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Speciation Of Heavy Metals In The Sediment Of River Challawa-Kano - Nigeria

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***Abstract*—Chemical speciation of heavy metals Pb,Cr, Cu, Fe and Zn in the sediment of River Challawa-Kano, Nigeria was conducted .The River receives industrial wastes discharges in addition to other anthropogenic activities. The results indicated that considerable percentages of the heavy metals were obtained in all the fractions, which indicate that they potentially pose to the aquatic ecosystem as well as health hazard to the users of the river water. The result of the geo-accumulation index (I-geo) indicated that the heavy metals Pb, Cu and Zn were practically unpolluted (PU). Higher variability of organic carbon(OC) was obtained at sampling site A5 .This may be associated to the proximity of the sampling site away from the effluents discharge, which made the OC content at this site to be higher. The pH-values of the sediment ranges from basic to slightly acidic.**

Keywords—River Challawa, Sediment, Speciation, Heavy Metals

I Introduction

The environmental risks of heavy metals in sediments have been and will continue to remain important issue of great concern. Mobility and toxicity of metals associated with sediments are generally affected by metal speciation and sediment composition .Industries contribute to the environmental pollution through the discharge of toxic obnoxious Effluents into the ecosystem, setting imbalance in the composition of the water and the aquatic lives thereby causing innumerable health problems to human and animal life. Since these industries pollute the water bodies through the discharge of effluents into the water bodies, the aquatic organisms require large amount of water to absorb oxygen, and by so doing they take the toxic substances into their body [2].

A. Problem

River sediments are basic components of our environment as they provide nutrients for living Organisms and serve as sinks for deleterious chemical species. Unfortunately, industrial and household waste discharges—directly or indirectly, through leakages in these systems—into water sources causing excessive pollution of surface and underground water. Consequently, water quality and irrigation value are lost. It is necessary to know the mechanisms of the trace metals transportation and their complexes in rivers to understand their chemical cycles in nature [12].The toxicity of metals depends especially on their chemical forms rather than on their total elemental contents, and therefore, speciation studies increasingly gain importance.

B. Research Focus

The term speciation of heavy metals in bottom sediments of natural and man-made water reservoirs refers to quantitative and qualitative differentiation of the forms of their occurrence. The criteria of division into various forms can be different, e.g.(l) functional - forms available for organisms living in water, mobile forms, exchangeable cations etc., (2) operational - according to procedures, reagents and extractant used for their isolation, identification and determination, and (3) according to the element oxidation state or specific compounds [5,12,15].The environmental impact of these five speciation patterns depends on the behavior regarding remobilization of Metals in exchangeable, carbonate-bound and Fe/Mn oxide bound are contributed by anthropogenic pollution, and are considered to be more mobile, dangerous and bioavailable. The organic matter / Sulphide-bound, and residual metals are stable and non- bio-available [8,9].

II The Study Area

Challawa River is located in Challawa industrial estate (11°45′42N, longitude 8°46′17E) in Kumbotso local Government of Kano State. Kano State is located in the Northern part of Nigeria covering an area extending between latitudes 12°40′ and 10°30′ and longitudes 7°40′ and 9°40′. Challawa River is one of the receiving rivers of effluents from Challawa industrial estate. The industries in the Challawa industrial estate range from tanneries and textile to foods and packaging industries. The effluents from the industries in the estate were connected by a canal and channeled directly into Challawa River as a point source. The climate of the area is dominated by the cyclical migration inter tropical convergence zone, which is marked with longer dry than wet season, and the highest rainfall in July and August [17]. The relevant human activities in the River are commercial sand dredging, fishing, washing, and recreation during hot hour of the day[16,17,].

C. Aim

The primary aim of this study is to investigate the heavy metals speciation at the River Challawa sediment. The result obtained may provide a better understanding of the environmental risks of the heavy metals in the sediments.

