LEVELS AND DISTRIBUTION OF IRON (Fe) AND MANGANESE (Mn) IN HAND DUG WELLS OF KURGWI VILLAGE AND ENVIRONS, PLATEAU STATE, NORTH-CENTRAL NIGERIA

¹Dung, S. ²G. Lawam , ³T. D. Mangdong C. L.

¹Department of Geology, College of Arts, Science and Technology, Kurgwi, Nigeria ²Department of Chemistry, College of Arts, Science and Technology, Kurgwi, Nigeria ¹nangbesig@gmail.com

ABSTRACT: Forty (40) shallow groundwater (Hand –dug wells) samples in Kurgwi and environs with depth range of 4.25 - 14.90 m were analysed for trace metals (iron and manganese) using combined ICP-AES/ICP-MS technique. The concentration of iron ranged from 0.01 - 1.05 mg/L while that of Manganese ranged from $49.86 \times 10^{-6} - 1.491$ mg/L. Physical parameters determined were temperature $28.5 - 31.0^{\circ}$ C, TDS 21.94 - 842.0 mg/L, conductivity $47.0 - 1678 \mu$ S/cm and pH 6.90 - 9.00. Geologically, Kurgwi village and environs are underlain mainly by basement complex rocks (Older Granites) as well as sedimentary rocks (Awall Formation) of the middle Benue trough. The study revealed that age of tube well had no impact on quantities of studied heavy metals, however, significant impact of tube wells depth was observed in decreasing depth order. Also, the more the depth, the more the TDS and conductivity, this implies that the soil is highly mineralized and most of these minerals get dissolved in the well water and thus the increase in TDS and conductivity with depth. It also shows that the dissolved salts are neutral salts since the pH is relatively constant at approximately 30° C. Chemical investigation reveals that mobilization of Fe and Mn as trace elements were low or almost non-existing in most samples.

Keywords: Groundwater, Concentrations, Kurgwi, Iron and Manganese.

1. INTRODUCTION

Groundwater refers to subsurface water that occurs beneath the water table in soils geologic formations that are fully saturated [1]. Groundwater is found in aquifers, which have the capability of both storing and transmitting it. It originates mainly from infiltration and percolation of meteoric water such as rain water or melted snow or ice and from seepage from streams, lakes, ponds, channels, reservoirs and other water bodies [2]. Two other sources of ground water are juvenile water and connate water. The quality of groundwater is as important as its quantity. Water quality is a measure of the dissolved solutes and gasses in the water as well as the matter suspended in and floating on it. Ground water quality determines the usefulness to which the water can be put. Water quality is a consequence of the natural, physical and chemical state of the water as well as any alteration that may have occurred as a result of (anthropogenic) activities, human [3]. Natural groundwater is never chemically pure because minerals, organic solids, organic liquids and gases are found dissolved in it to some extent [3]. Dissolved constituents in ground water are classified according to relative abundance (concentrations), as major, minor and trace

constituents [1].General chemical quality of ground water is determined or controlled by a variety of factors. These factors are natural and non- natural [4]. Major factors that influence the chemical composition of groundwater naturally includes petrographic properties of the vetoes zone and the aquifers, and physical hydrogeology of the geological setting. The non-natural factors that influence the chemical composition of groundwater is mainly anthropogenic influences, in particular land use [3].From the geochemical point of view, trace elements are metals whose percentage in rock composition does not exceed 0.1% [5]. Example of such elements are iron, nickel, cobalt, manganese and cadmium. These metals are found naturally throughout the earth, in rocks and soils trapped in stable form. Trace metals are of great environmental and human health concern because of their toxicity, their release into the environment through a range of natural terrestrial surface conditions [6]. Trace metals occur naturally in rocks and soils but increasingly higher quantities of metals are being introduced anthropogenically as micro-pollutants into our environment from several sources such as industrials. agricultural and domestic wastewater/effluents [7]. [8] observed that metals are

introduced into groundwater as a result of the weathering of rocks and soils. For example, volcanic eruptions and from several human activities involving mining, processing and uses of metals and industrial materials that contain metal contaminants. Heavy metals take part in biogeochemical cycles and are not permanently fixed in soils; therefore, assessment of their distribution in soils is a key issue in many environmental studies [9]. Heavy metals are included in soil minerals as well as bound to different phases of soil particles by a variety of mechanisms, mainly absorption, ion exchange, coand complexation. Moreover, precipitation, soil properties such as contents of organic matter, carbonates, oxides as well as soil structure and profile development influence the heavy metal mobility [10].

