American Journal of Earth Sciences
2019; 6(1): 14-19
http://www.openscienceonline.com/journal/ajes
ISSN: 2381-4624 (Print); ISSN: 2381-4632 (Online)

Contaminant Transport in the Alluvial Sediments of River Gbako Flood Plains around Baddegi, Central Bida Basin, Nigeria

Sidi Aliyu Ahmed[1, *], Nuhu Musa Waziri[2], Musa Tanimu Suleiman[2], Alhassan Tswako Maji[3], Mohammed Yakubu[3]

[1]Department of Geology and Mining, Ibrahim Badamasi Babangida University, Lapai, Nigeria

[2]Department of Geology, Federal University of Technology, Minna, Nigeria

[3]National Cereals Research Institute, Badeggi, Nigeria

Email address

aasidi@ibbu.edu.ng (S. A. Ahmed), saakusogi@gmail.com (S. A. Ahmed), nuhuwaziri@futminna.edu.ng (N. M. Waziri), musasuleiman86@gmail.com (M. T. Suleiman), tswakoma@gmail.com (A. T. Maji), myaksbida@gmail.com (M. Yakubu),

[*]Corresponding author

To cite this article

Sidi Aliyu Ahmed, Nuhu Musa Waziri, Alhassan Tswako Maji, Mohammed Yakubu, Musa Tanimu Suleiman. Contaminant Transport in the Alluvial Sediments of River Gbako Flood Plains around Baddegi, Central Bida Basin, Nigeria. *American Journal of Earth Sciences*. Vol. 6, No. 1, 2019, pp. 14-19.

Received: February 4, 2019; **Accepted**: April 25, 2019; **Published**: May 28, 2019

Abstract

Contaminant transport in the alluvial sediments of River Gbako flood plains around Baddegi, central Bida Basin, Nigeria was investigated to know the contaminant transport in sediments of the catchment flood plain around Baddegi. Four sampling pits, TR-1, TR-2, TR-3 and TR-4, were dug for the purpose of lithological studies and sediment sampling. Particle sizes analysis of the sediments shows sand dominated sediment with more than 50 per cent sand composition and small percentage of clay and silt. The sediments are young owing to the non-profile development in them. All the sediments collected in the catchment domain were acidic with a mean pH of 4.69 controlling other geochemical processes in the area. Partition coefficient values indicated the metals are compactible and preferentially accepted by the minerals with most of the coefficient values greater than one, $Di > 1$. Velocity of the metals in the sediment horizons is slower relative to the velocity of the water percolating through the sediment indicating retardation and possible mechanisms behind attenuation and groundwater purification in the area. Overall, partition coefficients are important parameters in assessing the potential impacts from metal contaminated soils.

Keywords

Contaminant Transport, Partition Coefficient, Floodplain, Sediment

1. Introduction

Partition coefficients are important parameters in assessing the potential impacts from metal contaminated soils [10]. Metal contamination in soils is one of the environmental issues globally, especially in areas where agricultural practices are largely supported by chemical fertilizers or where metal enrichment in soils is due to mining activities. The flood plains of River Gbako around Baddegi in kacha local Government Area, Niger State, Central Nigeria, is utilized for cereal crops farming due to it alluvial soil deposits. Chemicals are used to improve the soil nutrient and to boost crop production within the catchment areas of the floodplain. The chemicals can enrich the soil and contaminate the aquifer system. Soil contamination with heavy metals contributes to groundwater chemistry due to water-rock interaction. Ma *et al.* [10] argued that soil redox status varies temporally, and the intensity of redox status can be described by redox potentials in general. The redox status in surface soil is influenced by rainfall, bioactivity and changes in land use, whereas in vadose zone by fluctuation in water table [2]. According to Kongjoo *et al.* [9] the chemical composition of groundwater is regulated by various factors, which include atmospheric inputs, mineral weathering through water-rock interaction, anthropogenic activities and biogeochemical processes.