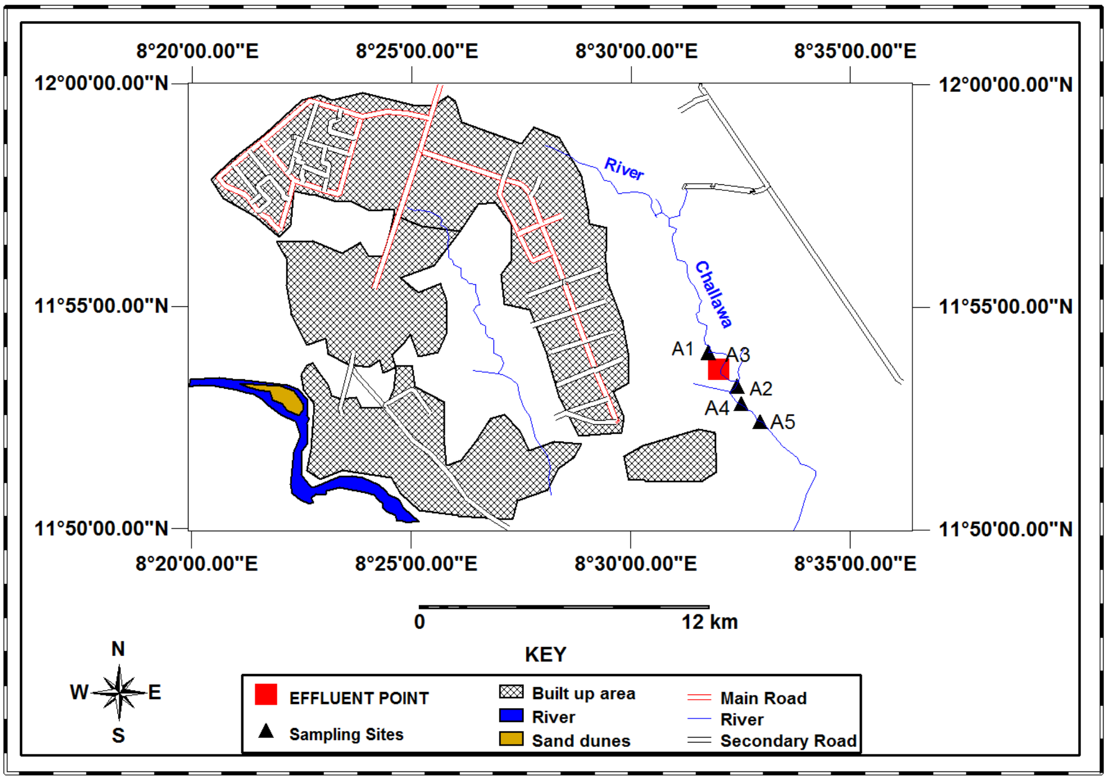

FIG.3.1: RIVER CHALLAWA SHOWING THE SAMPLING SITES

Source: Adapted and modified from goole earth by GIS section, department of Geography, ABU Zaria

III **Materials and Methods**

Sampling

Sediment samples were collected monthly for a period of eighteen months. Samples were collected at 1KM apart from each sampling site. Twenty five samples were taken. The bio-accumulative behaviors of the metals were taken at random on each sampling site. Samples were scooped with a plastic shovel and then packed in air tight polythene bags

IV Experimental Procedure

Debris and other unwanted materials were removed from the samples. The samples were air-dried in the laboratory for few days. Each of the samples was pulverised using a mortar and pestle. The samples were then sieved through a 2mm mesh and homogenised to get a uniform grain size. Soil pH and organic carbon were determined according to[1] procedure. The speciation forms of the metals were determined using [11,3].The procedure of [11] selected for this study was designed to separate heavy metals into five operationally defined fractions: water soluble, exchangeable, carbonate bound, Fe-Mn oxides bound, organic bound and residual fractions. A summary of the procedure is as follows: One gram of each soil was weighed into 30ml polypropylene sample bottle and the following fractions obtained..

(F1) Exchangeable. The residue from water soluble fraction was extracted with 8ml of 1ml $MgCl_2$(pH 7.0) 2for I hour.

(F2) Carbonate -Bound. The residue from exchangeable fraction was extracted with 8ml of 1M Ammonium acetate (adjusted to pH 5.0 with Acetic acid) for 5 hours.

(F3) Fe-Mn oxides-bound. The residue from carbonate fraction was extracted with 0.04M NH OH. 2HCl in 25% (v/v) Acetic acid at 96°C with occasional agitation for 6 hours

(F4) Organic- Bound. The residue from Fe-Mn Oxides bound fraction was extracted with 3ml of 0.02M Nitric acid and 5ml of 30% H O (adjusted to pH 2 with 2ml (HNO_3) was added and mixture heated to 85°C for 3 hours, with occasional agitation. A second 3ml the mixture heated again to 85°C for 3hours with intermittent agitation. After cooling, 5ml of 3.2MNH OAc in 20% (v/v) HNO_3 was added and the samples was made up to 20ml with deionized Water and agitated continuously for 30min.

10ml of 7M HNO3 on a hot plate for 6 hours. After evaporation, 1ml of 2M HNO was added and the residue after dissolution was diluted to 10ml. the residue was washed with 10ml of deionized water. The mobility factor of the metals in the sediment/ soil samples may be assessed on the basis of the absolute and relative contents of fractions weakly bound to soil/ sediment components. The relative index of metals was calculated as a mobility factor (MF) using

the following equation[18,19,20].

$$MF = \frac{(F1 + F2 + F3)}{F1+F2+F3+F4+F5} \times 100 \quad (1)$$

The Geo-accumulation index (*I-geo*), a widely used empirical relationship for evaluating the degree of metal contamination or pollution in soil or sediment samples of terrestrial or aquatic environments [25], was applied to evaluate the pollution status of the studied area. According to [7] the geo-accumulation index can be expressed as:

$$I\text{-}geo = \log_2 (Cn/5.1 x B_n) \qquad (2)$$

Where C_n is the total heavy metal concentration in the sediment sample;

B_n is the background value in unpolluted sample; and 1.5 is the background matrix correction factor introduced to minimize variations of heavy metals due to lithogenic effects.

The I-geo values are classified into seven (0 - 6) classes : I-geo < 0 (Class 0 for practically unpolluted, PU, samples); 0 < I-geo < 1(Class 1 for practically unpolluted to moderately polluted, MP, samples); 1 < I-geo < 2 (Class 2 for moderately polluted, MP, samples); 2 < I-geo < 3 (Class 3 for moderately polluted, MP, to heavily Polluted, HP, samples); 3 < I-geo < 4 (Class 4 for heavily polluted, HP, samples); 4 < I-geo < 5 (Class 5 for heavily polluted to very heavily polluted, VHP, samples); 5 < I-geo < 6 (Class 6 for very heavily polluted, VHP, samples). The background values of 36, 320, 0.3, 15, 17, 10 and 17μg/g for unpolluted soils for Zn, Mn, Cd, Cu, Ni, Co and Pb respectively were used against the mean total heavy metals in the sediments.

V **Result and Discussion**

pH – value of the sediment

Mean pH of the sediment at site A_1 was 8.22±0.51. The value ranged from 7.31to 8.90. The pH of the sediments from other sampling points site A_2 was (6.60±0.20). The values at site A_2 ranged from 6.35 to 6.85. While in site $A_{3,}$ mean pH value was 7.18±0.14, with a range from 6.82 - 7.48. At Site A_4 the sediment has a mean pH value of 6.65±0.19.The value ranged from 6.12 to 6.92. In site $A_{5,}$ the sediment has a mean value of 6.63±0.13 with a range of 6.45 to 6.93.The pH of the sediments at all the sampling sites were not highly varied as depicted by CV(%) values at sites A_1(6.20), Site A_2(3.03), site A_3(1.95), site A_4(2.86) and site A_5(1.96) respectively. From this result, the pH value at site A_1 is basic, while pH values at sites A_2 to A_5 were slightly acidic. This might be due to organic detritus deposited at the bottom of the reservoir [6].