According to a recent study [11] it is revealed that age of tube well had no impact on quantities of studied heavy metals, however, significant impact of tube wells depth was observed in decreasing depth order. Antimony and Aluminum values were found in higher quantities than standard recommended values in tube wells of lower depth. Arsenic and lead were found in below recommended values in all tube well water samples. The arsenic presence in the samples may be attributed to the population burden and the use of chemical fertilizers in the surrounding area of tube wells respectively, the quantity of Aluminum and Antimony were found higher than safe levels which is an alarming indication for the drinking water for public use. The fate and transfer of metals are complex and depend on the transport process involved, on the mineralogy of eroded particles and on soil and sediment properties [12; 13; 14]. The biogeochemical processes that control metal mobility and bioavailability include sorption on mineral and organic surfaces, dissolution, (bio-) mineralization, redox processes, complexation by biogenic or nonbiogenic ligands and uptake by the biota [15]. These processes could determine the metal speciation in the environment and therefore, their bioavailability and toxicity.

Trace elements play an important role in the contamination of the environment. This is due to continuous increase in their concentration in soils, sediments and water. They enter the environment through atmospheric deposition, erosion of the geological matrix and from an anthropogenic sources arising from both stationary (power plants, industries, incinerators, mining activities and residential heating) and mobile sources such as road traffic as well as by direct land application of wastewater sludge and pesticides [16]. Trace metals found in soils are immobilized into water and thus could be involved in absorption, co-precipitation and complex formation [17]. Sometimes they are co-adsorbed with other compounds such as oxides, hydroxides of iron, manganese or may occur in particulate form [18]. The effects of these elements depend on the total metal concentration in soil, speciation, mobility and bioavailability [19]. Manganese is less toxic metal as compared to other heavy metals and also an essential trace metal required for various biological functions. Nevertheless, it has number of detrimental properties such as the obstruction of water distribution grids, staining during laundry and the tainting of drinking water [20; 21]. Along with above these manganese both in excess and deficiency have harmful effects on health. During early eighteenth century the first occupational exposure of manganese and intoxication was reported [22]. Since then, lot of studies has been under taken to investigate and decipher the uptake, transport, metabolism and toxicity of manganese in the living system. Mostly manganese exposure to living body occurs by inhalation and ingestion of manganese rich compounds and may results in neurological pathology, since brain is thought to be vulnerable target for manganese accumulation [23]. Higher manganese concentrations affect central nervous system, heart, lung, liver and some other organs [24]. Ambient manganese concentrations in seawater have been reported to range from 0.4 to 10 μ g/l [25], with an average of about 2 µg/l [26]. Levels in fresh water typically range from 1 to 200 µg/l [26]. Accumulation of the manganese in brain tissue results in neurotoxicity which leads to progressive disorder of the extra pyramidal system similar to Parkinson's disease [24]. High concentration of manganese in the living system also affects DNA replication and cause mutations/ aberrations [27]. Other effects of manganese toxicity are associated with its role in (i) mucopolysaccharides and (ii) peptidoglycan synthesis [28].

1.1 LOCATION AND GEOLOGY OF THE STUDY AREA

The area of study is located partly within the Basement Complex and sedimentary formations in Kurgwi Area of Plateau State, Nigeria. The topographic map used was extracted from Kwalla Central, Sheet 211 on a scale 1:50,000 published by the Federal Survey Department of Nigeria. The study area lies approximately between latitude $8^{\circ} 40^{\circ} 54.00^{\circ}$ and $8^{\circ} 47^{\circ}$ 0.600" N and longitude 009° 12' 20.00" and 009° 18' 36.00" E, with a total surface area of approximately 148 KM². Villages that make up the study area are: Kurgwi, Baban fadama, Kwande, Ampiya-Kwande, AmpiyaKurgwi, Rumada, Angwan Mushere, Dabat, and Bamaiyi, all in Qua'an- Pan LGA of Plateau state.

