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Seasonal potential toxic metals contents of Yauri river bottom sediments: North western Nigeria

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A study was conducted to investigate the seasonal level of heavy metals in bottom sediments of Yauri River, Northwestern Nigeria. Thirty composite samples of bottom sediments were collected at six demarcated sites along the river during the 2010/2011 raining and dry seasons. The heavy metals concentrations were determined with atomic absorption spectrometer. The mean levels range of Cd, Cr, Cu, Fe, Ni, Pb and Zn were 4.38 to 23.11, 11.08 to 74.13, 10.87 to 42.13, 100.69 to 301.02, 25.85 to 116.32, 10.11 to 34.11 and 18.91 to 109.62 µg/g for raining season and 6.25 to 13.09, 18.95 to 77.61, 17.39 to 64.05, 138.25 to 349.50, 56.13 to 91.60, 17.39 to 45.02 and 21.80 to 131.16 µg/g for dry season, respectively. The values generally were lower than the world shale values and sediment quality guidelines values. Sediments pollution assessment was carried out using enrichment factor (EF), geoaccumulation index (I_{geo}), contamination factor (CF) and pollution load index (PLI). The calculations of EF showed that the river is contaminated with Cd, Cu, Pb and Zn. On the other hand the I_{geo} values suggested that the river is polluted with Cr and Pb and moderately polluted with Cu, Ni and Zn. Contamination factor values revealed that Fe and Ni have none to medium contamination while Cd and Pb are strongly polluted. Generally, according to the pollution load index (PLI) values calculated, the river is polluted with all the elements analysed. Some of the elevated concentrations of some of the heavy metals are probably due to anthropogenic and natural sources. It can be said that the environmental or human health impact involving these metals is occurring in the river and can cause hazard to sediments dwelling organisms in the river as well as the populace in the area through food chain.

Key words: Heavy metals, Nigeria, seasonal, enrichment factor, contamination factor.

INTRODUCTION

Heavy metals pollution of the environment, even at low levels and their resulting long term cumulative health effects are among the leading health concerns all over the world (Alloway and Ayres, 1997). They are of concern as contaminants to aquatic systems because of their toxicity at low concentrations.

Surface sediments are specific elements of the natural environment. They are a natural sponge that adsorbs all kinds of pollutants occurring in water. The structure of sediments together with their developed surfaces makes them a natural sorbent in which the accumulation of all sorts of harmful substances takes place. Pollutants originating from urbanized areas are deposited in the estuaries and form a loose layer of accumulated sediments. These accumulated sediments can be distinguished from the original parent soils by unique soil characteristics (Bellucci et al., 2003; Unnikrishnan and Nair, 2004).

The occurrence of elevated levels of heavy metals especially in sediments can be a good indication of man induced pollution. High levels of heavy metals can often be attributed to anthropogenic influences, rather than natural enrichment of the sediment by geological

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weathering (Davies et al., 1991). There can be significant temporal and spatial ariability in water column concentrations of heavy metals contaminants, which leads to problems in obtaining representative samples. Sediments, on the other hand, integrate contaminants over time and are in constant flux with the overlying water column. The analysis of heavy metals in the sediments permits detection of pollutants that may be either absent or in low concentrations in the water column (Davies et al., 1991). Their distribution in coastal sediments provides a record of the spatial and temporal history of pollution in a particular region or ecosystem. Heavy metal concentrations in the water column may be relatively low, but concentrations in the sediment may be elevated (Binning and Baird, 2001).

Therefore, knowledge of potential toxic metals concentration in Yauri River bottom sediments and its surrounding villages is important, which is the aim of the present study. Many studies on river bottom sediments of heavy metals concentration analysis have been conducted in various parts of the world (Loska and Wiechula, 2003; Karbassi et al., 2005), but there is paucity of Nigerian (especially with regards to Yauri River) information on this subject. This research therefore was conducted to investigate the seasonal level of heavy metals in bottom sediments of Yauri River; Northwestern Nigeria with a view of providing some reference data for North Western Nigeria. In addition, it also provides valuable information and advice for policy and decision makers on the pollution level of the area.