In general, sorption increases with increasing pH. That is, the lower the pH value the more metal can be found in solution and thus more metal is mobilized. When pH falls below 5 mobility is enhanced as a result of the increased proton concentration. At pH values above 7, some heavy metals tend to form hydroxy – complexes which will increase the solubility of the metal in question. Adsorption was greater at pH 6.5 than at pH 4.5. The adsorption of chromate did not change as significantly as other metals with pH changes. This is due to its oxyanion character in oxidizing condition, and the adsorption mechanisms are very differ Compared to that of positively charged metals. These results confirm that adsorption for most metal cations increases as pH increases.[10].

Organic Carbon

Mean organic carbon (OC) content of river Challawa sediment at sites A_1 and A_2 were 1.01±0.18mgkg and 0.60±0.05mg/kg respectively. The values at site A_1 ranged from 0.88mg/kg to 1.52mg/kg, while at site A_2 it ranged from 0.50mg/kg to 0.69mg/kg. The values at sites A_1 and A_2 were not highly varied as depicted by CV(%) values of 17.82 and 8.33 respectively.

However, the values of the OC content of the sediment at sites A_3 and A_4 over the period of investigation were 0.05±0.01mg/kg and 0.04±0.01 respectively. The values at site A_3 ranged from 0.03 to 0.07mg/kg, while at site A_4 it ranged from 0.02 to 0.06mg/kg. The values at sites A_3 and A_4 were slightly varied. This is depicted by CV (%) values of 20.0 and 25.0 respectively. At site A_5 the level of OC ranged from 0.01mg/kg to 0.07mg/kg with a mean OC content of 0.04±0.02mg/kg. The value of the OC content of the sediment at site A_5 was highly varied. This is depicted by a CV (%) value of 50.0. The high variability of OC content at site A_5 may be as a result of the fact that the sampling point A_5 was far away from the effluents discharge which made the OC content at site A_5 to be richer and highly variable.

Soil Organic Matter is a key for sorbing phase for metals. The dissolution of humic acid at higher pH is responsible for dissolution of Cu and Pb from soil. Organic matter is important for the retention of metals by soil solids, thus decreasing mobility and bioavailability. However because of the complexation of metals by soluble OM, the addition of OM can result in release of metals from solids to the soil solution. The increase in the solubility of the Cu and Pb is related to the dissolution of the HA component of the organic matter. This indicates that solution phase speciation reactions with organic matter dominate the partition of these metals at higher pH. Because under high pH, the DOM increases as a result solubility of HA[10].

Mobility of metals in compost varies with their speciation. High mobility factor values have been interpreted as symptoms of relatively high lability and biological availability of heavy metals in soil / sediment [14].

The result for mobility factor (MF) of the analysed heavy metals is presented in table 7. MF for Zn ranged from 70.83% at site $A_5$to 63.46% at sites A_2 and A_4 respectively. While the MF for Pb ranged from 62.06% at sites A_1 and A_3 to 58.06% at site A_4. However, the mobility factor for iron ranged between 43.28% to 33.87%, with the highest value at sites A_4, and the least at site A_1 and A_3. The mobility factors for copper and chromium ranged between 76.20% at site $_{A3}$ and 58.41% at site A_5 for copper. While chromium ranged between 28.18% at sites A_1 and A_3, to 23.97% at site A_5.

Geo-accumulation Index

The result for the geo-accumulation index (I-geo) for the analysed samples is heavy metals in the sediment samples are presented in Table 10. The negative values obtained according to contamination classification showed that the sediment was practically unpolluted by Pb, Cu and Zn. Background values (Bn) for Chromium and Iron were not available.

Speciation results

The results for speciation of heavy metals from Challawa sediments are shown in figures (4.32 - 4.37). The result for site A_1 shows that Pb (43.5%). In site A_2, Pb (35.7%) was found to be associated with exchangeable, and with only (10.7%) in the residual. In site three, Although Pb was fairly distributed in all the fractions, (32.8%) was found to be highly associated with the carbonate fraction. Where as in site A_4 Pb was found to be highest (30.6%) in the oxidisable form, In site A_5 , Pb was found to be highest (26.3%) in the organic fraction Lead in the sediments from the Goreckie Lake, was found mainly in the form bound to hydrated oxides of iron and manganese (34%), then in the residual fraction (34%), and bound to carbonates (21%). In a smaller amount it was bound to organic matter (10%) and exchangeable forms (0.8%) Lead in the sediments from the Goreckie Lake, was found mainly in the form bound to hydrated oxides of iron and manganese (34%), then in the residual fraction (34%), and bound to carbonates (21%). In a smaller amount it was bound to organic matter (10%) and exchangeable forms (0.8%)[16].

Zn (32.7%) was obtained in the acid-soluble fraction. The speciation result for zinc at site $A_1$was (34.85%) was found to be associated with the carbonates/ acid soluble fractions. Most Zn (40%), where as in site A_2 the amount of zinc (37.7%) was found to be highly associated with acid-soluble / bound to carbonates. In site A_3, Zn was also found to be in all the fractions with the highest percentage (25.9%) in the oxidisable fraction i.e. bound to organic matter. However, (7.9%) was obtained in the residual fraction. While in site A_4 Zn was highest (35.7%) in the carbonate fraction. Highest amount of zinc (32.7%) was obtained at site A_5 in the acid soluble/carbonate fraction, with a least value (12.6%) in the residual fraction. In sediments from the Canadian rivers the highest concentration of zinc was observed in the residual fraction, then in the fraction bound to hydrated oxides of iron and manganese, and a relatively small amount of this metal was found in the fraction bound to organic matter [11].