The map of the study area is underlain by two main rock groups as observed in the field: Basement complex rocks: Porphyritic granite, Medium- grained granite, and Fine - grained granite. Sedimentary Rocks: the Awgu Formation.



Figure 1: Map of Nigeria and Plateau State Showing the Study Area



Figure 2: Geologic map of the study area

2. MATERIALS AND METHODS

2.1 Field Sample Collection

Shallow groundwater samples were collected from fourty (40) locations in Kurgwi and environs. Sampling of water collected from hand-dug wells was deliberately carried in the month of May ($5^{th} - 7^{th}$ May), 2013, when the water table in the study area would have been at its lowest level for that year. For the purpose of knowing the precise depths to water tables, the water samples obtained were strictly from hand-dug wells. The sample locations in the study area are shown in Figure 3.The sample bottles were first washed with 1% HNO₃, rinsed with distilled water and allowed to dry in oven at 105° C for 24 hours.At each sample location, two (2) water samples were collected in a 250 ml polyethylene bottle capacity, one of the 250 ml bottle was acidified with nitric acid (HNO₃) to avoid bacterial growth, keep the ions in solution, and to prevent their adsorption and precipitation in solution. The water samples from hand-dug wells were collected using a plastic bucket, which had already been pretreated as the sample bottles, tied to a nylon rope. A meter tape was used to determine the depth to water level (water table).For precise results, determination of pH, temperature and conductivity were immediately carried out on-site using the pH/temperature/Mv meter.



Figure 3: Sample Location Map on the Satellite image of the Study Area

2.2 Sample Preparation and Preservation

After adding two drops of concentrated nitric acid to prevent any absorption and precipitation of some ions in the liquid samples collected, the polyethylene bottles containing all the water samples were wrapped and sealed. Before analyses, the water samples were filtered to remove suspended particles in the water. After each sample collection, the old thin film was removed and re-wrap with a new one. All the samples collected were labelled properly according to sample number. The samples collected were kept in a refrigerator for further analysis.

3. LABORATORY ANALYSIS

Acidified samples were analyzed for trace elements at the Acme Analytical Laboratories Vancouver, Canada. The combined ICP-AES/ICP-MS were used to determine the concentration of the trace elements (Fe and Mn).

4. RESULTS AND DISCUSSIONS

Average results for the parameters investigated for each sample were as presented in Tables 1, 2 and 3 below while Table 4 is the Pearson correlation of the chemical parameters. Figures 1 and 2 are the physical and geologic maps of the study area respectively, while figure 3 is the Satellite image of the study area showing the distribution of sampling points. Figure 4 represents the graphical distribution of each parameter with the depth of the wells where the water samples were obtained.

Parameter/	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
Sample Site													
TDS (mg/L)	165.5	123.6	65.81	105.7	199.4	842	178.5	210.4	468.8	148.6	210.4	118.7	114
													.7
Conductivit	273	245	130	212	393	1678	361	420	920	291	413	233	228
y (µS/cm)													
Temperatur	29.9	30.7	30.2	28.9	30	31	30	30.2	29.6	29.7	29.9	29.2	28.
e (°C)													5
Elevation	246	237	235	225	227	227	219	222	233	243	241	248	209
(M)													
Depth of	6.42	8.54	7,72	11.35	10.96	6.1	9	6.51	10.21	6.7	4.25	7.5	5.5
well (M)													1
Ph	7	6.9	8.2	8.3	8.3	7.5	8.5	8.3	8	8.6	8.5	8.7	9
Fe (mg/L)	< 0.00997	< 0.00997	0.317	< 0.00997	< 0.00997	< 0.00997	< 0.00997	< 0.10	< 0.00997	0.1047	0.0119	< 0.0099	0.2
	2	1	1	1	2	7	2		4		7	71	014
Mn (mg/L)	0.02069	0.05883	0.121	0.04435	0.04804	1.491	2.49E-04	2.49E	0.03497	0.0896	0.1124	0.01741	0.0
								-04		3			599
													4