STUDY AREA

Yauri Local Government Area of Kebbi state, Northwestern Nigeria was the study area (Figure 1). It is located southward on the earthen bank of River Niger and falls within latitudes 10° N and 30° N and longitudes 3° W and 6° W of the globe. The area has flat topography with a few elevated areas. It is an extension of the Sokoto plain: dotted with some dome-shaped hills and complemented by a portion of the great River Niger and its numerous tributaries, which gently meanders on the landscape. Relative to its geographical location, the study area enjoys a tropical type of climate, generally characterized by two extremes of temperatures (Adamu, 2000). The mean annual rainfall of the area is 1040 mm. The wet/rainy season last for 5 to 6 months that is, between April/May to October with heaviest amount of rainfall in August. During the dry season temperature ranges from a minimum of 15 to 24℃ in December/January to a maximum of 32 to 39℃ in April/May. Yauri town is an agricultural town with most of its inhabitant being farmers and due to the presence of the river, fishing is a common activity. To the inhabitants of Yauri town, river Niger was an important flow for them and was used for different purposes like, water supply, irrigation, fishing, recreation, drinking and domestic water supply. As the population of Yauri town continues to rise, human activities including soil fertility remediation, indiscriminate refuse and waste disposal and the use of septic tanks, soak away pits and pit latrines increases. Economic activities along the river course include fishing; washing; recreational swimming; refuse dumping; auto-mechanic workshop; animals slaughter (Abattoir) among others, which can lead to increase in concentrations of heavy metals in the river sediments that can increase the rate at which their negative effects can pass to populace through food chain.

MATERIALS AND METHODS

All reagents (Nitric acid, metallic salts and percholoric acid) used were of analytical grade (Sigma Aldrich Chemicals Corporation). Glass wares (polyethylene bottles and Teflon beakers) and sample containers (50 mL, Fisher scientific) used were thoroughly washed with non-ionic detergent solution and rinsed with triple distilled water, followed by soaking in 10% nitric acid (65%, Sigma Aldrich Chemicals Corporation) for 48 h and finally rinsed with triple distilled water.

Sample collection

Thirty composite samples of bottom sediments (0 to 2 cm) were collected at six demarcated sites that are mostly agricultural settlements with farming and fishing activities as the dominants human endeavour's along the river (Figure 1): P_1 (Tillo village), P_2 (Tondi village), P_3 (Yauri market site), P_4 (Gungun Sarki area), P_5 (Zamare village) and P_6 (Gumbi village), with five composite samples from each demarcated sites from the Yauri River. Sediment samples were collected using a grab sampler (Berg Ekman Dredge Cot-214 WA 180). All the samples were ice preserved and transported to the laboratory. They were stored at 4℃ in refrigerator until pretreatment and analysis. The samples were collected between June to October, 2010 for raining season and between January to May, 2011 for dry season.

Analysis of sediment samples

The samples were air-dried at 100℃ for 48 h in the oven. The dried samples were passed through standard screen to remove large particles. For the digestion of the sediment sample, one gram of dried and homogenized sediment samples was weighed and placed into acid washed Teflon vessels. The digestion was performed with a mixture of HNO_3 and $HClO_4$ acid (Imperato et al., 2003).

The digested samples were analyzed for heavy metals using Atomic Absorption Spectrophotometer, Alpha Star Model 4 (Chem Tech Analytical) at the Centre for Energy Research and Development of the Obafemi Awolowo University, Ile–Ife, Nigeria. The instrument was operated as per the instrument handbook and data were acquired with Hewlett Packard (HP) Pavilion 3134 software. The analytical precision and accuracy of the method was accomplished by analyzing a blank and four replicate samples of IAEA certified material, Soil-7. Metal contents were expressed as µg/g and three determinations were done for all samples.

