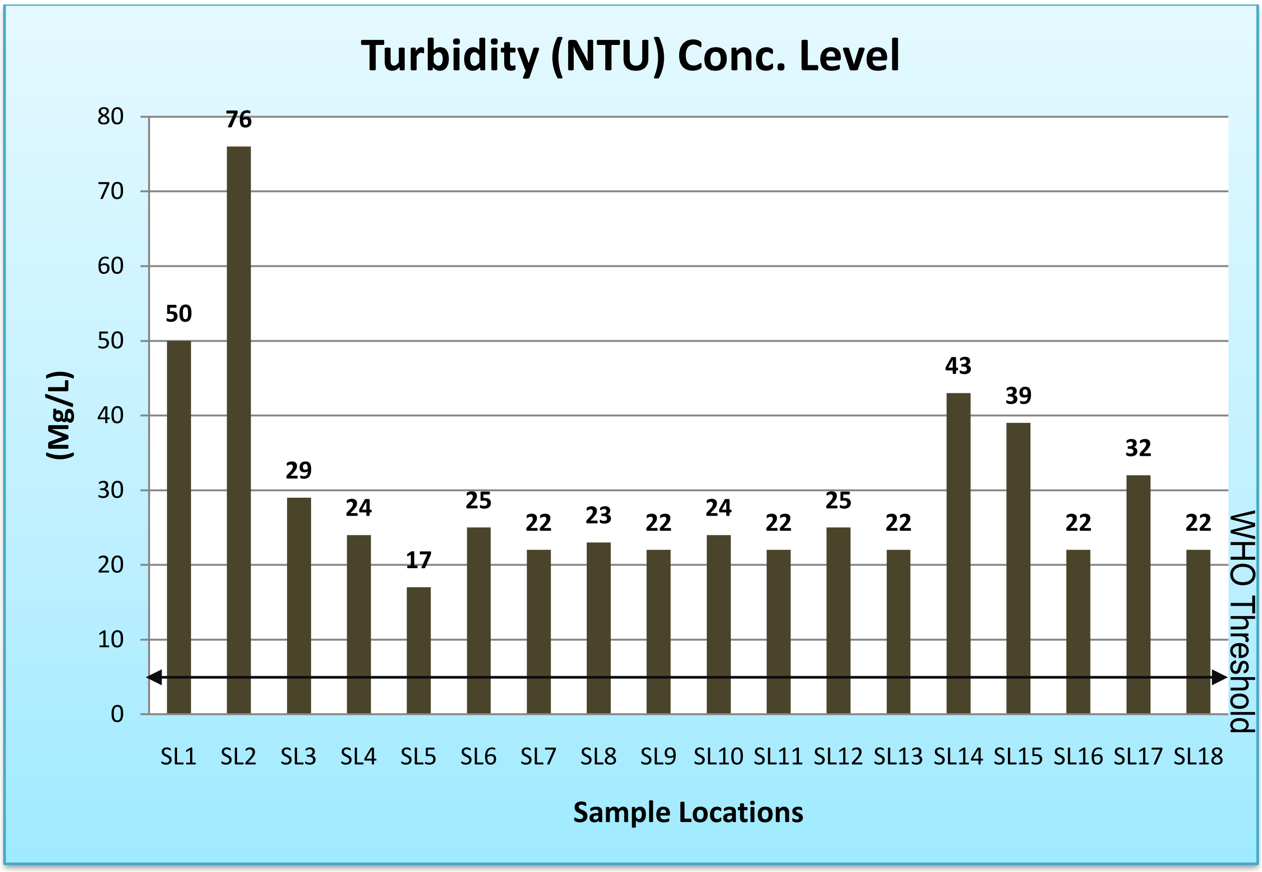

Fig. 13. Concentration values of Turbidity in all sampled locations
Source: Field Work, 2021

As shown in Figure. 13, Turbidity concentrations in all the sampled points were higher than the permissible limits of WHO (2011) and the NSDWQ (2007). The general elevated levels of Turbidity in the study area shows high total dissolved and suspended solids. The concentrations patterns of Turbidity are almost regular with the highest values of 76 mg/l and 50 mg/l at SL2 & SL1 and lowest concentration values of 17 mg/l and 22 mg/l returned at SL5 and SLs 7, 9, 11, 13, 16 & SL18 respectively. The high level values of Turbidity in all the sampled locations shows that there is high suspended solids and total dissolved solids materials and elements in the Meme basin, which results from the scattered and numerous natural flow paths and tributaries in the Meme basin around and within Lokoja and its environs. Again, it could be attributed to the various waste dumps from the municipal city that finds their way into the water body through surface and sub-surface flow (Ward et al., 2018).

Total Hardness

The details of Total Hardness concentration in the stream water samples are shown in figure 14. As shown in figure 14, the values of Total Hardness ranged from 5.1 mg/l at SL14 to 33 mg/l at SL12 with a mean value of 8.66 mg/l.