Highest level of Cu (69.5%) at site A_1 was associated with oxidisable/bound to organic matter, while in site A_2 Cu was highest (65.3%) in the acid-soluble fraction. In site A_3 almost the same percentages of Cu (15.8%) was obtained in all the fractions. The results for copper at site A_4 was found to be highest (25.9%) in both the carbonates and residual fractions While at site $A_{5,}$ highest percentage of Cu (40.0%) and (30.0%) were found to be highly associated with the oxides (reducible) and residual fractions respectively. Copper, was mainly found in the residual fraction (83%). Much fewer amounts of this metal were bound to organic matter (16%) and hydrated oxides of iron and manganese (2.9%)[11,16].

In site A_1 Cr (14%) was associated with exchangeable, while at site A_2 highest value (42.5%) was obtained in the residual, with a least (3.7%) in the acid soluble/ carbonate fraction. Highest fraction (45.3%) Cr at site A_3 was obtained in the residual fraction, with least value (15.6%) obtained in the carbonate fraction. In site A_4, highest value (49.3%) was obtained in the residual fraction, with a least (12.06%) in the reducible/ oxides, and exchangeable fractions respectively. Whereas at site A_5, highest value (47.90%) Cr was in the residual, with least (2.8%) in the acid- soluble/ carbonates. Comparing the values with Chromium, in the sediments from Goreckie Lake, was mainly found in the residual fraction (56%) and in that bound to organic matter (38%), while in smaller amounts in the fractions bound to hydrated iron and manganese oxides [16].

Highest concentration of Fe (40.0%) at site A_1 was obtained in the oxidisable/ organic matter, with a least (4.7%) in the exchangeable. At A_2, highest value (46.1%) was obtained in the oxidisable/ organic matter, with a least value (7.5%) in the exchangeable fraction. However, highest values for sites A_3, A_4 and A_5, were 41.2%, 46.3% and 46.2% all in the oxidisable /organic matter respectively. Whereas least values of Fe for sites A_3, A_4 and A_5 were 7.4% in the exchangeable, for site three, 10.4% in the residual for site four and site five 9.0% in the exchangeable.

Metal ions in this fraction correspond to metal species with highest trend to mobilize, thus hazardous. Metals in acid-soluble fraction (Pb and Zn) can be remobilized into the water system. Comparing this with the work of [7], where the Mean levels of total heavy metal (μg/g) in the sediment samples ranged between 10.99 ± 2.18 – 74.62 ± 11.96 in Pb and 645.10 ± 62.15 – 3753.03 ± 176.29 in Mn. The apparent mobility and potential bioavailability for each metal in the sediment was 70%. The study showed that the sediment samples were contaminated with heavy metals to varying degrees primarily as a result of effluents discharging into the river from the dumpsite within the vicinity of the river.

Mean speciation results for all the five sites discussed above indicate that Pb was highest (29.7%) and (25.4%) in both the carbonate and oxidizable fractions respectively. Both these forms of fractions may be potentially risk in the environment in relation to pH changes .Zn was also found to be present in all the fractions despite its chemical mobility. Highest percentage (35.2%) was obtained in the acid-soluble 9carbonate) fraction. The exchangeable fraction is the most important form from environmental point of view as the corresponding quality is easily leached by water [2]. In this study however, (17.3%) Zn was found to be associated with the exchangeable fraction, thus this may easily be leached into the water and causes a health hazard after certain period of bioaccumulation on the users of such water. Cu was found to be highest (36.1%) in the oxidizable fraction with little amount (5.0%) in the exchangeable fraction. Thus, suggesting very low concentration in the exchangeable fraction as compared with the oxidizable fraction. Although Cr is present in all the fractions, (45.9%) Cr was found to be highly associated with the residual fraction.

VI Conclusion

Conclusively, the result of the speciation study showed that significant amount of the heavy metals analyzed were present in all the fractions. However, in natural media, trace metals undergo numerous changes during their transport due to dissolution, precipitation and sorption phenomena. Trace element concentrations of river basins depend on not only industrial and household waste inputs but also on the geochemical composition of the area. High concentrations of Pb, Fe, Zn, and Cr are thought to have resulted from anthropogenic influences, practically from industry and pesticides used in agriculture, and are found to present a pollution risk to the ecosystem and the users of the river water.

VII **Recommendation**

Having carryout a speciation studies, the research is in complete for the fact that the actual oxidation states of the metals was not quantified. There is also the need to investigate other pollutants in both the water and the sediment before the quality of the water can be ascertained.

