Assessment of Heavy Metal Pollution of Water, Sediments and Algae in River Benue at Jimeta-Yola, Adamawa State, Nigeria

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Abstract

Heavy metal pollution of water, sediments and Algae in the upper region of River Benue at Jimeta-Yola, Adamawa state, Nigeria was assessed. The concentrations of the heavy metals (Pb, Hg, Ni, Cu, Cr, Zn, Mn, Fe) in the samples were analyzed using Atomic Adsorption Spectrometer. Pollution parameters such as enrichment factor, contamination factor, pollution load index and geo-accumulation index were evaluated. The result of heavy metal analysis showed that, the concentration (ppm) of the metals in water samples ranged as follows: Pb(0.25-0.50), Hg(0.00-2.00), Ni(0.10-0.31), Cu(0.03-0.13), Cr(0.00-1.33), Zn(0.01-0.04), Mn(0.03-0.06) and Fe(105.15-118.75) respectively. This result when compared with the EPA maximum permissible limits for drinking water showed that, all the metals except Cu and Zn had values above the permissible limits. The evaluation of enrichment factor revealed that, Hg showed extremely high enrichment while Pb showed significant enrichment for Algae, water and sediment samples. The contamination factor showed low contamination for all metals except Hg which showed considerable contamination for sediments, water and Algae samples. The pollution load index for sediments, water and Algae indicated no pollution. The geo-accumulation index of the metals in sediments, water and Algae indicates no or minimal pollution. The samples were enriched with Hg and Pb. These metals are capable of causing various types of cancer, brain and kidney damage among other ailments.

Key words: Heavy metal, pollution, water, sediment, Algae.

Introduction

Pollution is defined as the undesirable state of the natural environment being contaminated with harmful substances as a consequence of human activities. Pollution caused by heavy metals is increasing with the increase usage of chemicals in industry and agriculture (Abdullah *et al*., 2015). Heavy metals are individual metals and metal compounds that can impact human health. Examples of heavy metals includes: lead, mercury, and copper, among others. These are all naturally occurring substances which are often present in the environment at low levels; in large amounts, they can be dangerous (Sabine and Wendy, 2009).

Aquatic ecosystem is the ultimate recipient of almost everything including heavy metals. Pollution of heavy metals in aquatic environment is a growing problem worldwide and has reached an alarming rate during the recent years, because they are indestructible and most of them have toxic effects on living organisms (Ogoyi *et al*., 2011; Öztürk *et al*., 2009; Mmolawa *et al*., 2011). There are various sources of heavy metals: some originates from anthropogenic activities like draining of sewerage, discharge of hospital wastes and industrial effluents, among other activities. Conversely, metals also occur in small amounts naturally and may enter into aquatic ecosystem through leaching of rocks, airborne dust, forest fires and vegetation. As heavy metals cannot be degraded, they are continuously being deposited and incorporated in water, sediments and aquatic organisms, thus causing heavy metal pollution in water bodies (Ogoyi *et al*., 2011; Öztürk *et al*., 2009). Heavy metal pollution in the aquatic ecosystem may have a very great effect on the Algae (which constitute the main food source for bivalve molluscs in all their growth stages) zooplankton and for larval stages of some crustacean and fish species. Furthermore, bio-concentration and magnification could lead to high toxicity of these metals in organisms, even when the exposure is low. Pollutants in the aquatic ecosystem stimulate the production of reactive oxygen species (ROS) that can damage fish and other aquatic organisms leading to their population decline. Apart from destroying the aquatic ecosystem, the accumulation of these toxic metals in aquatic food chain is a threat to public health (Ogoyi *et al*., 2011; Singh and Kalamdhad, 2011).

Since river Benue runs through Jimeta-Yola the capital city of Adamawa state, its water quality is greatly affected by land use and activities of the area. Indiscriminate discharge of industrial wastes and agricultural activities taking place in the area which involves the use of fertilizers, herbicides and pesticides; the use of chemicals as a fishing technique among others has made it imperative to assess the river to know whether or not the levels of its heavy metal pollution is above the world recommended levels.

Materials and methods

The study area

Yola (Jimeta) the Adamawa state capital is located between latitude 9˚16' N and longitude 12˚26' E along the bank of river Benue one of the two major rivers in Nigeria. It has a population of 198,247 based on the 2006 census. It is the administrative capital of Adamawa state where the government house, ministries, and parastatals are located (Phanuel and Glanda, 2016).