Table 1: Parameters and Contents of Trace Elements for Locations 1 - 13

 Table 2: Parameters and Contents of Trace Elements for Locations 14-26

Para	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26
meter/													
Sampl													
e Site													
TDS	101.7	252.3	121.6	300.2	219.4	120.7	272.2	202.4	181.5	37.89	71.79	173.5	95.72
(mg/L)													
Condu	205	502	244	598	438	242	543	404	360	76	144	349	194
ctivity													
(µS/c													
m)													
Tempe	29	28.5	28.9	29.3	29.4	29.4	29	29.5	29.8	30	29.8	30	30.5
rature													
(°C)													
Elevati	215	119	184	183	178	183	175	182	183	194	182	180	206
on (M)													
Depth	6.44	7.21	8.7	12.8	14.17	14.9	11.45	7	9.86	7.8	10.17	10.25	6.08
of well													
(M)													
Ph	8.5	8.3	8.7	8.2	8.5	8.7	8.1	8.3	8.5	9	8.6	9	7.2
Fe	0.06082	0.01895	< 0.00997	< 0.0099	< 0.009	< 0.00997	< 0.0099	< 0.0099	< 0.00997	0.841	0.027	< 0.00	0.0199
(mg/L)			1	73	972	1	72	72	2	5	92	9972	4
Mn	0.1573	2.39E-04	0.03878	5.49E-	0.0076	0.001366	0.00634	0.03994	<49.86E-	0.068	0.021	0.0103	0.0844

(mg/L)		04	58	2		6 54	07	6 2	
Parameter	TDS(mg/l) Conductivit (µmho\cm)		Temperature (°C)	Elevation (M)	Depth of well (M)	рН	Fe (mg\l)	Mn (mg\l)	
TDS(mg/l)	1	0.993979953	0.147126561	-0.05602	0.072385762	-0.36842	-0.57294	0.648153	
Conductivity (µmho\cm)	0.993979953	1	0.122635016	-0.0539	0.09450933	-0.34727	-0.59654	0.659108	
Temperature (°C)	0.147126561	0.122635016	1	0.169239	-0.25534944	-0.4447	0.296708	0.322309	
Elevation (M)	- 0.056019012	-0.0539042	0.169239445	1	-0.19447107	0.036795	-0.12118	0.214362	
Depth of well (M)	0.072385762	0.09450933	-0.25534944	-0.19447	1	0.129952	0.13929	-0.21288	
pH	- 0.368417931	-0.3472701	-0.44470485	0.036795	0.129952382	1	-0.28491	-0.11969	
Fe (mg\l)	- 0.572939294	-0.5965444	0.296707807	-0.12118	0.139289673	-0.28491	1	0.115075	
Mn (mg\l)	0.648152587	0.65910829	0.322309036	0.214362	-0.21288076	-0.11969	0.115075	1	

 Table 3: Parameters and Contents of Trace Elements for Locations 27-40

Param	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	MEAN
eter/S															
ample															
Site															
TDS	107.	142.	172.	208.4	337.1	142.	335.1	344.1	532.6	339.1	272.2	337.1	21.94	37.	210.85
(mg/L)	7	6	5			6								8	
Condu	217	283	304	410	665	279	666	683	1051	670	574	473	47	77	412.38
ctivity															
(µS/cm															
)															
Tempe	29.4	31	31	30.5	30.4	28.9	29.8	28.9	29.5	30.4	30.3	30.7	30.6	30.	29.81
rature														2	
(°C)															
Elevati	189	194	195	187	177	209	203	182	183	191	174	176	199	181	200.40
on (M)															
Depth	6.41	4.78	7.49	6.41	5.29	5.46	11.98	8.9	9.38	10.78	8.7	6	7.91	5.8	8.34
of well														5	
(M)															
pН	7.6	7.9	7.8	7.6	7.6	8.6	7	7.1	7	7.2	7.5	7.4	7.8	7	8.01
Fe	<0.0	0.03	0.44	< 0.0099	< 0.00997	0.04	< 0.009973	< 0.0099	< 0.009	< 0.0099	< 0.0099	<0099	0.3789	1.0	0.26
(mg/L)	0997	291	77	72	3	886		73	974	73	72	73		5	
(8,)	1				-									-	
Mn	0.03	0.03	0.31	0.00299	0.02381	0.07	6.98E-05	6.98E-	<49.87	2.69E-	0.05	0.0086	0.0253	0.0	0.08
(mg/L)	686	916	25	2		829		05	E-6	04		66		633	