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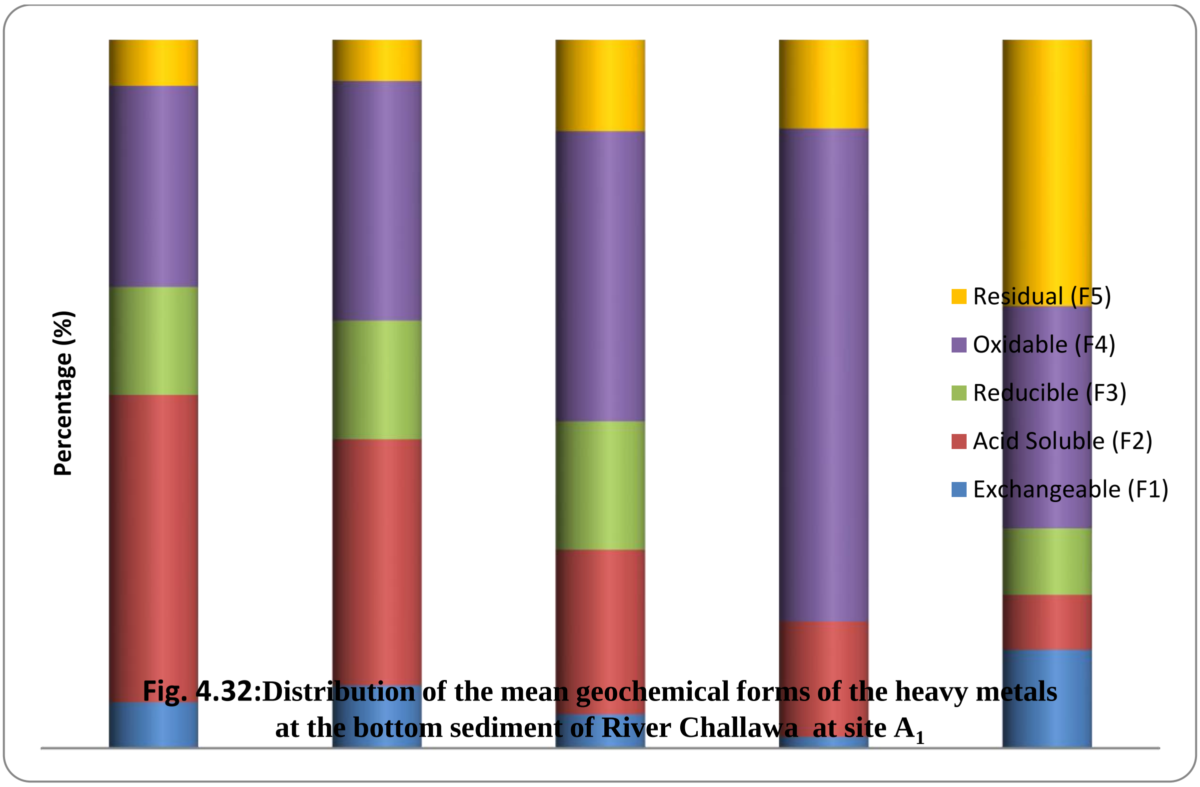

Fig. 4.32: Distribution of the mean geochemical forms of the heavy metals at the bottom sediment of River Challawa at site A_1

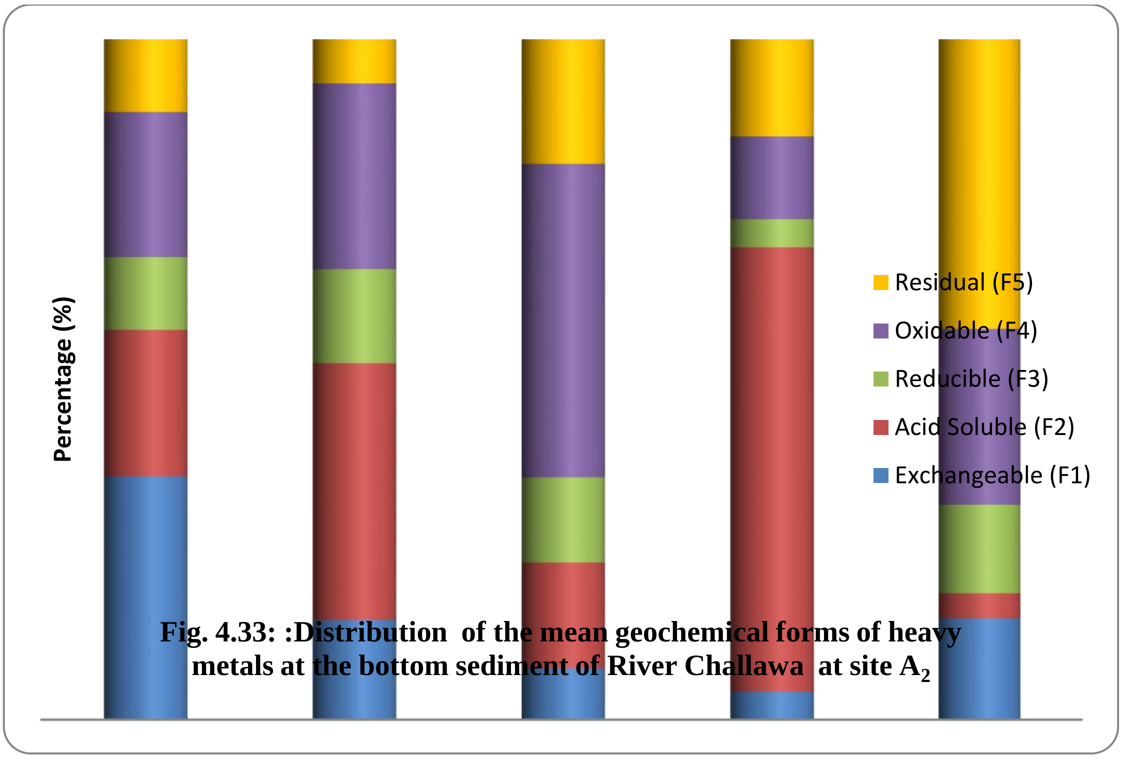

Fig. 4.33: :Distribution of the mean geochemical forms of heavy metals at the bottom sediment of River Challawa at site A_2