Determination of enrichment factor

In the present study, enrichment factor (EF) was used to assess the

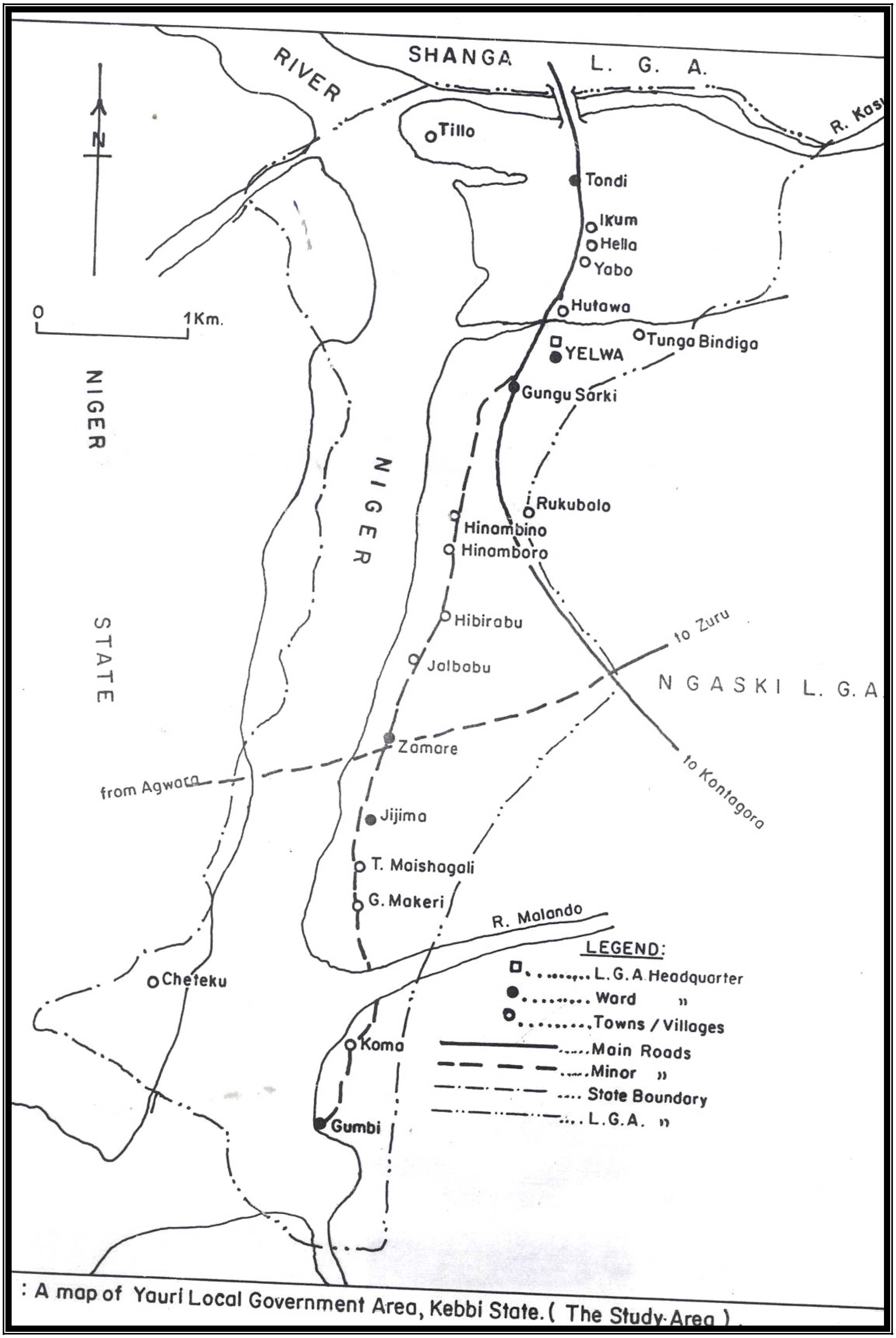

Figure 1. Map of sampling villages.

level of contamination and the possible anthropogenic impact in sediments of Yauri river bottom sediments. To identify anomalous metal concentration, geochemical normalization of the heavy metals data to a conservative element, such as, Al and Si. Iron was employed. Several authors have successfully used iron to normalize heavy metals contaminants (Mucha et al., 2003). In this study iron has also been used as a conservative tracer to differentiate natural from anthropogenic components.

Ergin et al. (1991) defined metal enrichment factor as follows:

$$\text{Enrichment factor} = \frac{(M/Fe)_{Sample}}{(M/Fe)_{Background}}$$

Where $(M/Fe)_{Sample}$ is the ratio of the examined element in the examined environment and Fe concentration of the sample and $(M/Fe)_{Background}$ is the ratio of metal and Fe concentration of a background. Five contamination categories were recognized on the basis of the enrichment factors; EF < 2 - depletion to minimal enrichment; EF = 2 to 5 - moderate enrichment; EF = 5 to 20 - significant enrichment; EF = 20 to 40 - very high enrichment; EF > 40 - extremely high enrichment (Sutherland et al., 2000).

Determination of geoaccumulation index

The geoaccumulation index (I_{geo}) introduced by Muller (1969) was also used to assess metal pollution in sediments of Yauri river.

Geoaccumulation index ($I\text{-}_{geo}$) values for the elements were calculated using the equilibrium equation according to Diatta et al. (2008) and background levels of element in non-contaminated soils.

$$I\text{-}_{geo} = \mathrm{Log}_2\,(C_n/1.5\,B_n)$$

Where C_n is the measured concentration of the heavy metal (n) in the sediment sample; B_n is the geochemical background value and 1.5 is the background matrix correction factor due to lithogenic effects. Muller (1969) proposed an index for geoaccumulation with seven classes depending on its value: less than 0 or 0 no pollution; values from 0 to 1 not polluted to moderately polluted (class 1); 1 to 2, moderately polluted (class 2); 2 to 3, moderately polluted to polluted (class 3); 3 to 4, polluted to strongly polluted (class 4); 4 to 5, strongly polluted (class 5); 5 to 6 strongly polluted to very polluted (class 6) and greater than 6, very polluted (class 7).