Metals like lead (Pb), Zinc (Zn), chromium (Cr), manganese (Mn) and iron (Fe) can concentrate in sediment through adsorption and ion exchange processes. Partition behaviour of trace metals and their velocity through sediment can explain some principles behind groundwater purification and attenuation of pollutants in contaminant prone areas.

The implication of the activity of metals introduced either through lithogenic or anthropogenic process in sediments and groundwater requires scientific explanation to understand their mobility and the effect on the environment and especially water resources. The aim of this study is to evaluate the contaminant transport in alluvial sediments of River Gbako floodplain around Baddegi, Central Bida Basin, Nigeria.

2. The Study Area

The area is part of the active floodplains of River Gbako around Baddegi, Central Bida Basin, Nigeria. It is located on latitude 09°03'00"N to 09°06'00"N and longitude 006°05'00"E to 006°9'00"E. the area is made up of two main stratigraphic sections geologically; they are alluvial deposits and Jima member of the Bida sandstone. The alluvial deposit covers an area of about 3km^2 of the active flood plains of River Gbako around Baddegi Town. It has brownish colour and fine grained appearance. The alluvial deposits are underlain by the Jima sandstone; sediments in the area are rich in quartz which is the dominant mineral in the alluvial deposits. Iron concretion and orthoclase feldspars forms parts of the minerals. Lithological units in the area revealed thick laterite horizon. The climate of the area is moist sub-humid according to Thornthwaite's classification [15]. The mean annual average temperature of the area ranges between 33°C and 34 °C [11]. Rainfall in the area is most intense in the period between April and October and is preceded by dry season from around November to March. According to the NCRI Agro met, the average annual rainfall ranges between 900.6 and 1340.4 mm. The area is populated by mainly farmers and the largest settlement in the area is Baddegi.

3. Research Methodologies

3.1. Sediment Sampling and Description

Four sampling pits, TR-1, TR-2, TR-3 and TR-4, were dug for the purpose of lithological studies and sediment sampling. The pits were dug with a pick axe, shovel and hoe to depths of 0.3m, 2.0m, 1.4m and 1.2m respectively. Table 1 shows the geographic coordinates of pits, elevation above mean sea level, and depths of the sampling. Sediments were collected at 0.1m (TR-1) and 0.2m (TR-2, TR-3, and TR-4) intervals to the maximum depth for each pit. The sediments were collected with a spade and stored in polythene bags and appropriately labelled with depth of sampling and location coordinates. Field and laboratory descriptions of the sediment were carried out before chemical analysis.

3.2. Sediment Analysis

Analysis of the sediment was conducted at the central services laboratory National Cereal Research Institute Baddegi. The sediments were air dried and processed by milling them with mortar and sieved through a 2mm sieve before laboratory analysis was conducted. Sediments particles sizes analysis was carried out using hydrometer method as reported by [6]. Cation exchange capacity was obtained by summation [13]. The sediment samples were analysed using Atomic Absorption Spectrometry (AAS) for the concentration of potentially toxic elements. Hydraulic conductivity of the sediments was estimated from particle size analyses using empirical formula as mentioned by [7].

***Table 1.** Identification codes of samples, location coordinates, and elevations of the sampling pits.*

No	Code	Coordinates	Elevation (m)	Depth (m)
1.	TR-1	N09°04'44.9" E006°07'16.4"	80.00	0.30
2.	TR-2	N09°03'59.7" E006°05'50.0"	102.00	2.80
3.	TR-3	N09°04'27.0" E006°06'34.3"	74.00	1.40
4.	TR-4	N09°03'17.6" E006°08'17.6"	77.00	1.20