Sample preparation and analysis

12 samples were collected at four different points (point 1 and 2 were collected before Jimeta bridge while points 3 and 4 were collected after Jimeta Bridge) at distances of between 100 and 300 metres from the study area with the help of the local fishermen. These samples comprised 4 samples of bed sediments, 4 samples of surface water, and 4 samples of Algae. The sediment and Algae samples were collected in black polyethylene bags while the water samples were collected in 1litre plastic containers and tagged for identification. The sediment and Algae samples were sprayed in trays and air dried for 48 hours under ambient temperature. The air dried samples were subsequently oven dried in the laboratory at a temperature of 105˚C and then pulverized using mortar, pestle and 1mm standard sieve.

3g each of the samples were weighed into a digestion flask and 30cm^3 of aqua regia was added and digested in a fume-cupboard until clear solution was obtained. This solution was cooled, filtered and then made up to 100ml mark in a standard volumetric flask with de-ionized water.

Standard solutions (2ppm, 4ppm and 6ppm) were prepared from 1000ppm stock solution of the metals. The concentration of the heavy metals Hg, Cu, Ni, Cr, Pb, Fe, Zn and Mn in the respective samples were analyzed using AAS.

Theoretical Calculations of Heavy Metal Pollution Parameters

Geo-accumulation index (I_{geo})

The geo-accumulation index (I_{geo}) has been employed to evaluate pollution of sample by heavy metals. The (I_{geo}) of a metal in sample can be calculated with the formula; given by Akpan and Thompson, (2013) as

$$(I_{geo}) = \log_2 \frac{C_{metal}}{1.5C_{control}} \quad 2$$

Where, C_{metal} is the concentration of heavy metals in enriched samples, $C_{control}$ is the concentration of the metal in the unpolluted control,

The factor 1.5 is introduced to minimize the effect of possible variation in the background or control values.

The geo-accumulation index has seven classes depending on it value as in the Table1.

Table1: Classes of geo-accumulation index.

(I_{geo})	(I_{geo}) class	Sample quality
0	0	No pollution
0-1	1	Not or minimal pollution
1-2	2	Moderately polluted
2-3	3	Moderately polluted to polluted
3-4	4	Polluted to strongly polluted
4-5	5	Strongly polluted
5-6	6	Strongly to very strongly polluted
>6	7	Very strongly polluted

(Akpan and Thompson, 2013).

Enrichment factor (EF)

Enrichment factor (EF) can be used to differentiate between the metals originating from anthropogenic activities and those from natural procedure, and to assess the degree of anthropogenic influence. Akpan and Thompson (2013), gives the definition of enrichment factor as stated below:

Enrichment factor EF(X)

$$= \frac{(\frac{X}{N})_{sample}}{(\frac{X}{N})_{control}} \quad 3$$

EF(X) is the enrichment factor for the metal X, $(\frac{X}{N})_{sample}$ is the ratio of the concentration of metal X to major metal N (Fe or Al) in the sample. $(\frac{X}{N})_{control}$

is the ratio of the concentration of the metal X to major metal N (Fe or Al) in a reference material such as the control sample. Both aluminium (Al) and iron (Fe) can be used as the metal for normalization because their anthropogenic sources are small compared to natural sources. Generally, the value of enrichment factor in Table2 evaluates the level of impartation of the sample by the metals.

Table 2: Contamination criteria based on enrichment factor.

Classification	Degree of enrichment
EF = 1	No
EF = 2	Minimal
2< EF < 5	Moderate
5 < EF < 20	Significant
20 < EF < 40	Very high
Ef >40	Extremely high

(Faweya *et al., 2013*; Akpan and Thompson, 2013).

Contamination factor (CF)

Contamination factor (CF) gives an indication of the degree of contamination of sample. Foley (2011) defined contamination factor as the ratio of concentration of metal in a sample to the concentration of metal in the background or control value.

$$CF = \frac{C_{sample}}{C_{background}} \quad 3$$

Where, C_{sample} ,is the concentration of heavy metal in enriched samples, $C_{background}$, is the background concentration of metal.

Table 3: contamination criteria based on contamination factor

Classification	Degree of contamination
CF < 1	Low
1 = CF < 3	Moderate
3 = CF < 6	Considerable
CF = 6	High

(Foley, 2011)

Pollution load index (PLI)

Pollution load index (PLI) is used in evaluating the pollution level for an environment. It is given as

$$PLI = (CF1 \times CF2 \times CF3 \times \ldots \times CFn)^{1/n} \quad 4$$

Where, CF is the contamination factor and n is the number of metals investigated. The PLI value > 1 indicates pollution while PLI value < 1 indicates no pollution (Mmolawa *et al*, 2011).