Determination of contamination factor

Contamination factor (CF) is the ratio obtained by:

$$CF = [C_{heavy\ metal}] / [C_{background}]$$

The contamination levels may be classified based on their intensities on a scale ranging from 1 to 6 (0 = none, 1 = none to medium, 2 = moderate, 3 = moderately to strong, 4 = strongly polluted, 5 = strong to very strong, 6 = very strong) (Hakanson, 1980).

Determination of pollution load index

Pollution load index (PLI) for the entire sampling site was determined as the nth root of the product of the nCF.

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \cdots \times CF_n)^{1/n}$$

This empirical index provides a simple, comparative means for assessing the level of heavy metal pollution (Usero et al., 2000). The PLI value > 1 is polluted whereas < 1 indicates no pollution.

RESULTS AND DISCUSSION

The results of the determination of the analytical precision and accuracy of the method used in analyzing the heavy metals concentrations in Yauri river bottom sediments are given in Table 1.

Higher percentage recoveries obtained for both metals (96.24 to 99.75%) and IAEA- certified material (96.63 to 98.26%) have proved that the sample preparation method and analytical procedure described in this study were satisfactory.

The concentrations found for the seven elements examined in the bottom sediments in both raining and dry seasons are shown in Table 2. Mean concentrations of Cd, Cu, Fe, Ni and Pb were generally higher in sediments in both seasons than the background values while Cr and Zn are lower. Generally, mean metals concentrations in sediments during raining season are lower than that of dry season.

Table 2 presents the mean ± SD of heavy metals concentrations in the surface sediments of all sampling points studied for both raining and dry (values in brackets) seasons in the Yauri river. The concentrations of heavy metals in the sediments were higher at sampling points P_3, P_5 and P_6 that were identified as hotspots. Most of the heavy metals detected at these points may have originated due to run offs from auto-mechanic workshops, irrigation activities, fertilizers, refuse dumps among others. The results were similar to others reported by other researchers (Yahaya et al., 2009, 2010; Abdulrahman, 2001; Aprile and Bouvy, 2008; Habes and Nigem, 2006).

From the results, generally, iron has the highest mean concentration at all the sampling points for both raining and dry seasons. The higher level of Fe recorded within the study area could be related to run-off from rusted metallic roofing sheets on the houses in the area, scrap metal dump sites and refuse dump sites.

The sources of cadmium in the urban areas are much less well defined than those of lead, but metal plating and tire enforced with metals were considered the likely common anthropogenic sources of Cd in street dust through burning of tires and bad roads (Yel et al., 2003) as shown in Table 2. Cadmium high mean concentration levels at all the sampling points could be attributed to the above reason and in addition to rural/urban effluents along the river course and atmospheric precipitation. Cadmium is extremely toxic, that it could cause adverse health effects to end user when water with high percentage is consumed and it is also toxic to fish and other aquatic organisms (Bakan and Ozkoc, 2007), (Leivouri, 1998).

Lead and Nickel concentrations within the study area is pointed to the fact that naturally, Pb and Ni are distributed in surface waters due to weathering of minerals and

Table 1. Results of amount of metal recovered from 5.0 mg/L spiked distilled water and IAEA certified material (in brackets).

Metal	Cd	Cr	Cu	Fe	Pb	Zn
Mean (mg/L)	5.960 (0.996)	4.590 (0.980)	3.960 (0.9765)	4.300 (0.998)	4.000 (0.937)	4.450 (0.995)
SD	0.034 (0.023)	0.061 (0.033)	0.029 (0.017)	0.016 (0.020)	0.010 (0.025)	0.042 (0.019)
CV	0.57 (2.31)	1.33 (3.37)	0.73 (1.74)	0.37 (2.00)	0.25 (2.67)	0.76 (1.91)
Recovery (%)	99.42 (97.69)	98.67 (96.63)	96.26 (98.26)	99.63 (98.00)	99.75 (97.33)	99.24 (98.09)

Table 2. Metals mean ± SD values (µg/g) of sediments concentrations at different sampling points during raining and dry (in brackets) seasons.