3.3. Metal Partition and Transport

Empirical formula was used to calculate partition coefficient values of two metals (Fe and Zn) in order to know how they are partitioned to the solid (sediments) or to the liquid (water). The concentration of the metals in the sediment and the concentration of such metals in the water were divided. Thus, partition coefficient is represented by [5] as thus:

$$D_i = \frac{C_i^{\text{solid}}}{C_i^{\text{liquid}}} \tag{1}$$

Where D_i is partition coefficient, C_i^{solid} is concentration of metals in sediment and C_i^{liquid} is concentration of metals in water. Metals that are compatible and preferentially accepted by the minerals have D_i >1, while D_i < 1 indicate incompatible metals. Partition coefficient D_i = 0 for metals that do not readily react with soil matrix and travel with almost the same velocity as the velocity of the water, but this seldom occurs for most elements. For metals that react readily with the soil materials they often have partition coefficient $Di \geq (1)$ and travel with a velocity lower than the velocity of water moving through the same soil material.

The velocity of the metals (Fe, and Zn) in the sediment was calculated from the relation [5].

$$V = \frac{n}{n+(1-n)\frac{C\,i\,solid}{C\,i\,liquid}} V\,liquid \tag{2}$$

V is velocity of metal in the solid (sediments, soils); n is porosity of the sediment,

$V\,liquid$ is velocity of the water, $C_i^{\,solid}$ is concentration of metal in sediment and

$C_i^{\,liquid}$ is concentration of metal in water.

4 Results

Some selected characteristics of the sediments are presented in table 2. Partition coefficients values of Fe and Zn in the sediments from three sampling pits table 3 and metal mobility (velocity) through the sediments horizons are represented in table 4.

Table 2. *Some Characteristics of the Sediments in the Floodplains of River Gbako around Baddegi, Central Bida Basin.*

Sampling intervals (m)	pH	M.C (%)	O.C (%)	O.M (%)	CEC (cmol/Kg)	Fe (cmol/Kg)	Zn (cmol/Kg)	Soil Particle size		
								Sand	Silt	Clay
TR-1										
0.1	4.52	15.38	1.28	2.20	6.44	5.84	2.42	62.40	12.32	25.28
0.2	4.13	10.83	1.12	1.93	9.12	5.83	2.41	80.95	11.32	17.73
0.3	4.61	12.85	0.12	0.21	6.87	4.86	2.32	81.95	5.29	12.76
TR-2										
0.2	4.27	6.35	1.32	2.27	6.34	5.53	2.57	77.96	6.28	15.76
0.4	4.21	6.99	0.70	1.20	5.44	5.50	2.35	62.96	4.28	34.76
0.6	4.64	7.21	0.12	0.21	4.30	5.20	2.52	74.96	7.28	23.76
0.8	5.94	10.23	0.22	0.37	3.13	4.86	2.31	68.96	3.28	27.76
1.0	4.36	12.16	1.22	2.10	3.50	4.81	2.30	71.96	11.28	16.76
1.2	4.49	12.3	0.36	0.62	4.29	4.53	2.33	62.96	2.28	34.76
1.4	4.54	11.33	0.12	0.21	5.48	4.53	2.31	62.96	2.28	34.76
1.6	4.77	11.25	0.12	0.21	4.23	4.61	2.31	62.96	2.28	34.76
TR-3										
0.2	5.13	5.37	0.03	0.10	2.53	4.53	2.64	79.96	5.28	14.76
0.4	5.54	4.82	0.67	1.67	6.59	4.51	2.63	72.96	10.28	16.76
0.6	4.56	7.55	0.03	0.10	4.56	4.33	2.61	72.96	9.28	15.96

TR=Sampling pits, M.C= Moisture content, O.C= Organic carbon, O.M=Organic Matter, CEC= Cation exchangeable Capacity.

Table 3. *Partition coefficient values of the sediment in the three sampling pits.*

Depth (m) TR-1	Partition Coefficient (Fe)	Partition Coefficient (Zn)
0.1	0.99	0.99
0.2	0.99	0.99
0.3	0.83	0.95
TR-2		
0.2	1.22	1.1
0.4	1.21	1.03
0.6	1.15	1.02
0.8	1.07	1.01
1	1.06	1.01
1.2	0.99	1.02
1.4	0.99	1.01
1.6	1.02	1.02
TR-3		
0.2	0.88	0.95
0.4	0.88	0.82
0.6	0.88	0.83

TR=Sampling pits.