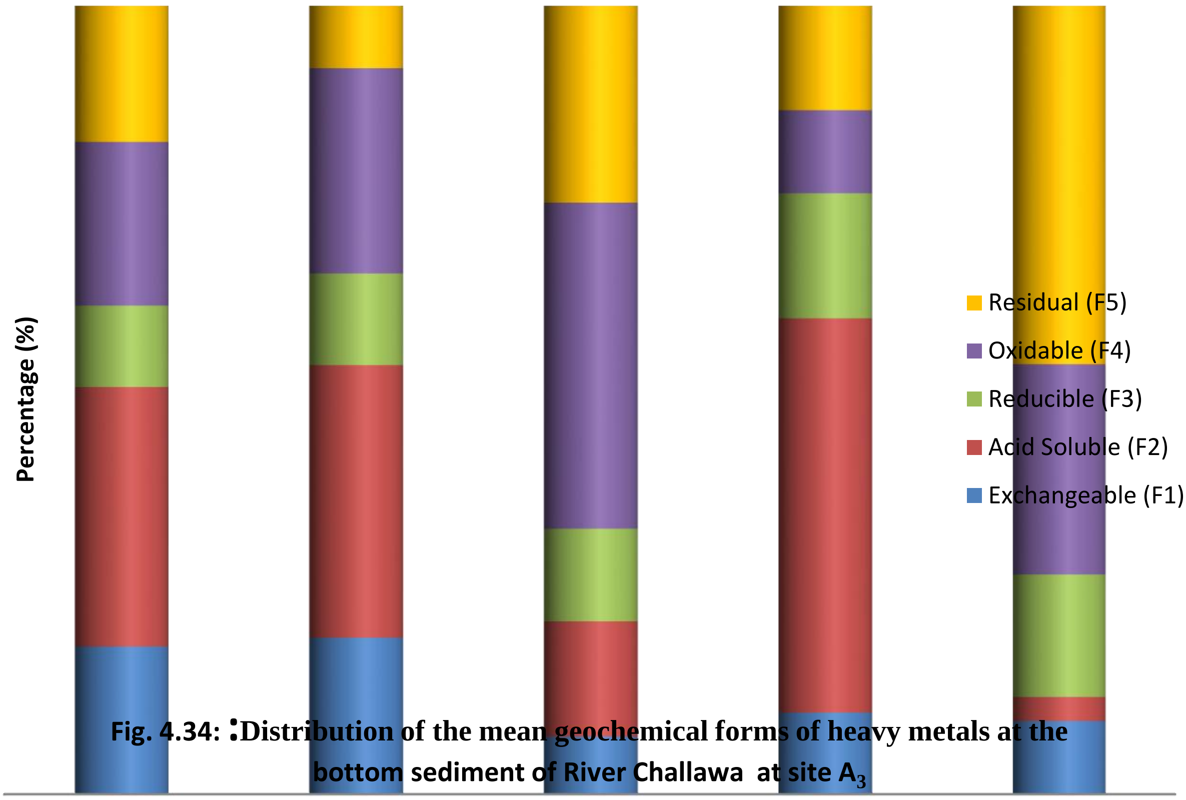

Fig. 4.34: :Distribution of the mean geochemical forms of heavy metals at the bottom sediment of River Challawa at site A_3

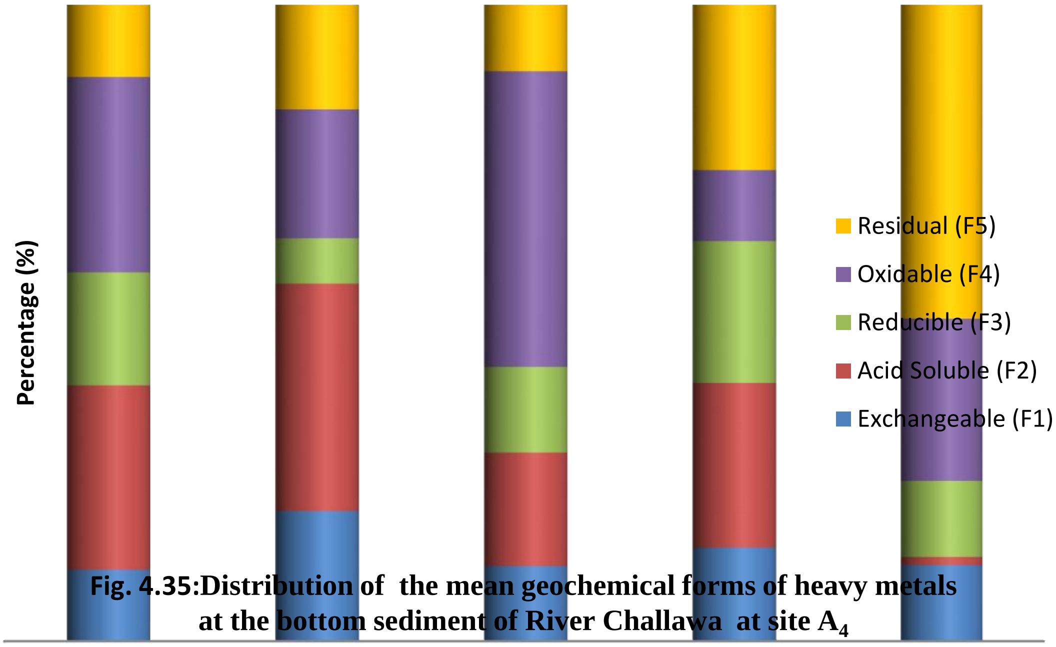

Fig. 4.35:Distribution of the mean geochemical forms of heavy metals at the bottom sediment of River Challawa at site A_4