Sampling point	Cd	Cr	Cu	Fe	Ni	Pb	Zn
P_1	4.38 ± 3.20 (6.52 ± 0.10)	13.10 ± 4.00 (18.95±1.05)	10.87 ± 1.11 (17.39±0.24)	105.94 ± 0.06 (138.25 ±0.04)	25.85 ± 0.34 (56.13 ±0.01)	24.51 ± 0.33 (30.52 ±0.08)	27.08 ± 0.04 (32.10 ±1.50)
P_2	5.09 ±0.60 (7.34±0.38)	11.08 ± 1.42 (20.74 ± 1.07)	15.63 ± 0.09 (33.16 ± 0.41)	100.69 ± 0.51 (154.30 ± 0.08)	31.70 ± 0.63 (67.04 ± 0.32)	17.55 ± 1.58 (23.45 ± 1.32)	18.91 ± 0.53 (21.80 ± 1.03)
P_3	23.11 ± 0.02 (13.09 ±1.13)	74.13 ± 0.14 (98.33 ± 0.03)	42.13 ± 0.33 (56.32 ± 0.03)	301.02 ± 0.16 (349.50 ± 0.09)	116.32 ± 0.05 (91.60 ± 0.07)	34.11 ± 0.06 (45.02 ± 1.04)	109.62 ± 0.49 (131.16 ± 0.27)
P_4	5.80 ± 0.19 (10.07 ± 0.11)	18.64 ± 1.21 (22.30 ± 0.16)	27.16 ± 1.08 (41.07 ± 0.59)	129.13 ± 0.32 (176.66 ± 0.01)	44.82 ± 0.07 (63.49 ± 0.55)	10.11 ± 2.20 (17.39 ± 0.06)	38.14 ± 0.03 (55.13 ± 2.01)
P_5	6.04 ± 0.73 (9.47 ± 0.09)	52.36 ± 0.23 (77.61 ± 0.21)	34.23 ± 1.42 (49.72 ± 0.14)	169.09 ± 0.25 (203.73 ± 0.06)	63.07 ± 0.55 (88.10 ± 3.30)	16.92 ± 0.14 (27.63 ± 3.80)	66.13 ± 0.41 (90.23 ± 0.06)
P_6	8.19 ± 2.30 (11.53 ± 0.47)	46.15 ± 0.01 (64.05 ± 2.03)	29.46 ± 1.01 (36.12 ± 0.47)	197.52 ± 0.70 (200.13 ± 0.11)	51.76 ± 0.11 (72.56 ± 0.93)	18.41 ± 0.35 (22.96 ± 2.20)	71.92 ± 1.24 (81.04 ± 2.03)
Mean	8.77±1.17 (9.67±0.38)	35.91±1.17 (50.33±0.76)	26.58±0.84 (38.96±0.31)	167.23±0.33 (203.76±0.07)	60.73±0.28 (73.15±0.86)	20.27±0.78 (27.07±1.42)	55.30±0.46 (68.58±1.15)

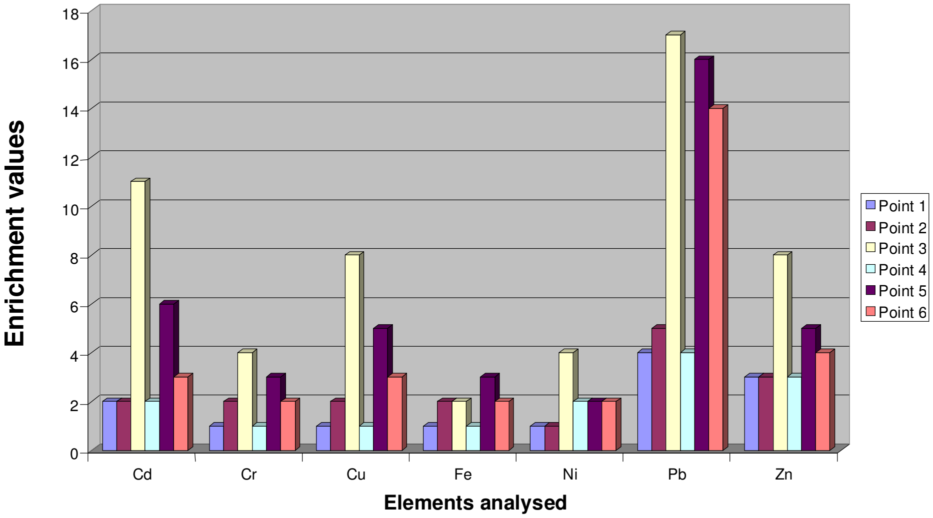

Figure 2. Raining season enrichment factor values.

atmospheric deposition (Spencer and Macleod, 2002; Collins and Stotzky, 1992).

Also lead and nickel recorded high values for both seasons could be related to technical uses, most of which are: electric storage batteries, leachate from sludge containing nickel-cadmium batteries, nickel plate items and emissions from burning of fossil fuels and gasoline which contain high levels of tetraethyl lead (TEL), which is still in use despite its ban in 2004.

Zinc level in the study area could be attributed to the high concentrations of cadmium and iron in that Zinc occurs in nature with other metals of which Fe and Cd are the most common. It is one of the heavy metals that are essential to humans but could be toxic even at low level concentrations. Ingesting extreme amounts of Zn can impair immune function and causes nausea, headaches, vomiting, dehydration, fatigue, possible kidney failure and prostate cancer.