5. Discussions

5.1. Characteristics of the Alluvial Sediment

Alluvial deposits of the catchment area represent the active flood plains of the River around Baddegi. Characteristics soil type is dominated by thin layer of eroded materials and large percentage of sand with intercalations of clay (table 2). Silt materials in this catchment domain are insignificant. Yilmaz and Karacan [16] defined alluvium as loose, unconsolidated soil which is then eroded, deposited, and reshaped by water in some form in a non-marine setting. The catchment areas of the River around Baddegi is part of the central Bida basin of which the lithology is made up of sandstone with the Jima and Doko member series, thus, the parent rock (sandstone) weathered and contributed to the sediment deposition. The Jima member is dominated by cross-stratified quartzose-sandstones, siltstones and clay stones, typical of the characteristics of the sediments in the area [12]. Ashraf *et al.* [1] concluded that alluvium is made up of a variety of materials including fine particles of silt and clay and larger particles of sand and gravel and often contains a good deal of organic matters.

Sediment profile development in the area is poor except for the thin layer of transported materials overlying the sandy deposits signifying continuous sedimentation and apparently recent geological processes of erosion and transportation. Ashraf *et al*. [1] concluded that non profile development in the soil may be due to the young nature of the deposit. Clay intercalation serves as a binding medium to the grains of the sandy deposits in the floodplains; this can affect porosity and permeability of the sediment. The clay was brownish with reddish stains inclusions of iron concretion evidence of leaching. Overall, the sediments are rich in quartz, orthoclase feldspars and shows thick laterite deposits at the boundaries between the flood plains and the mainland. Large scale flooding of the catchment areas during raining seasons and adequate drainage makes differentiation between the floodplains and mainland difficult.

5.2. Hydraulic Conductivity (*K*) of the Sediment

Estimation of average hydraulic conductivity from soil particle sizes shows the four pits have nearly the same hydraulic conductivity with slight variation for pit (TR-1) with the three other pits (TR-2, TR-3, and TR-4). TR-1 has estimated average hydraulic conductivity of 4.2m/day while TR-2, TR-3 and TR-4 have estimated average hydraulic conductivity of 3.4m/day. The average hydraulic conductivity values for the pits correlate to the vertical estimate of hydraulic conductivity of a medium- grained sandstone geologic material [4].

Table 4. *Velocity in m/day of the two metals in the sediments collected from the sampling pits.*

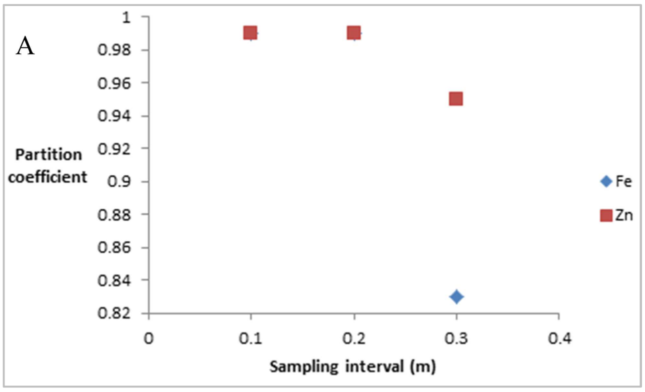
TR-1		
Sampling Interval	**Fe**	**Zn**
0.1	0.09	0.09
0.2	0.09	0.09
0.3	0.09	0.09
Total	0.27	0.27
Average	0.09	0.09
TR-2		
0.2	0.06	0.06
0.4	0.06	0.06
0.6	0.06	0.06
0.8	0.07	0.07
1.0	0.07	0.07
1.2	0.07	0.07
1.4	0.07	0.07
1.6	0.07	0.07
Total	0.53	0.53
Average	0.46	0.46
TR-3		
0.2	0.08	0.06
0.4	0.08	0.08
0.6	0.08	0.08
Total	0.24	0.22
Average	0.08	0.07

TR=Sampling pit.