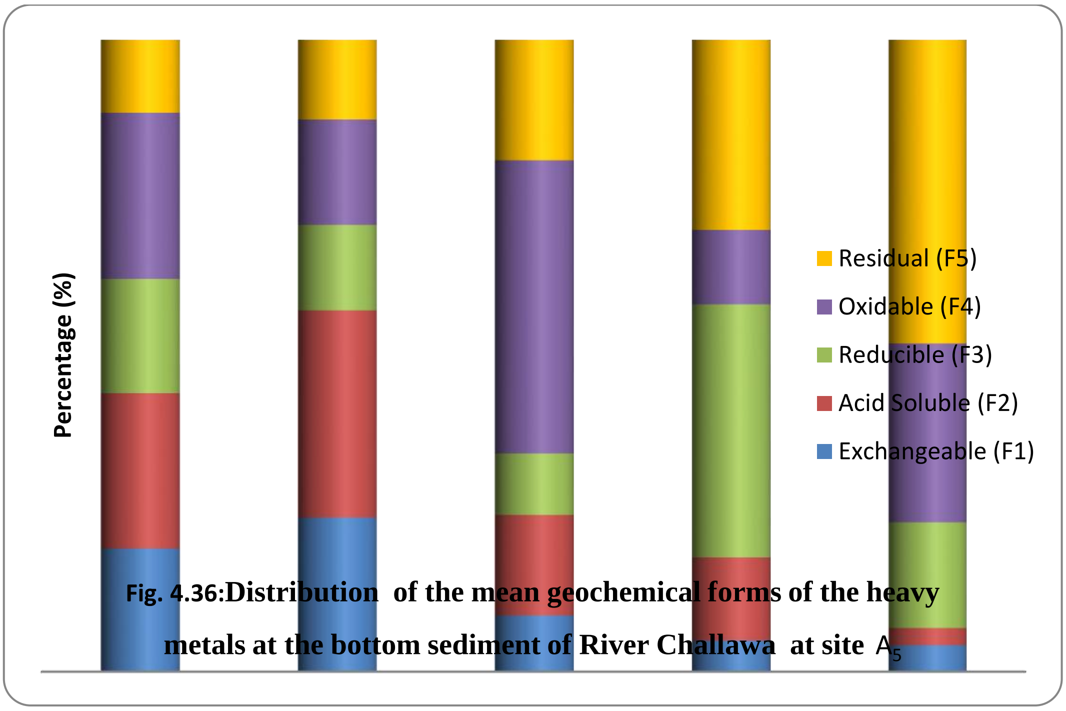

Fig. 4.36:Distribution of the mean geochemical forms of the heavy metals at the bottom sediment of River Challawa at site A_5

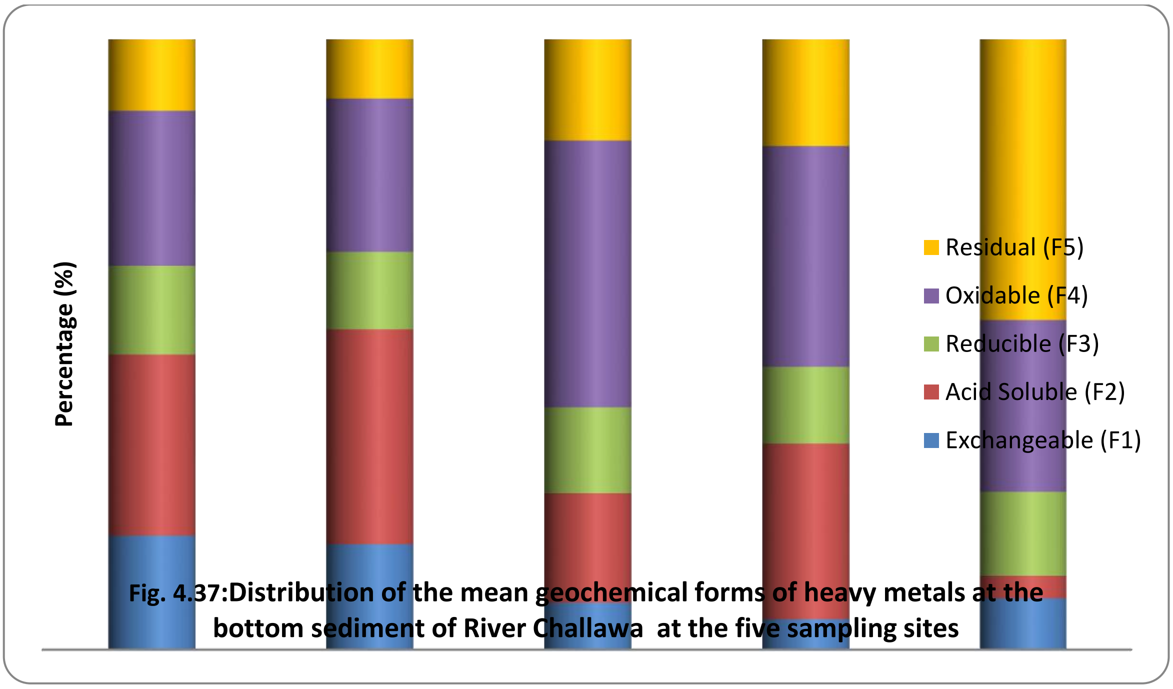

Fig. 4.37:Distribution of the mean geochemical forms of heavy metals at the bottom sediment of River Challawa at the five sampling sites

Table 1 Distribution of the mean geochemical forms of heavy metals for River Challawa sediments Site A_1

Fraction	Pb	Cr	Cu	Fe	Zn
F1	2.50(6.5%)	1.94(14.0%)	0.77(1.6%)	3.07(4.7%)	2.36(8.9%)
F2	4.32(43.5%)	0.65(7.8%)	3.65(16.4%)	6.13(22.9%)	4.04(34.8%)
F3	1.36(15.2%)	3.23(9.4%)	ND	4.84(19.7%)	1.37(16.7%)
F4	2.73(28.3%)	5.48(31.3%)	0.77(69.5%)	17.10(40.0%)	3.04(33.7%)
F5	2.27 (6.5%)	9.36(37.5%)	0.96(12.5%)	10.32(12.6%)	0.93(5.8%)
Mt	13.18	20.65	7.31	41.45	11.74

Table 2 Distribution of the mean geochemical forms of heavy metals for River Challawa sediments Site A_2

Fraction	Pb	Cr	Cu	Fe	Zn
F1	1.59(35.7%)	2.90(14.8%)	0.77(4.1%)	5.16(7.5%)	3.04(14.6%)
F2	4.09(21.6%)	0.32(3.7%)	1.35(65.3%)	7.74(15.5%)	5.28(37.7%)
F3	2.50(10.7%)	2.90(13.0%)	1.14(4.1%)	5.18(12.5%)	2.98(27.3%)
F4	4.32(21.4%)	11.94(42.5%)	0.58(12.2%)	20.0(46.1%)	2.98(27.3%)
F5	2.42(6.5%)	6.13(25.9%)	5.19(12.2%)	1.50(18.3%)	2.42(6.5%)
Mt	14.78	43.23	14.09	5.19	24.19