Higher concentrations of copper detected in the bottom sediments of river Yauri for both raining and dry seasons (42.13 and 56.32 µg/g respectively) at sampling point P_3, indicated a higher input of organic matter deposition in this site, which might come from urban and local industrial wastes after sediment composition. The sampling points: P_3, P_4, P_5 and P_6 recorded almost equal levels of Cu in sediments for both seasons, which can be attributed to the presence of cluster mechanical and automobile fitting shops, in which predominant industrial activities include car fitting, metal fabrication (welding, painting among others), repair of car brakes and tyres, waste water run-off, domestic effluents and sewage from nearby settlements as well as leachates of garbage's through gutters. Points P_1 and P_2 recorded the least mean concentrations, probably because they are further away from the road and also received very little waste from the garages and the municipality.

The EF values of the heavy metals analyse in this study for both raining and dry seasons are shown in Figures 2 and 3. Enrichment factor is a good tool to differentiate the metal source between anthropogenic and naturally occurring. Samples having EF value greater than 5 are considered to be contaminated with that particular element. All the sampling points have EF values between 0 to 5 for both seasons, except Cd, Cu, Pb and Zn at sampling point P_3. The highest EF value is seen for Pb with a value of 17.57 (for dry season at P_3). Cadmium has the second highest EF with a value of 14.30 (for dry season at P_3). Moderate enrichment was observed for Cd and Zn at P_1, P_2, P_4 and P_6 for both seasons. Lead EF values at P_1, P_2 and P_4 indicated that the river is moderately polluted. It can be presumed that the high/significant EF values for Cd, Cu, Pb and Zn at point P_3 for both seasons are from anthropogenic inputs - fertilizers and pesticides used in agricultural activities, run-offs from Yelwa town and garbage disposal among others. The difference in EF values may be due to the difference in the magnitude of input for each metal in the sediments and/or the difference in the removal rate of each metal from the sediments. Since the bioavailability and toxicity of any heavy metal in sediments defend upon the chemical form and concentration of the metals (Kwon et al., 2001), it can be inferred that metals in sediments samples with the highest EF values, along with higher labile fractions in sediments are potential sources for mobility and bioavailability in the aquatic ecosystems.

Sampling point P_3 has the highest EF values for both raining (EF_{Pb} = 17.05) and dry (EF_{Pb} = 19.15) seasons. While P_4 has the least EF value (EF_{Fe} = 0.59) for the raining season and EF_{Cr} = 1.24 value for dry season. The difference in EF values may be due to the difference in magnitude of input for each metal in the sediment and/or the difference in the removal rate of each metal from the

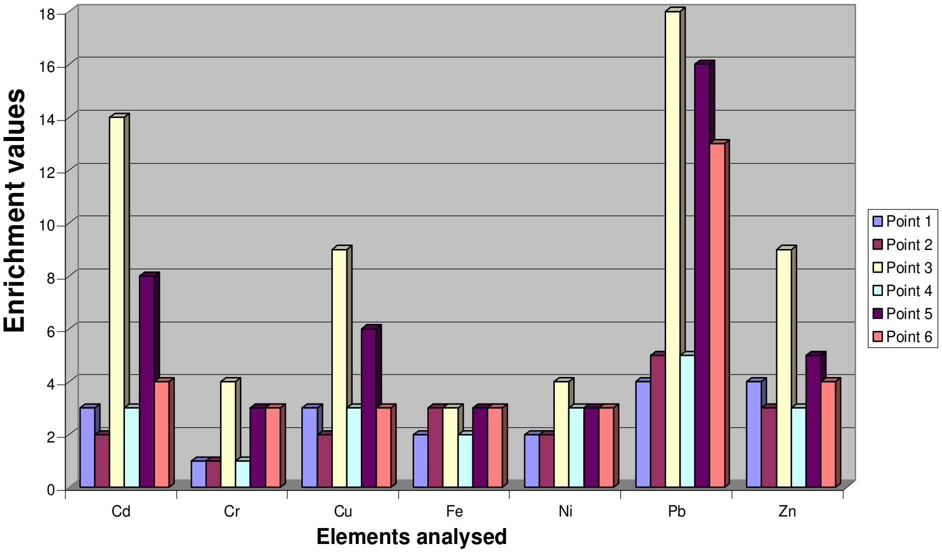

Figure 3. Dry season enrichment factor values.