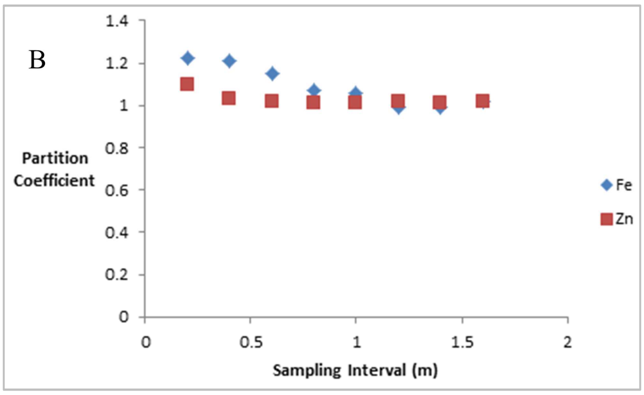
5.3. Contaminant Transport in the Aquifer Sediment

The two metals (Fe and Zn) have shown partition coefficient values of greater than zero $Di > 0$ in the sediments table 4 and in some cases, they have partition coefficient of $Di > 1$ indicating they are partitioned in the sediment and readily attached to the grain surfaces of the sediments. The pattern of partitioning amongst the metals figure 1 is similarly the same in all the sampling pits. Slight variations however, were observed. In sampling pit 1 TR-1, Fe and Zn have shown strong relation as they have the same partition coefficient value of 0.99 in the first two sampling intervals Table 4 until the third sampling intervals where Zn partitioned more in the sediment than Fe. Iron (Fe) and Zinc (Zn) have the same partition pattern in sampling pit 2 (TR-2) indicating similarity in chemical behaviour of Fe and Zn. Overall, mobilization and immobilization of metals are affected by a variety of soil properties [8].

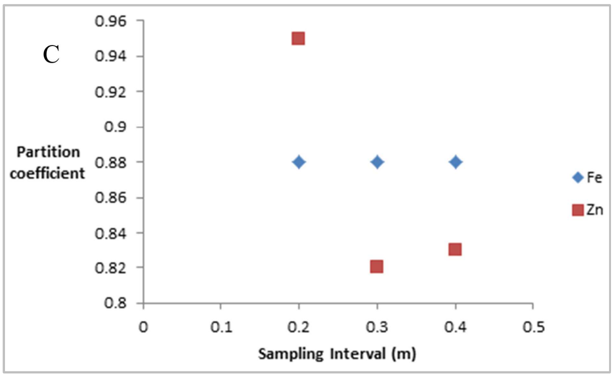
Similar partitioning pattern was observed in sampling pit three TR-3 except that slight variations were observed, the controlling factors could be the behaviours of the grain surfaces of the sediments to the metals, this probably explains the principles behind attenuation of pollutant and groundwater purification in the area as water samples collected within catchment basin and analysed have not been largely contaminated by the metals except Fe whose concentration in both soil and water is at elevated levels. Relationship between texture of sediment and the partition coefficient values seems relatively strong. While observed relationship was seen between percentage clay composition and partitioned coefficient values in some cases especially in sampling pit TR-2, the assumption is not true in all cases.