Table 3 Distribution of the mean geochemical forms of heavy metals for River Challawa sediments Site A_3

Fraction	Pb	Cr	Cu	Fe	Zn
F1	2.5(19.0%)	1.94(9.4%)	0.77(10.5%)	3.07(7.4%)	2.36(20.1%)
F2	4.32(32.8%)	0.65(3.1%)	3.65(50.0%)	6.13(14.8%)	4.04(34.4%)
F3	1.36(10.3%)	3.23(15.6%)	1.15(15.8%)	4.84(11.7%)	1.37(11.6%)
F4	2.73(20.7%)	5.48(26.6%)	0.77(10.5%)	17.10(41.2%)	3.04(25.9%)
F5	2.27(17.2%)	9.36(45.3%)	0.96(13.2%)	10.32(24.9%)	0.93(7.9%)
Mt	13.18	20.65	7.31	41.45	11.74

Table4 Distribution of the mean geochemical forms of heavy metals for River Challawa sediments Site A_4

Fraction	Pb	Cr	Cu	Fe	Zn
F1	1.59(11.3%)	2.91(12.0%)	0.77(14.8%)	5.16(11.9%)	3.04(20.6%)
F2	4.09(29.0%)	0.32(1.30%)	1.35(25.9%)	7.74(12.9%)	5.28(35.7%)
F3	2.51(17.7%)	0.290(12.0%)	1.15(22.0%)	5.81(13.4%)	1.06(7.1%)
F4	4.32(30.6%)	6.13(25.3%)	0.58(11.10%)	20.0(46.3%)	2.98(20.2%)

F5	1.51(11.3%)	11.94(49.3%)	1.35(25,9%)	4.16(10.4%)	2.42(16.4%)
Mt	14.09	24.19	5.19	43.23	14.78

Table5 Distribution of the mean geochemical forms of heavy metals for River Challawa sediments Site A_5

Fraction	Pb	Cr	Cu	Fe	Zn
F1	2.73(19.7%)	0.97(4.20%)	0..58(5.0%)	4.03(9.0%)	3.42(24.7%)
F2	3.41(24.6%)	0.65(2.80%)	1.54(13.3%)	7.25(16.4%)	4.53(32.7%)
F3	2.50(18.0%)	3.87(16.9%)	4.62(40.0%)	4.36(9.7%)	1.87(13.5%)
F4	3.64(26.2%)	6.45(28.2%)	1.35(11.7%)	20.81(46.2%)	2.30(16.6%)
F5	1.59(11.5%)	10.97(47.90%)	3.45(30.0%)	8.55(19.0%)	1.74(12.6%)
Mt	13.86	22.90	11.54	45	13.85

Table6 Distribution of the mean geochemical forms of heavy metals for River Challawa sediments for the five sampling sites

Fraction	Pb	Cr	Cu	Fe	Zn
F1	2.4(18.7%)	1.74(8.4%)	0.58(5.0%)	4.13(7.7%)	2.55(17.3%)
F2	3.82(29.7%)	0.77(3.7%)	3.35(28.8%)	9.68(18%)	5.18(35.2%)
F3	1.86(14.5%)	2.84(13.8%)	1.46(12.6%)	7.58(14.1%)	1.88(12.7%)
F4	3.27(25.4%)	5.81(28.1%)	4.19(36.1%)	23.55(43.7%)	3.70(25.10%)
F5	1.50(11.7%)	9.48(45.9%)	2.04(17.5%)	8.94(16.6%)	1.43(9.7%)
Mt	12.87	20.65	11.62	53.37	14.74

Table 7: Mean Heavy Metal mobility factor at the different sites

SITES	Pb	Cr	Cu	Fe	Zn
A1	62,06%	28.18%	70.99%	33.87%	66.17%
A2	58.06%	25.30%	62.81%	43.28%	63.46%
A3	62.06%	28.18%	76.20%	33.87%	66.18%
A4	58.06%	25.34%	63.01%	43.28%	63.46%
A5	60.89%	23.97%	54.41%	34.76%	70.83%
Mean	60.23	26.19	65.48	38.81	66.02

Table 8" Mean Organic Carbon for the five sampling sites

Sites	Max(mg/kg)	Mini(mg/kg)	Mean	Std	CV(%)
A1	1.52	0.88	1.01	0.18	17.82
A2	0.69	0.50	0.60	0.05	8.33
A3	0.07	0.03	0.05	0.01	20.00

A4	0.06	0.02	0.04	0.01	25.00
A5	0.07	0.01	0.04	0.02	50.00

Table 9: Mean pH- values

Sites	Max(mg/kg)	Mini(mg/kg)	Range	Mean	Std	CV(%)
A1	8.90	7.31	1.59	8.22	0.51	6.20
A2	6.85	6.35	0.50	6.60	0.20	3.03
A3	7.48	6.82	0.66	7.18	0.14	1.95
A4	6.92	6.12	0.80	6.65	0.19	2.86
A5	6.93	6.45	0.48	6.63	0.13	1.96

Table 10: Geo-accumulation index(I-geo) values at various sites

Site	Pb	Cr	Cu	Fe	Zn
A1	-0.82(PU)	NA	-1.02(PU)	NA	-1.19(PU)
A2	-0.77(PU)	NA	-0.74(PU)	NA	-0.89(PU)
A3	-0.82(PU)	NA	-1.02(PU)	NA	-1.19(PU)
A4	-0.79(PU)	NA	-1.17(PU)	NA	-1.10(PU)
A5	-0.80(PU)	NA	-1.28(PU)	NA	-1.12(PU)

PU = practically unpolluted; MP = moderately polluted; HP = heavily polluted; VHP = very heavily polluted; NA= B – value not available