Results

Table 4: Concentration (ppm) of heavy metals in sediment samples obtained from AAS analysis.

samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	1.00	2.0	1.85	1.49	0.67	1.57	10.82	146.48
2	1.00	2.0	1.03	1.52	0.00	1.37	4.28	137.43
3	0.25	1.0	3.08	1.23	0.67	0.68	8.07	140.49
4	0.50	1.0	1.33	1.55	0.67	0.94	4.96	140.73
Average shale	20	0.4	68	45	90	95	850	47200

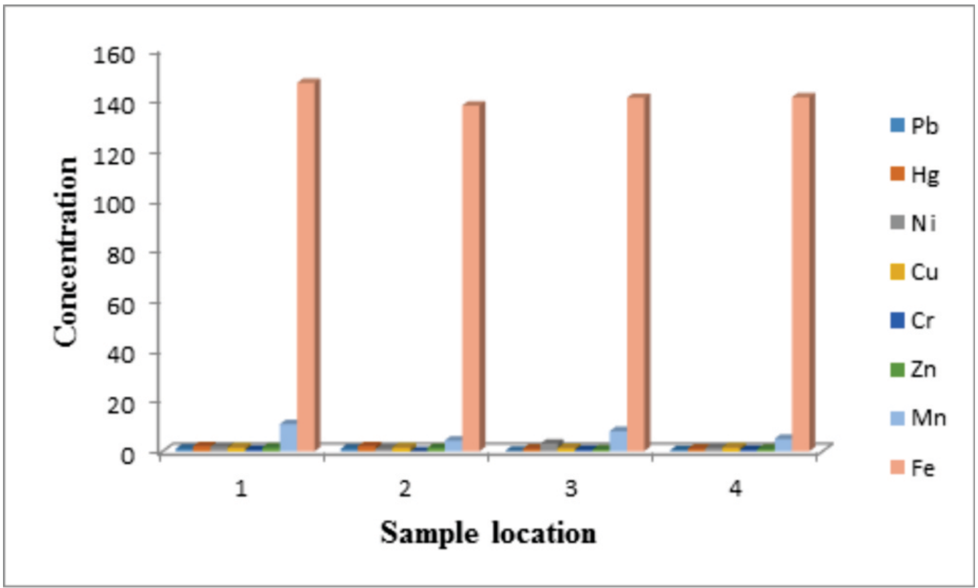

Figure 1: Concentration of heavy metals in sediment samples.

Table 5: Concentration (ppm) of heavy metals in water samples obtained from the AAS analysis.

samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	0.50	0.0	0.31	0.10	0.00	0.01	0.06	105.15
2	0.25	2.0	0.21	0.13	0.67	0.04	0.03	118.72
3	0.50	1.0	0.1	0.03	0.00	0.03	0.03	112.86
4	0.50	0.0	0.31	0.03	1.33	0.04	0.03	108.58
Average shale	20	0.4	68	45	90	95	850	47200

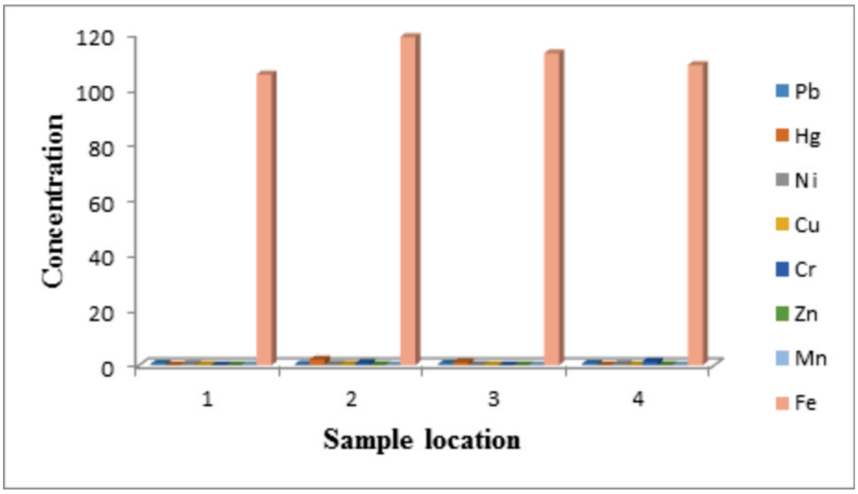

Figure 2: Concentration of heavy metals in water samples.