A=Sampling pit TR-1



B= Sampling pit TR-2

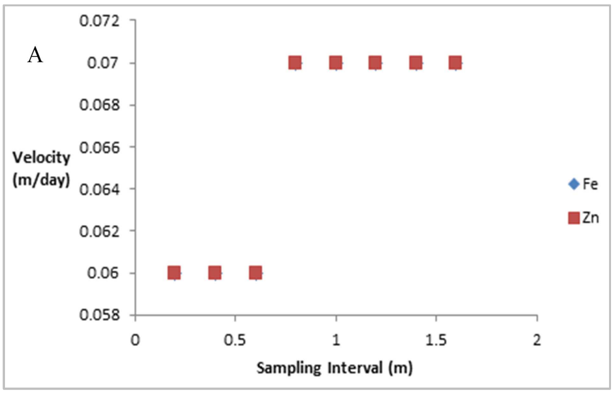


C=Sampling pit TR-3

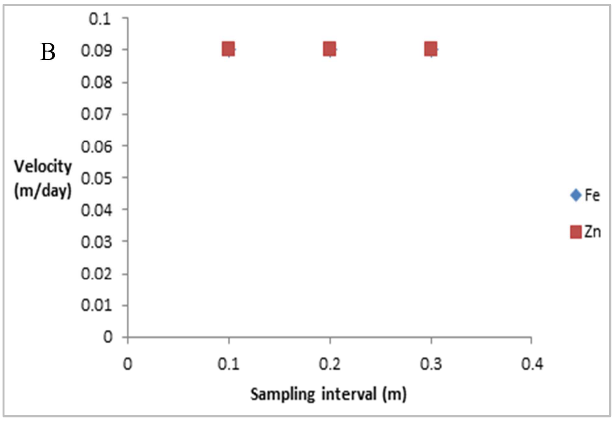
Figure 1. *Partition Coefficient Values against sampling intervals in three sampling pits.*

All the sediments collected in the flood plains were acidic having range value of 1.81 and mean value of 4.69 and minimum and maximum values of 4.13 and 5.94 respectively; showing between strongly acidic to moderately acidic soils. The acidity of soil affects many chemical processes especially, the availability of metals in the soils [14]. Cation exchange capacity has a range value of 6.59 and mean value is 5.20 cmol/Kg with minimum and maximum values of 2.53 and 9.12 cmol/kg respectively. The CEC of soils varies according to the clay percentage, the type of clay, soil pH and amount of organic matter. Soils with a low CEC are more likely to develop deficiencies in potassium (K^+), magnesium (Mg^2+) and other cations while high CEC soils are less susceptible to leaching of these cations [3]. The CEC also changes with depth; high organic content indicates high CEC while Low organic content in soil indicates low CEC.

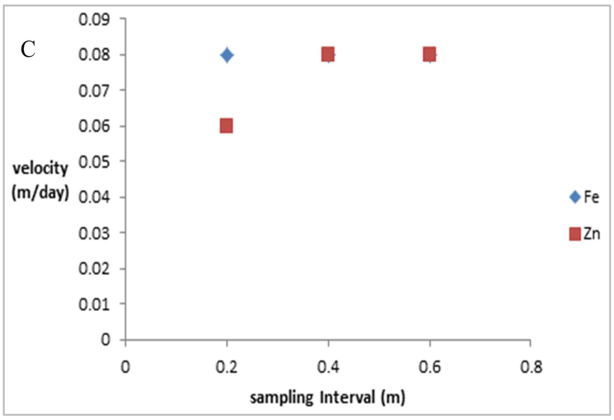
The Velocity of the metals Fe and Zn in the sediments was determined figure 2. Fe has average velocity of 0.09, 0.46, and 0.08 m/day in TR-1, TR-2, and TR-3 respectively. The Zn however, has average velocity of 0.09, 0.46, and 0.07m/day in TR-1, TR-2 and TR-3 respectively Table 4. The velocity of the metals in the sediment is low relative to the velocity of the water 4.2m/day in TR-1, and 3.4m/day in TR-2, TR-3, and TR-4. Overall, the metals were partitioned in the sediment preferentially and accepted and could not move with the same velocity as the velocity of the water moving through the sediment horizon hence the principle behind groundwater purification within the flood plains aquifers system.