Fig. 4: Profiles of Conductivity, TDS, Temperature, Depth of well and pH of shallow well water



Fig. 5: Profiles of Temperature, Depth of well and pH of shallow well water

5. DISCUSSION

5.1 Physical Parameters in the Study Area

In all the wells sampled, the static water levels in the study area have depths ranging from 4.25 to 14.9 m. The pH of water samples in the study area ranged from 6.9 - 9.0, with a mean of 8.01, indicating almost neutral to slightly alkaline condition. Nine (9) samples out of the forty (40) have pH higher than WHO (2011) recommended range of 6.5 - 8.5.

The Electrical conductivity of water in the study area ranged from 47 – 1678 μ S/cm, with a mean value of 412.38 μ S/cm which is above the [29] standard for drinking water. In the study area 22 of the forty (40) locations have their electrical conductivities above [29] permissible limit of 300 μ S/cm. The locations are Angwan Bori, Angwan Dem, Angwan Gagar, Angwan Waje, Angwan Ankwai, all in Kurgwi, Angwan Kasa, Angwan Liman, Sabon Pegi, all in Kwande, Ampiya - Kwande, Angwan, Gube (two locations), Ampiya – Kurgwi (two locations) Rumada (two locations), Agwan kasuwa, Angwan Mushere and Shiptak (all in Dabat).

The temperature of water samples in the area ranged from 28.5 – 31.0 °C, with a mean of 29.8. Total dissolved solids (TDS) in the area ranged from 21.95 - 842 mg/L, with a mean TDS of 210.85 mg/L, Angwan Dem, Kurgwi having the highest value of 842 mg/L. The TDS of samples of water in the area are almost all below WHO permissible limit of 500 mg/L with the exception of the samples obtained from Angwan Dem whose value is 842 mg/L. The study revealed that age of tube well had no impact on quantities of studied heavy metals, however, significant impact of tube wells depth was observed in decreasing depth order, which agrees with the other published works [30; 11]. The research reveals that the pH and temperature are independent of the depth of the wells. Also, the more the depth, the more the TDS and conductivity, this implies that the soil is highly mineralized and most of these minerals get dissolved in the well water and the increase in TDS and conductivity with depth. In both plots, the behaviour of TDS and conductivity are similar due to the fact that conductivity is basically a dependent on TDS, thus the characteristic behaviour.

5.2 Concentrations of Fe and Mn in the Study Area.

The concentration of Iron and manganese as analysed from the forty (40) water samples collected ranged from 0.1197 - 1.05 and $6.98 \times 10^{-6} - 1.491$ mg/L respectively. These elements occur in concentrations above WHO permissible limits in a number of locations.

The concentration of Fe was above WHO permissible limit of 0.3 ppm or mg/L in Angwan Muskwani, Kurgwi, Child friendly Primary School (Kwande), Angwan Kasuwa (Dabat) Bamaiyi (Old Jondshakal), and Angwan Kwanka (Kurgwi). Manganese was above WHO permissible limit of 0.05 mg/L in Angwan Muryen (Kurgwi), Angwan Dem (Kurgwi). Angwan kwanka (Kurgwi), Angwan Dem (Kurgwi), Baban Fadama, Child Friendly School (Kwande), Angwan Sarki (Dabat), Angwan Kasuwa (Dabat), Ampiya - Kwande, and Bamaiyi (Old Jonshakal). These concentrations could be characteristic of the soil and rock types within and around the study sites as is rightly observed by other researchers, which has always been in contact with the rocks and could be accumulated into the human, plant and animal tissues [30; 19; 17; 18].

The slight alkaline nature of water in the area is probably responsible for low concentration of trace elements in groundwater samples of the area. The presence of Fe and Mn in concentration above their WHO permissible limits in a few samples may be probably due to slight acidic nature and deposition of organic matter (reducing condition) in groundwater in such areas.