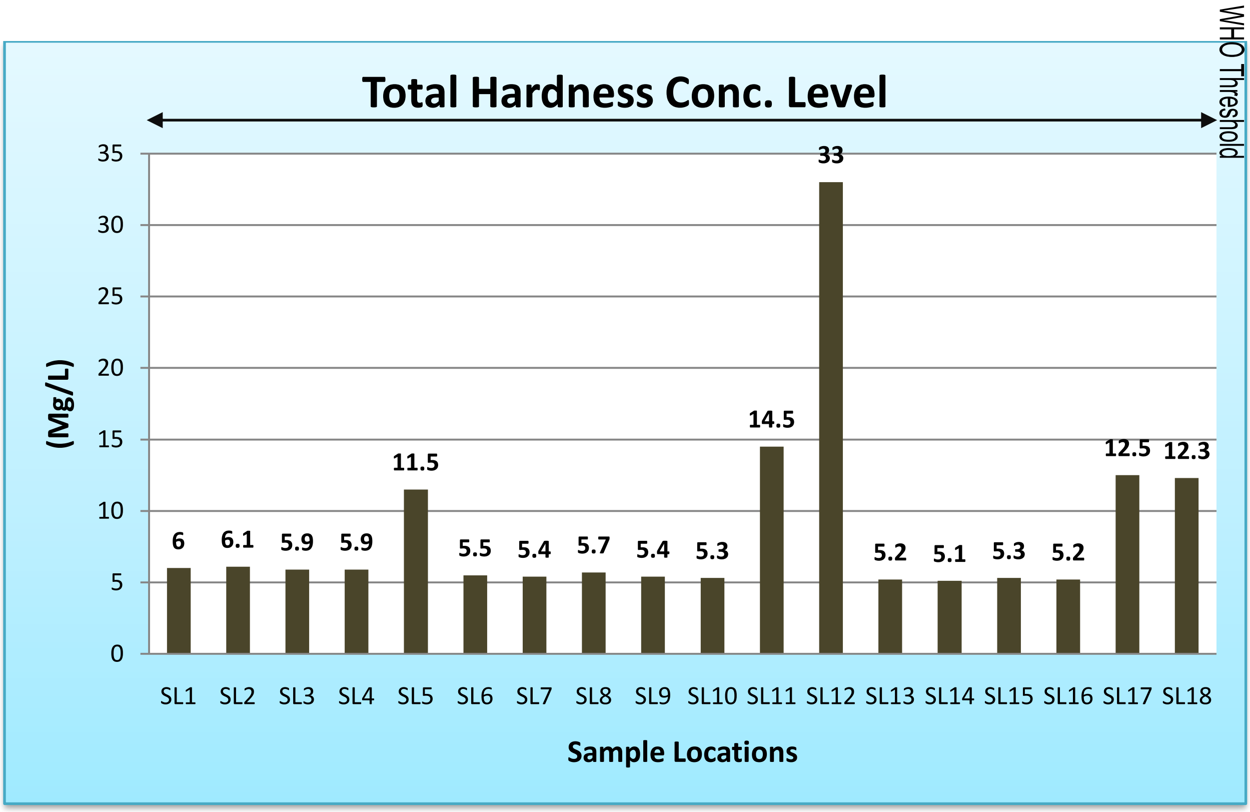

Fig. 14: Concentration values of Total Hardness in all sampled locations

Source: Field Work, 2021

Figure 14, shows that Total Hardness concentration in all the sampled locations were below the permissible limits of WHO (2011) and the NSDWQ (2007). The concentrations patterns of Total Hardness are relatively regular with the highest values of 33 mg/l and 14.5 mg/l at SL12 & SL11 and lowest concentration values of 5.1 mg/l and 5.2 mg/l returned in SL14 and SL13 & SL16 respectively (see Fig. 22). The general low concentrations of Total Hardness in all the 18 sampled locations could be attributed to the type of the underlying rock materials the river is flowing on, the river is flowing mostly on basement complex rock which has resulted in low content or concentration of Ca^{2+}ions and Mg^{2+}ions, and, this has had effect on the presence of calcium, magnesium and converting the value to equivalent concentrations of calcium carbonate ($CaCO_3$) in $mgdm^{-3}$.

Summary of the Research Findings

This study was undertaken to assess heavy metals contamination in streams within Meme River basin of north central Nigeria.. The results of our analysis have provided detailed answers to the questions that provoked the research. Thus, the findings of this paper have revealed that☹

i) most of the analyzed parameters returned elevated, high values above both the WHO (2011) and NSDWQ (2007) guideline values for drinking water supplies. Heavy metal pollution therefore, has adverse effects on stream water quality within the Meme basin.

(ii).two parameters (Turbidity and Ph) returned elevated, high values at all the sample sites in Meme River basin

iii) five heavy metals, namely, Arsenic, Chromium, Nickel, Copper and Iron returned elevated at all the sample sites in the upper part of the Meme River basin, probably due to natural factors such as rock weathering, soil erosion and dissolution of water-soluble salts.

iv). five heavy metals, namely, Cadmium, Manganese, Lead and Zinc returned higher concentration values at sites situated at the lower parts of the Meme River basin, probably due to anthropogenic activities such as mining, manufacturing and industrial activities and waste dumps into steam water channels.

7.2 Conclusion and Recommendations

This research work has shown that the streams within the Meme River basin are heavily polluted with heavy metals, principally by Arsenic, Chromium, Nickel, Copper and Iron. These pollutants returned elevated values at the upper and lower sections of the basin, including where many residents depend almost exclusively on streams for their domestic water needs. This shows that streams within the basin are polluted and unfit for domestic uses.

Based on the findings of the research the following recommendations were made:

(i). The federal and Kogi state governments could take steps to treat/ remove the heavy metals in streams of the basin to ensure that drinking water from these streams are safe and healthy before consumption.

ii).The governments should enforce laws against indiscriminate waste disposal and discharge of industrial effluents into steams

(iii), There is need to create stream water monitoring and pollution control unit within the basin. The unit should have responsibility for surface water management in the area. This may go a long way in reducing/eliminating surface water pollution and subsequent contamination of the surface water in the study area.

iii) The basin residents should be enlightened on the possible health risks associated with exposure to the pollutants in the streams water and educated on how to properly treat stream water before consumption .

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