A=Sampling pit TR-1



B= Sampling pit TR-2



C=Sampling pit TR-3

Figure 2. *Velocity of metals through the sediment horizons in the sampling pits.*

6. Conclusions

Contaminant transport in the aquifer sediments of River Gbako flood plains around Baddegi central Bida Basin Nigeria was investigated. Particle sizes analysis shows sand dominated sediment with more than 50 per cent sand composition and small percentage of clay materials that binds the grain matrix reducing effective porosity and permeability. Silt materials in the sediment is insignificant as they are minute and could be remnant of weathered parent rocks in the basin, the sediment are young owing to the non-profile development in them. The sediments are acidic with a mean pH of 4.69 controlling other geochemical processes in the area. Partition coefficient values indicated the metals are compatible and preferentially accepted by the minerals with most of the coefficient values greater than one *Di > 1*. Velocity of the metals through the sediment horizons is slower relative to the velocity of the water percolating through the sediment indicating retardation and possible mechanisms behind attenuation and groundwater purification in the area.

Acknowledgements

The Research Analysis was conducted at the Central

Service laboratory, National Cereal Research Institute (NCRI) Baddegi, Nigeria.

References

[1] Ashraf, M. A, Maah M. J., Yosoff I. (2012). Chemical Speciation and Potential Mobility of Heavy Metals in the Soil of Former Tin Mining Catchment *Scientific World journal* 125608.

[2] Boul, S. W., Hole, F. D., McCracken, R. J., Southard, R. J., 1997. Soil Genesis and Classification. Iowa State University Press, Ames, IA.

[3] Cornell University Cooperative Extension (CUCE) (2007) Cation Exchange Capacity (CEC). Agronomy Fact Sheet Series # 22. Department of Crop and Soil Sciences, College of Agriculture and Life Sciences, Cornell University.

[4] David K. T (2005), *Groundwater Hydrology*. University of California, USA.

[5] Albarede, F. (2009). *Geochemistry: An introduction*. Cambridge University press. NY, USA.

[6] Gee GW, Bauder JW. (1986). Particle Soil Analysis. In: Klute A, editor. *Methods for Soil Analysis. Part 1: Physical and Mineralogical Methods*. Madison, Wis, USA: American Society of Agronomy; pp. 475–490. (Soil Science Society of America Book Series No. 5).

[7] Hazen, A. (1911). Discussion: Dams on sand foundations: Transaction. *American Society of Civil Engineers*, 73, 199.

[8] Jones LHP, Jarvis SC. (1981). *The fate of heavy metals.* The Chemistry of Soil Processes. NY, USA: Wiley.

[9] Kongjoo, K., Natarajan, R., Hyun, J. K., Seok, H. K., Gab, S. H., Seong T. Y... Sang, H. L. (2005). Evaluation of Geochemical Processes Affecting Groundwater Chemistry Based on Mass Balance Approach. *Geochemical Journal, 39 (4), 357*-369.

[10] Ma, L. Q, Rhue, R. D, Dong, Y. (2000). Relation of enhanced Pb Solubility to Fe partitioning in Soils. Environmental Pollution. 110, 515-522

[11] NCRI (2014), National Cereal Research Institute Baddegi, Agro-meteorology Data Manual.

[12] Obaje, N. G. (2009). The Mid-Niger (Bida) Basin. *In Geology and Mineral Resources of Nigeria*, (pp. 91-101). Berlin Heidelberg: Springer.

[13] Ross, D. Kettering, Q. (2011). Recommended Soil Test for Macronutrients. P 39-47. In J. T Sins and A. Wolf (Eds) Recommended Soil Testing Procedure for the North-eastern united states. North east Regional bulletin # 493. 3rd edition. Agricultural experiment station, University of Delaware, New York, De.

[14] Soil Survey Manual (1993). Soil conservation services. U. S Department of Agriculture handbook 18.

[15] Thornthwaite, (1931). *Thornwaite Climate Classification 'A Dictionary of Ecology'.* Great Clarendon Street, Oxford University Press.

[16] Yilmaz I, Karacan E. (1997). Geotechnical properties of alluvial soils: an example from south of Sivas (Turkey) *Bulletin of Engineering Geology and the Environment*. 55, 159-165.