The Mn and Fe concentrations being high in some locations make the water not so suitable for laundry purposes. Mn and Fe when high in water can cause reddish-brown or black stains on laundry and household fixtures when in contact with oxygen, an oxidation process. Also, high levels of dissolved iron and manganese concentrations may result in objectionable taste and precipitation [1]. The presence Mn & Fe in groundwater of the area is possibly due to weathering of Fe & Mn- rich minerals and soils associated with rocks of the area. The concentration of these elements in the water samples do not show any correlation but are both correlated to TDS and conductivity. This indicates that both elements got to the water body as a result of dissolution of some minerals in the soil strata and are active components of the water conductivity. This also probably depicts different source compound composition.

6. CONCLUSION

Investigation on the concentrations of trace elements Fe and Mn in shallow groundwater (hand-dug wells) was carried out in Kurgwi and environs. Physical parameters such as temperature, TDS, conductivity and pH were determined. It was observed that groundwater in the area was generally slightly alkaline with relatively high total dissolved solids, indicative of fragile soil and rock types. Also, based on the pH of water in the area, Fe and Mn mobilization is generally low as reflected in the concentrations of these elements in most samples. Concentrations of Fe and Mn were above WHO, [29] permissible limits in a number of locations. This is possibly attributed to slight acidic nature of water in some locations and also due to reducing condition (deep wells deposition of organic matter) in such areas. The high concentration of Mn and Fe in some locations makes the water unsuitable for laundry purposes. This study showed that Iron (Fe) and Manganese (Mn) are metals that occur naturally in soils, rocks and minerals. In the aquifer, groundwater comes in contact with these solid materials dissolving them, releasing their constituents, including Fe and Mn, to the water. More so, high concentrations of Fe and Mn in water cause reddish-brown or black stains on laundry and household fixtures. High concentrations of Fe and Mn may impact objectionable taste to groundwater, due to the oxidized colloidal particles such as MnO2 and Fe₂O₃ that could form in the matrix, and could also be a point of adhesion to other particles, which upon decomposition, produce offensive odour and taste.

REFERENCES

- [1] Schwartz, F.N., and Zang, H. <u>Fundamentals of</u> <u>Groundwater</u>. John Wiley and Sons. Inc.583P. (2002).
- Krynine, D.P. and Judd, W.R. Principles of Engineering Geology and Geotechnics. CBS Publishers and Distributors, 4596// A, II – darya ganj, new delhi – 110002 (pp 172 – 173), (2005).
- [3] Fetter, C.W. Applied Hydrogeology. 2nd Edition.
 CBS Publishers, New Delhi, Bengalore. Pune Kochi Chennai.592p, (2007).
- [4] Dennis, N. Natural Variations in the Composition of Groundwater. Drinking Water Program, Oregon Department of Human Services, Springfield, Oregon. P 1 – 8. (2002).
- [5] Monika,Z. and Romic,M. Soil contamination by trace metals. Geochemical behavior as an element of Risk assessment, earth and environmental sciences, Dr Imran Ahmad Dar (Ed) ISBN: 978 – 953-307, 307- 468 - 9. (2011).
- [6] Johan,L., Carl, J., Mohrherr, K., Ranga, R. Trace Metal Assessment in Soils in a small city and its rural surrounding Pensacola, FL, USA *Environmental Earth science*: 65: 1781 – 1793. (2012).
- [7] Benson,N.,Udosen,E.D. and Akpabio,O. Interseasonal distribution and partitioning of heavy metals in sub tidal sediment of Qua Ibeo estuary and associate Creeks Niger delta (Nigeria). Environmental monitoring, (2008).
- [8] Aremu, M.O., Atolaiye,B.Oand Labaran,L. (2010). Environmental complication of metal concentrations in soils, plant, foods and pond in area around the Derelict Udege mines of Nasarawa state, Nigeria. Bulletin chemical society Ethiop: 24(3). (2008).
- [9] Salim I, Miller C, Howard J. Combined sequential extraction-adsorption isotherm analysis of the heavy metal retention characteristics of a michigan landfill bottom liner. In: Proceedings of Joint CSCE-ASCE National Conference on

Environmental Engineering; Montreal, Canada. pp. 821–828. (1993).