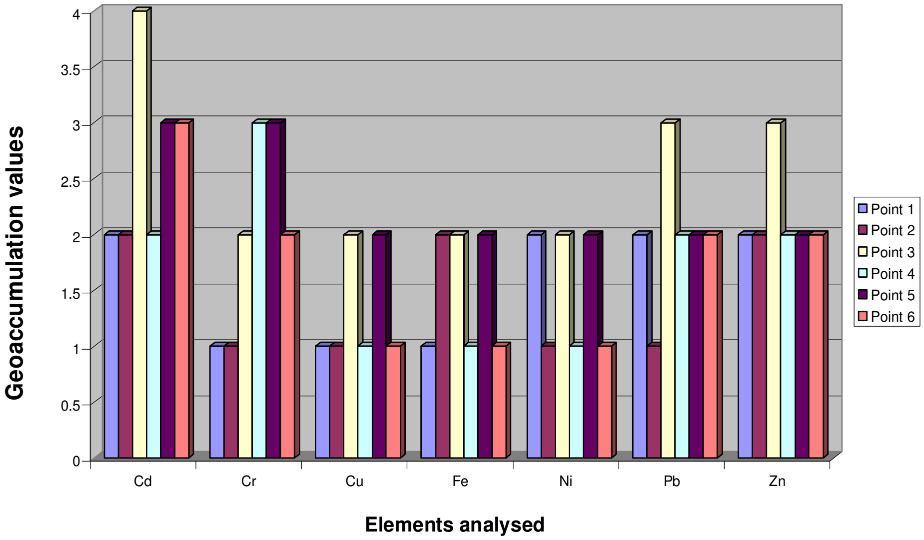

Figure 4. Raining season geoaccumulation index values.

sediment.

The raining and dry seasons calculated geoaccumulation index (I_{geo}) for Yauri river sediments are given in Figures 4 and 5 respectively. Geoaccumulation index values of heavy metals in the river bottom sediments (Table 3) for both raining and dry seasons are in the order: $P_3 > P_5 > P_4 > P_6 > P_2 > P_1$.The average geoaccumulation values suggested that the river is polluted with Cr and Pb in both seasons at point P_3. These may be due to the market and automobile workshops in the site that contribute to the high concentration. Moderate pollution (class 2) was observed at points P_1 and P_2 for Cr, Cu, Ni and Zn in both seasons. Results for points P_4 and P_6 for both seasons revealed that Cd, Cr, Pb and Zn have class 3 statuses (moderately to pollute). However, Karbassi et al. (2008) mentioned that I_{geo} failed to various degrees to indicate the intensity of pollution.

Contamination factor values for the metals analysed in both seasons as shown in Table 3, revealed that Fe and Ni fall under the category of none to medium contamination at points P_1, P_2, P_4 and P_6 for both seasons. Similarly, Zn falls under same category at points P_4, P_5 and P_6 in both seasons. A moderate to strong contamination pattern is observed for Cd, Cr, Cu, Pb and Zn at sampling points P_1, P_2 and P_4 for both

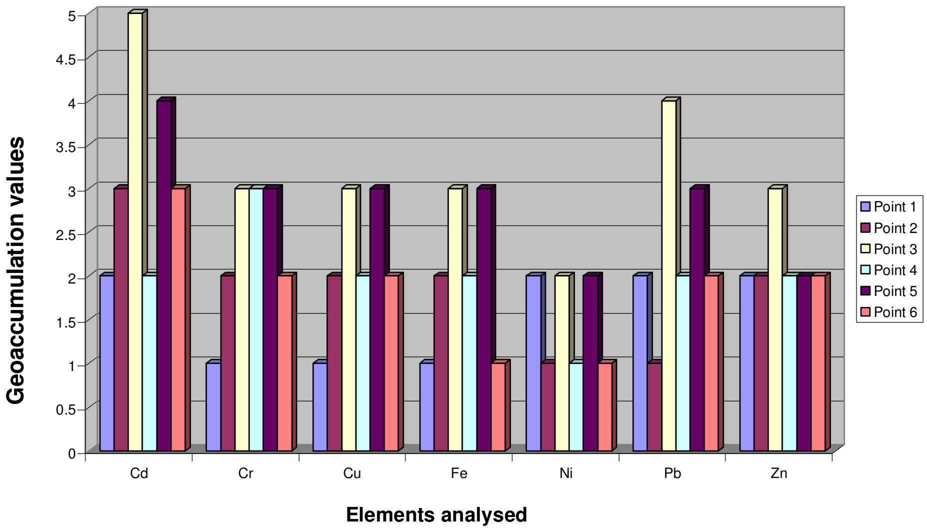

Figure 5. Dry season geoaccumulation index values.

Table 3. Contamination factors and Pollution load index of the metals during raining and dry (in brackets) seasons.