Table 6: concentration (ppm) of the heavy metals in Algae samples obtained from AAS analysis.

samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	0.25	1.0	0.92	1.49	0.00	3.65	48.51	141.96
2	0.25	1.0	1.23	1.03	0.66	1.10	48.35	145.01
3	0.25	3.0	1.03	1.42	0.66	0.94	43.88	132.05
4	0.25	2.0	1.33	1.42	0.00	4.08	50.23	136.21
Average shale	20	0.4	68	45	90	95	850	47200

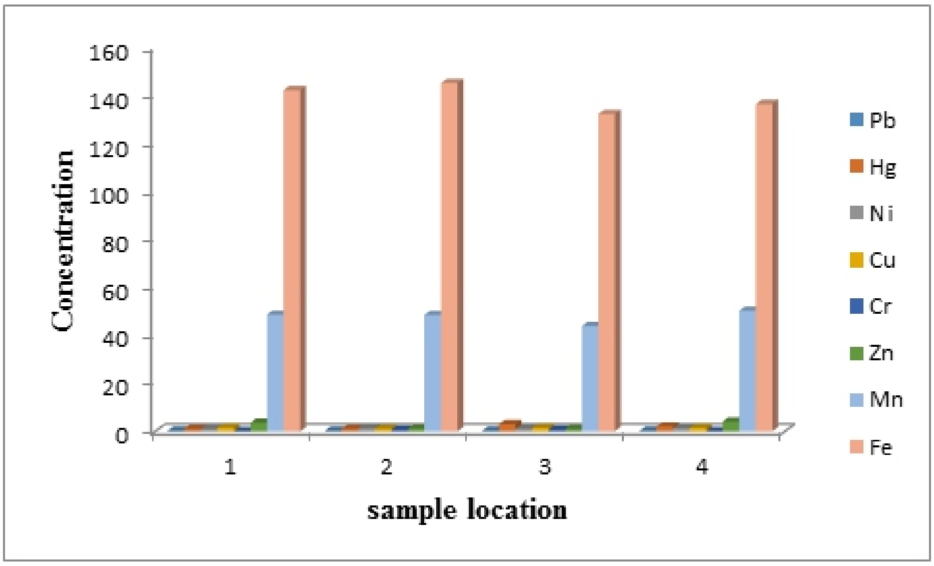

Figure 3: Concentration of heavy metals in Algae samples.

Table 7: Enrichment factor (EF) of the Algae samples.

Samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	4.16	831.20	4.50	11.01	0.00	12.77	18.98	1
2	4.07	813.73	5.89	7.45	2.39	3.77	18.51	1
3	4.47	2680.80	5.41	11.28	2.62	3.54	18.45	1
4	17.33	1732.62	6.78	10.93	0.00	14.88	20.48	1

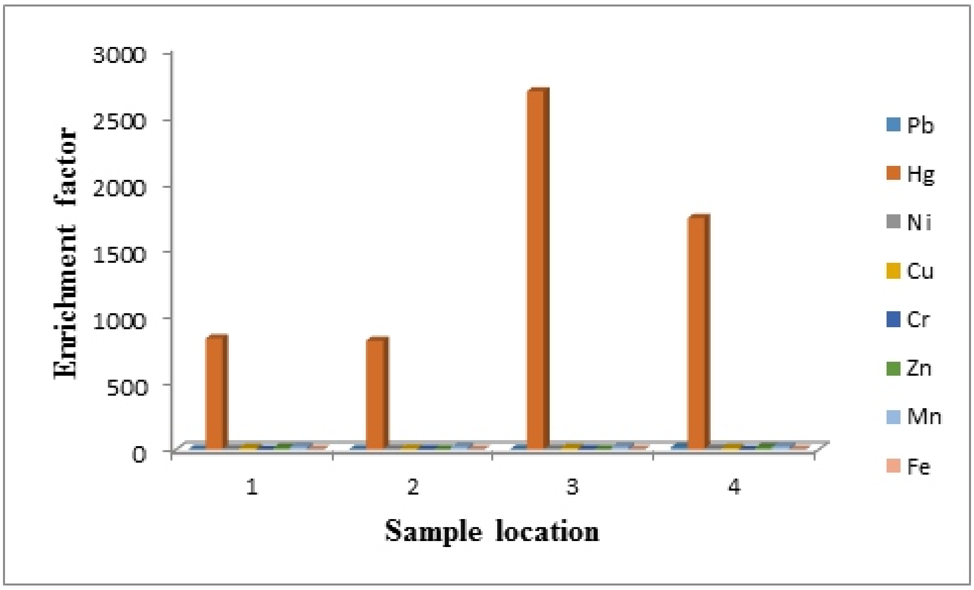

Figure 4: Enrichment factor of the Algae samples.

Table 8: Enrichment factor (EF) of water samples.

Samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	11.22	0.00	2.05	1.00	0.00	0.05	0.03	1
2	4.97	1987.87	1.23	1.15	2.96	0.17	0.01	1
3	10.46	1045.54	0.62	0.28	0.00	0.13	0.15	1
4	10.87	0.00	1.98	0.29	6.42	0.18	0.02	1

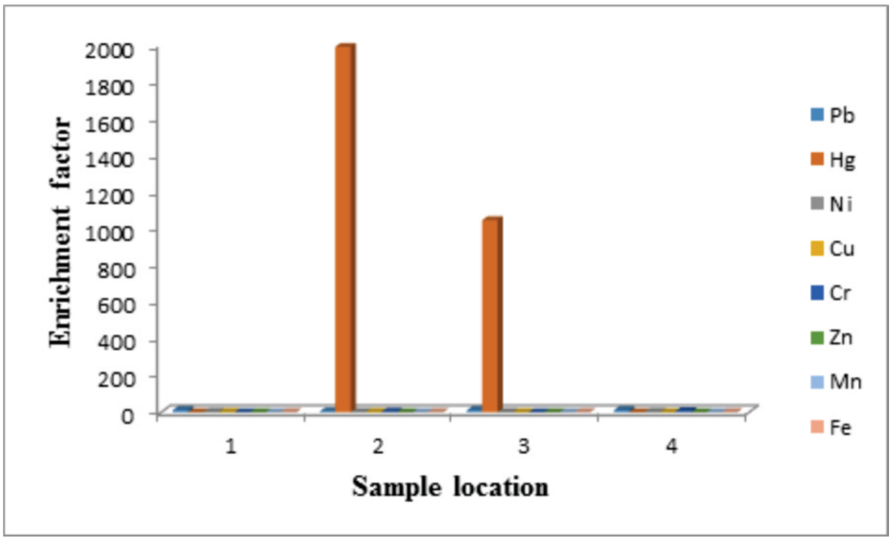

Figure 5: Enrichment factor of water samples.

Table 9: Enrichment factor (EF) of sediment samples.

samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	16.11	1611.14	8.77	10.67	2.4	5.33	4.10	1
2	17.17	1717.24	5.20	11.60	0.0	4.95	1.73	1
3	4.20	839.91	15.22	9.180	2.5	2.40	3.19	1
4	8.38	838.49	6.56	11.55	2.5	3.32	1.96	1

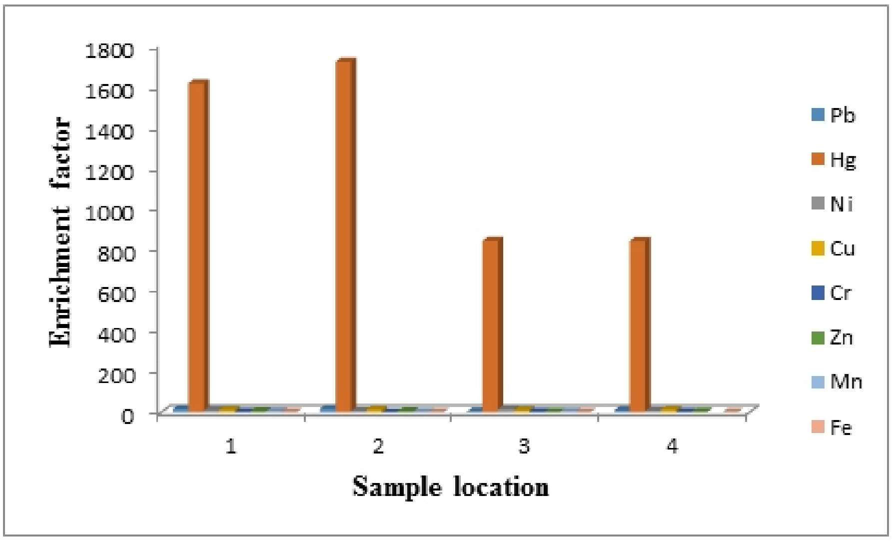

Figure 6: Enrichment factor of sediment samples.