- Kabata-Pendias A, Pendias H. *Trace elements in* soils and plants. 3rd edition. Boca Raton, Florida, USA: CRC Press. (2001).
- [11] Afrasiab, K. T., Imrana, N. S., Pramuk, P., Mohammad, S., Ashraf, K., Mohammad, W. K. and Sadat H. (2014). Detection of heavy metals (Pb, Sb, Al, As) through atomic absorption spectroscopy from drinking water of District Pishin, Balochistan, Pakistan; *InternationalJournal of Current Microbilogy and Applied Science*, **3** (1)299 – 308.
- Krishnamurti G.S.R., Naidu RSolid-solution equilibria of cadmium in soils. Geoderma 113, 17–30. (2003).
- [13] Razo I., Carrizales L., Castro J., Díaz Barriga F., Monroy M. Arsenic and heavy metal pollution of soil, water and sediments in a semi-arid climate mining area in Mexico. Water Air Soil Pollut. 152, 129-152. (2004).
- D'Amore J.J., Al-Abed S.R., Scheckel K.G., Ryan J.A. Methods for Speciation of Metals in Soils: A Review. J. Environ. Qual., Vol. 34: 1707–1745. (2005).
- [15] Kraemer S.M., Hering J.G. Biogeochemical controls on the mobility and bioavailability of metals in soils and groundwater. *Aquatic Sciences*, 66, 1–2. (2004).
- [16] Song, F. and Gao Y. Chemical Characteristics of Precipitation of metropolitan Newark in the US East Coast Atmospheric Environmental, 43, 4903 -4913. (2009).
- [17] Okafor E. and Opuene, K. Preliminary Assessment of Trace Metals and Polycyclic aromatic hydrocarbons in sediment. *International Journal of environmental sciences and technology* 4 (2), 233 – 240.

- [18] Awofolu, O. R., Mbolekwa, Z., Mtshemla, V.and Fatoki, O.S. (2005). Levels of trace metals in water and sediments from Tyume River and its effects on an irrigated farmland. *Water S.A.*, **31**(1) 87 -94. (2007).
- [19] Szakovo, J., Miholova, D., Tlustos, P., Sestakova, I. and Frkova, Z. (2010). Effect of Soil Properties and Sample Preparation on Extractable and Soluble Pb and Cd fractions in soils agricultural sciences, 1 (3), 119 -130.
- [20] Hallberg K. B. and Johnson D. B. (2005) Biological manganese removal from acid mine drainage in constructed wetlands and prototype bioreactors. Sci. *Total Environ*.338:115-124.
- [21] Mariner R, Johnson DB and Hallberg KB (2008) Characterisation of an attenuation system for the remediation of Mn(II) contaminated waters. Hydrometallurgy94:100-104.
- [22] Offodile, M.E. and Reyment, R.H. (1977). Stratigraphy of the Keana-Awe Area of the Middle Benue Region of Nigeria: Bulletin Geological Institutions University Uppsala (N.S.) 7:37-66.
- [23] Röllin HB and Nogueira CMCA (2011) Manganese: Environmental Pollution and Health Effects. Encyclopedia of Environmental Health 617–629.
- [24] Crossgrove J and Zheng W (2004) Manganese toxicity upon overexposure. NMR Biomed. 17:544-553.
- [25] ATSDR (2000) Toxicological profile for manganese. Atlanta ,GA, United States Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry.
- [26] Barceloux DG (1999) Manganese. *Clinical Toxicology*, 37:293–307.
- [27] Gerber GB, Leonard A and Hantson P (2002) Carcinogenicity, mutagenicity and teratogenicity of manganese compounds. Crit. Rev. Oncol. Hematol.42:25-34.

- [28] Keen CL and Leach RM (1988) Manganese. In: Seiler HG, Sigel H and Sigel A (Eds), Handbook on toxicity of inorganic compounds. New York, Basel: Marcel dekkerinc. 405-414.
- [29] WHO (World Health Organization) (2011):
 Guidelines for drinking water quality (4th edition, pp. 186), available at (http://www.who.int).
- [30] Okegye J. I. and Gajere J. N. (2015). Assessment of Heavy Metal Contamination in Surface and Ground Water Resources around Udege Mbeki Mining District, North-Central Nigeria: J Geol Geophys, 4:3 ISSN: 2329-6755