Sampling site	CF_{Cd}	CF_{Cr}	CF_{Cu}	CF_{Fe}	CF_{Ni}	CF_{Pb}	CF_{Zn}	PLI
P_1	2.53	1.15	2.08	0.49	0.66	1.96	1.48	1.42
	(2.78)	(1.70)	(2.40)	(0.89)	(0.82)	(2.13)	(1.82)	(2.00)
P_2	1.98	1.69	0.67	1.70	0.53	1.71	1.54	1.32
	(2.06)	(1.98)	(1.13)	(2.03)	(1.13)	(1.89)	(1.62)	(2.00)
P_3	3.76	2.47	2.04	1.98	1.97	3.81	1.83	3.33
	(3.94)	(3.03)	(2.66)	(2.16)	(2.07)	(4.00)	(2.06)	(4.11)
P_4	2.19	1.05	1.79	0.69	0.44	1.82	0.76	1.12
	(2.27)	(1.39)	(2.05)	(1.12)	(0.90)	(2.01)	(1.12)	(1.71)
P_5	3.07	2.26	2.01	1.54	1.52	2.64	1.04	2.46
	(3.69)	(2.76)	(2.50)	(2.00)	(1.86)	(2.92)	(1.30)	(4.46)
P_6	2.89	2.18	1.92	1.22	0.88	1.98	1.01	1.91
	(3.02)	(2.81)	(2.07)	(1.71)	(1.07)	(2.04)	(1.36)	(2.56)

seasons. Cadmium is strongly polluted at P_3, P_5 and P_6 while lead is only strongly polluted at P_3 in both seasons. Highest value of CF_{Cd} (3.94) was recorded at P_3 during the dry season, signifying a strong pollution in the river. Sampling points P_1 with CF_{Fe} = 0.49 (raining season) was the least revealing that the river is moderately polluted at that season. Heavy metals accumulate in the sediments through complex physical and chemical adsorption mechanisms depending on the nature of sediment matrix and the properties of the adsorbed compounds (Leivouri, 1998). Several processes lead to the association of heavy metals with solid phases, such as the direct absorption by fine-grained inorganic particles of clays; adsorption of hydrous ferric and manganic oxides which may in turn be associated with clays; adsorption on or complexation with natural organic substances, which may also be associated with inorganic particles, and direct precipitation as new solid phases (Calmano et al., 1993). Heavy metals concentrations in sediments are also strongly determined by local geology or anthropogenic influences. The weathering of minerals is one of the major natural sources, while anthropogenic sources include use of fertilizers and herbicides, irrigation, industrial effluent and leakages from service pipes

Table 4. Comparison of results obtained with world shale value and sediment quality guideline values (µg/g).

Metal	Cd	Cu	Cr	Fe	Ni	Pb	Zn
Earth's background values							
WS[a]	0.3	45	90	4.72	68	20	95
US[b]	0.11	33	26	4.10	_	19	95
Guideline value							
ISQG[c]	0.6	35	52.3	_	52	35	123
PEL[d]	3.5	197	160	_	_	91.3	315
LEL[e]	0.6	16	_	20.000	16	31	120
SEL[f]	10	110	_	40.000	75	250	820
Present study							
Raining season	8.77	26.58	35.91	167.23	60.73	20.27	55.30
Dry season	9.67	38.96	50.33	203.76	73.15	27.07	68.58

[a]World shale value, [b]Unpolluted sediments, [c]Interim sediment quality guideline, [d]probable effect level, [e]lowest effect level, [f]severe effect level (MacDonald et al., 2000; GESAMP, 1982; CCME, 1999; OMOE, 1993).

(Bird et al., 2005).

Pollution load index (PLI) of the heavy metals in the bottom sediments is also shown in Table 4. The pollution load index as presented in Table 4 provided a simple comparative means for assessing a river quality. Pollution load index values of Yauri bottom sediments ranged from 1.12 to 3.33 during the raining season and 1.71 to 4.46 for the dry season. According to these values, the river is polluted with all the elements analysed during both raining and dry seasons, suggested that environmental or human health impact involving these metals is occurring in the river.

From the comparison as presented in Table 4, generally, level of all the elements analysed were lower than world shale values and sediment quality guidelines values with the exception of cadmium which has higher values that can be attributed to the earlier reason stated.

Conclusions

The seasonal potential toxic metals contents of Yauri river bottom sediments were determined in this study. Heavy metal – Cd, Cr, Cu, Fe, Ni, Pb and Zn – concentrations were analysed using atomic absorption spectrophotometer. Sediment pollution in the present study was assessed using enrichment factor (EF), geoaccumulation index (I_{geo}), contamination factor (CF) and pollution load index (PLI). The calculations of EF showed that the river is contaminated with Cd, Cu, Pb and Zn. On the other hand the I_{geo} values suggested that the river is polluted with Cr and Pb and moderately polluted with Cu, Ni and Zn. Contamination factor values revealed that Fe and Ni have none to medium contamination while Cd and Pb are strongly polluted.

According to the PLI values calculated, the river is polluted with all the elements analysed. Some of the elevated concentrations of some of the heavy metals are probably due to anthropogenic sources near the river and natural source.

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