Table 10: contamination factor (CF) of sediment samples.

samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	0.05	5.0	0.027	0.033	0.007	0.017	0.013	0.003
2	0.05	5.0	0.015	0.033	0.000	0.014	0.005	0.003
3	0.013	2.5	0.045	0.027	0.007	0.007	0.009	0.003
4	0.025	2.5	0.02	0.034	0.007	0.01	0.006	0.003

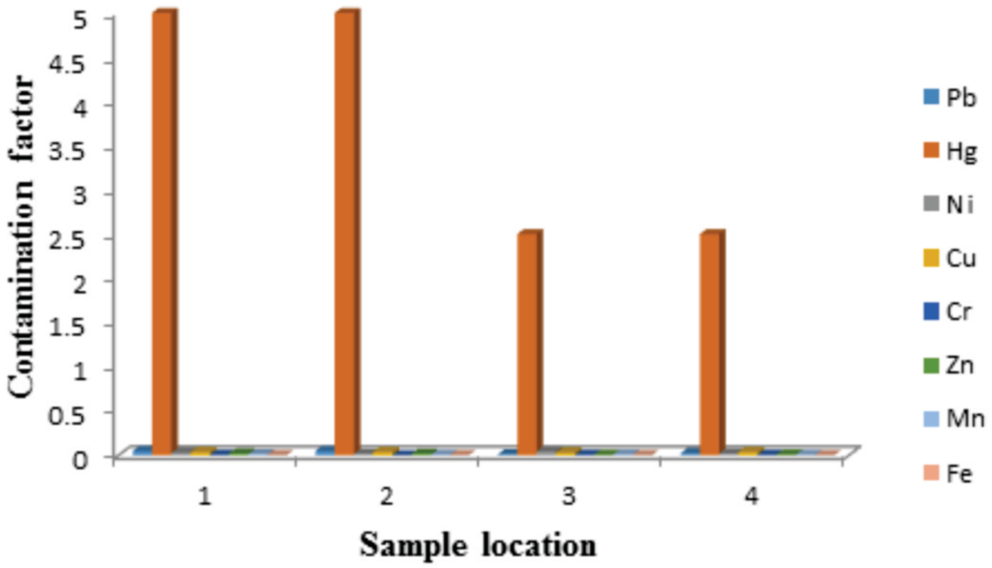

Figure 7: Contamination factor of sediment samples.

Table 11: Pollution load index (PLI) of sediment samples.

Sample	PLI
1	0.03
2	0
3	0.02
4	0.02

Table 12: Contamination factor (CF) of water samples.

samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	0.025	0.0	0.005	0.002	0.000	0.0001	0.00007	0.002
2	0.013	5.0	0.003	0.003	0.007	0.0004	0.00004	0.003
3	0.025	2.5	0.001	0.001	0.000	0.0003	0.00004	0.002
4	0.025	0.0	0.005	0.001	0.015	0.0004	0.00004	0.002

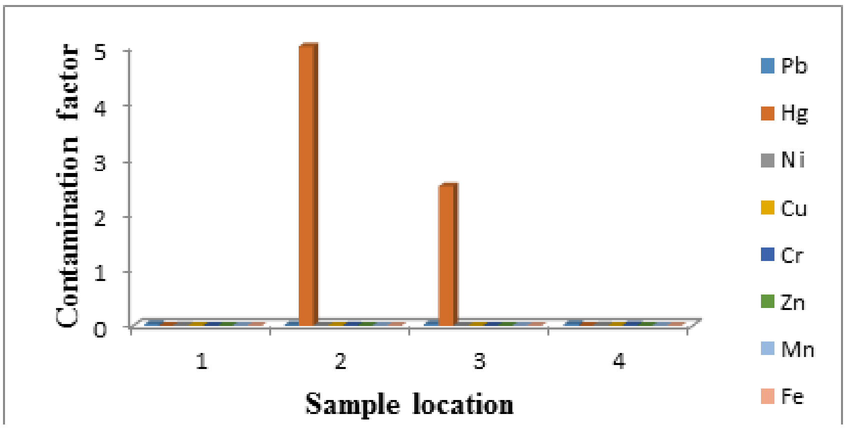

Figure 8: Contamination factor of water samples.

Table 13: Pollution load index (PLI) of water samples.

Sample	PLI
1	0.00
2	0.01
3	0.00
4	0.00

Table 14: Contamination factor (CF) of Algae samples.

samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	0.013	2.5	0.014	0.033	0.000	0.038	0.057	0.003
2	0.013	2.5	0.018	0.023	0.007	0.012	0.057	0.003
3	0.013	7.5	0.015	0.032	0.007	0.010	0.052	0.003
4	0.050	5.0	0.020	0.032	0.000	0.043	0.059	0.003

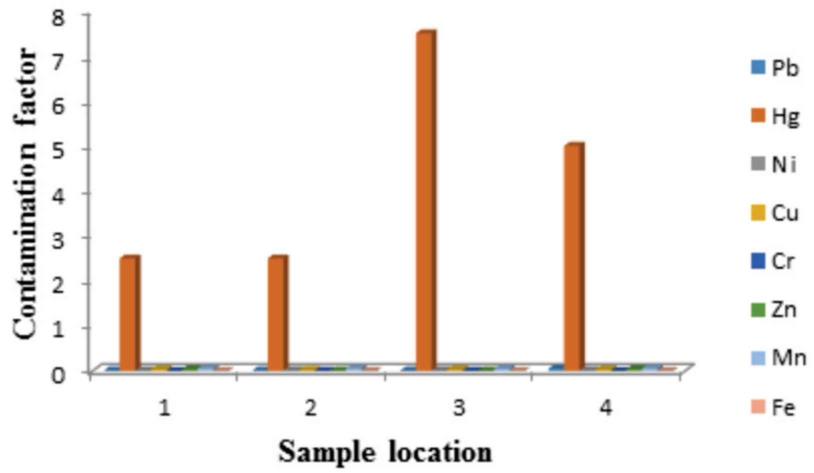

Figure 9: Contamination factor of Algae samples.

Table 15: Pollution load index (PLI) of Algae samples.

Sample	PLI
1	0.00
2	0.03
3	0.03
4	0.00

Table 16: Geo- accumulation index of heavy metals in sediment samples.

samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	-4.92	1.74	-5.8	-5.51	-7.64	-6.51	-6.27	-8.97
2	-4.92	1.74	-6.64	-5.44	ND	-6.64	-8.38	-8.97
3	-6.97	0.74	-5.06	-5.8	-7.64	-7.64	-7.38	-8.97
4	-5.88	0.74	-6.27	-5.44	-7.64	-7.16	-7.97	-8.97

ND: Not detected.

Table 17: Geo- accumulation index of heavy metals of water samples.

samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	-5.88	ND	-7.64	-9.97	ND	-13.8	-14.29	-9.97
2	-6.97	1.74	-8.97	-8.97	-7.64	-11.7	-15.61	-8.97
3	-5.88	0.74	-9.97	-11.29	ND	-12.29	-15.61	-8.97
4	-5.88	ND	-7.64	-11.29	-6.64	-11.7	-15.61	-8.97

ND: Not detected.

Table 18: Geo-accumulation index of heavy metals in Algae samples.

samples	Pb	Hg	Ni	Cu	Cr	Zn	Mn	Fe
1	-6.97	0.74	-6.8	-5.51	ND	-5.27	-4.72	-8.97
2	-6.97	0.74	-6.38	-6.06	-7.64	-6.97	-4.72	-8.97
3	-6.97	2.32	-6.64	-5.57	-7.64	-7.16	-4.88	-9.11
4	-4.92	1.74	-6.27	-5.57	ND	-5.11	-4.68	-9.04

ND: Not detected.

Discussion

Concentration of heavy metals

The concentration (ppm) of the heavy metals obtained from AAS analysis in sediments, water and Algae samples is as shown in Tables 4, 5, 6 and Figures 1, 2, 3 respectively.

The result of Table 4 and Figure 1 have shown that, the concentration (ppm) of the metals in sediment ranged as follows: Pb from 0.25 to 1.00, Hg from 1.00 to 2.00, Ni from 1.03 to 3.08, Cu from 1.23 to 1.55, Cr from 0 to 0.67, Zn from 0.68 to 1.57, Mn from 4.28 to 10.82 and Fe from 140.49 to 146.48 respectively. Literature has revealed that, Ogaga *et al.,* (2015) had the mean concentration of heavy metals (ppm) in sediments of Warri River in Niger Delta as follows: Fe(6782), Cu(22.50), Pb(55.25), Cr(8.43), Ni(6.83) and Zn(110). Edward *et al.,* (2018), also reported value in the range Cu (0.19-0.22), Ni (0.02-0.05), Pb(0.02-0.04), and Zn(0.01-0.12). Maitera *et al.,*(2011) also reported the value in the range: Mg (10.65-102.00), Zn (0.213-0.444), Pb(0.28-0.474) and Mn(0.178-0.76). The result of the present study is similar to the literature.

The result of Table 5 and Figure 2 have shown that, the concentration (ppm) of the metals in water ranged as follows: Pb from 0.25 to 0.50, Hg from 0 to 2.00, Ni from 0.10 to 0.31, Cu from 0 .03to 0.13, Cr from 0 to 1.33, Zn from 0.01 to 0.04, Mn to 0.03 to 0.06 and Fe from 105.15 to 118.72 respectively. This result when compare with the EPA maximum permissible limits for drinking water, showed that all the metals except Cu and Zn had values above the permissible limits (MDH, 2005; ATSDR, 2005; Sabine and Wendy, 2009). A perusal of literature reveals that, Ogaga *et al.,* (2015) reported heavy metal concentration (ppm) of water in Warri River, Niger Delta, Nigeria to range as follows: Fe(0.3-0.7), Cu(0.0008-0.0176), Zn(0.0033-0.0502) and Cr(0.1693-0.2352). Edward *et al*.,(2018) also reported that, the concentration of heavy metals (ppm) in upper Benue River range as follows: Cu(0.19-0.22), Ni(0.02-0.05), Pb(0.02-0.04) and Zn(0.01-0.12). Hong *et al.,*(2014) also reported mean concentration (ppm) of heavy metals in River Benue at Jimeta/Yola metropolitan, Adamawa state to be as follows: Fe(0.293), Zn(0.398), Mn(0.651), Cu(0.272), Cr(0.06) and Pb(0.02). The result of the present study is high compared to the literature.

The result of Table 6 and Figure 3 has shown that, the concentration (ppm) of the metals in Algae ranged as follows: Pb from 0.25 to 1.00, Hg from 1.00 to 3.00, Ni from 0.92 to 1.33, Cu from 1.03 to 1.49, Cr from 0 to 0.66, Zn from 0.94 to 4.08, Mn from 43.88 to 50.23 and Fe from 132.05 to 145.01 respectively. A perusal of literature reveals that, Anbalagan and Sivakami, (2018) reported heavy metal concentration (ppm) of Algae of Mukkombu in River Cauvery, India to range as follows:Cu(50.2-69.64), pb(15.6-19.2), Zn(86.4-104.6) and Fe(172-180.6). The result of the present study is lower than the literature.

Enrichment factor

The enrichment factor (EF) of the heavy metals in Algae, water and sediments samples were calculated using equation (2) and Iron as the tracer, the results are as shown in Tables 7, 8, 9 and Figures 4, 5, 6 respectively.

The result of Table 7 and Figure 4 when compared with the standards given in table 2 ((Faweya *et al., 2013*; Akpan and Thompson, 2013) indicates on average the following: Pb, Ni, Cu, Zn and Mn showed significant enrichment; Hg extremely high enrichment; Fe showed no enrichment and Cr showed moderate enrichment.

The result of Table 8 and Figure 5 when compared with the standards given in Table 2 (Faweya *et al., 2013*; Akpan and Thompson, 2013) indicates on average the following: Ni, Cu, Zn, Mn and Fe showed no enrichment; Cr showed minimal enrichment; Pb showed significant enrichment and Hg showed extremely high enrichment.

The result of Table 9 and Figure 6 when compared with the standards given in Table 2 (Faweya *et al., 2013*; Akpan and Thompson, 2013) indicates on average the following: Fe showed no enrichment; Cr, Zn, Mn showed moderate enrichment; Pb, Ni, Cu showed significant enrichment and Hg showed extremely high enrichment.

Contamination factor

The contamination factor (CF) of the heavy metals in the sediments, water and Algae samples were calculated using equation (3) and the results are as shown in Tables 10, 12, 14 and Figures 7, 8, 9 respectively.

These results of contamination factor when compared with standards given in Tables3 (Foley, 2011) indicates on average low contamination for all the metals except Hg which showed considerable contamination.

Pollution load index (PLI)

The pollution load index (PLI) of sediments, water and Algae samples at the sampled points were calculated using equation (4) and the results were presented in Tables 11, 13 and 15 respectively. These results when compared with the standards indicate no pollution (Mmolawa *et al*, 2011).

Geo-accumulation index of the heavy metals

The geo-accumulation index of the heavy metals in the sediments, water and Algae was calculated using equation (1) and the results is as shown in Tables 16, 17 and18 respectively. These results when compared with the standard given in Table1 (Akpan and Thompson, 2013) indicates no or minimal pollution.

Conclusion

The study revealed that the concentration of all the metals under study except Cu and Zn had average values above the permissible limits for water samples. The calculated values of enrichment factor revealed that, Pb showed significant enrichment while Hg showed extremely high enrichment for Algae, water and sediment samples. The calculated values of contamination factor showed low contamination for all metals except Hg which showed considerable contamination for sediment, water and Algae samples. The calculated values of pollution load index of sediment, water and Algae samples indicated no pollution. The calculated values of geo-accumulation index of the metals in sediment, water and Algae indicates no or minimal pollution.

The result of this research has shown that, the samples were enriched with Hg and Pb. These metals are capable of causing various types of cancer, brain and kidney damage, miscarriage in pregnant women among other ailments.

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