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Assessment of Heavy Metal Status of Groundwater in Parts of Aba, Southeastern Nigeria

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ABSTRACT

Heavy metal status of groundwater in parts of Aba was investigated. This was done to assess the quality of the water for human consumption. Fifteen (15) groundwater samples were obtained from the vicinity and analyzed in the laboratory for some heavy metals by atomic adsorption spectrophotometric method. The water is slightly acidic to alkaline with pH values ranging from (4.8 – 8.0). Nine parameters: Lead (Pb), Chromium (Cr), Nickel (Ni), Copper (Cu), Zinc (Zn), Cadmium (Cd), Cobalt (Co), Iron (Fe) and Manganese (Mn) were analyzed and the results compared with the World Health Organization (WHO) standards. Analytical results revealed slightly high Cr in locations 1,2,3,4, ranging from 0.01(mg/l) to 0.10 (mg/l). Also Ni, Cu and Zn had higher concentrations of 1.25 (mg/l), 5.98 (mg/l) and 6.0 (mg/l) respectively. Cadmium showed the highest contamination level using geo-accumulation (Geol) index and contamination factor $C_{f.}$ Results showed that the indices which changed the water quality were due to anthropogenic factors from dumpsites and industrial wastes. Hydrogeological investigations showed that aquifer in the area were largely unconfined sands with intercalation of gravels, clay and shale. In order to detect further threat to groundwater quality in the area, routine monitoring of heavy metals and treatment are recommended.

Keywords: Heavy metal, groundwater, hydrogeology, water, contamination, Aba

INTRODUCTION

The term "heavy metal" is referred to chemical elements with high relative atomic mass. These elements occur naturally and can be detrimental to the lives of plants and animals even at very low concentration levels (1 to 2 micrograms). Some of these include: beryllium, cadmium, selenium, manganese, lead, mercury, arsenic, nickel, chromium amongst others. When used in industrial processes and if released into the environment, they are transported usually by natural agents (air or water). Heavy metals have a tendency to build up in certain body organs (such as the brain or liver), as such the prescribed average safe level for these elements in foods and water are often exaggeratedly high. (Gueu *et al.*, 2007; Adam *et al.*, 2008; Vinedhini and Narayanan, 2008).

Monitoring ground water quality is very necessary as most people depend on it. The occurrence of heavy metals in ground or surface water can be from natural sources. For example, if minerals containing these metals are the in soil zones or aquifer. Also, other anthropogenic sources may include fossil fuel (coal, natural gas, oil, etc), coal, industrial effluent, solid waste disposal, mining & metal processing (Ugwuja *et al.*, 2014). But the main anthropogenic sources of these of heavy metal contamination is mining, disposal of untreated and partly treated waste (chemicals dumped out of an industry) containing toxic metal, metal debris and chelates, which can as a results of industrial recklessness and careless use of heavy metal containing fertilizer and bug-killing chemicals in farms. (Hatje *et al.*, 1998; Amman *et al.*, 2002 and Nouri *et al.*, 2008).

Due to the nature Aba, periodic studies are carried out to monitor the levels of these metals. There are other activities apart from refuse dumpsites which can be responsible for metal pollution in the area such as paint industries, chemical industries as well as chemical markets where different type of chemicals are being manufactured and sold (Amadi and Nwankwoala, 2013; Amadi *et al.*, 2014). During the rainy season these chemicals are discarded in-appropriately on running water for it to wash the chemicals away, Also the wastes coming from industries are discarded in rivers and sewage channels which might find its way into groundwater system. Thus the intense anthropogenic activities and the resulting huge amount of waste generated and disposed on daily basis led to the choice of Aba for this water chemistry investigation.

In Aba, Abia State, fast growth of cities with more people and industrial development in the last 20 years have triggered some serious environmental worries and there is need to study the quality of groundwater in the area since the Inhabitants of the area depend on this for their water supply needs. Indiscriminate dumping of refuse in Aba has become not only an eye sore, but a serious environmental problem. Waste dumps are common along Port Harcourt-Enugu Express way particularly in Ariaria and Osisioma, these wastes which are mostly made up of domestic garbage, industrial wastes, agricultural wastes and municipal wastes, pose a serious threat to the environment including the ground water system. If the groundwater system is polluted it will pose a great danger to the inhabitance who depend mostly on the water for their domestic water supply. It is therefore necessary to carry out this work to assess the potability of the water in the area. Heavy metals concentration of the water was studied because they are considered the most dangerous category of pollutants.

THE STUDY AREA

Aba is one of the largest trading and industrial cities in South Eastern Nigeria. The high number of large markets such as Ariaria, New market, Cemetery Market and industries, fabricating companies such as chemical industry, glass industry, lubricating industry resulted to an increased population density and high accumulation of wastes. Aba lies within latitudes N5^{o}06'23'' and E 7^{o}22'00'' and situated in the South eastern part of Nigeria. Aba is Accessible through different large link Road, from the South, through Port Harcourt Enugu express way, from the East through Ikot Ekpene Road, from the West through Aba-Owerri Road and from the north through Enugu-Port Harcourt way. Other networks of roads connecting these parts of the area and its environs include: Azikiwe Road, Uruata Road, Aba Azumini, Ovom-Opobo Road, Faulks road, Omuma Road, and Ngwa Road.

The study area has two seasons (dry and wet season). The dry season starts from November until March, while the wet season begins from early April and end about late October. Rainfall is as a result of a moist equatorial marine air mass from the Gulf of Guinea, associated with a prevailing wind in the south to west direction. Average rainfall is about 2500mm (Uma *et al.*, 1990). There are periods with intense rainfall in the wet season and this is evident in the wide spread events of floods in parts of the country. There is also a short period within the month of August also known as august break characterized by little or no rainfall. The dry season period is characterized by the most common influences of dry and dusty North-East winds as well as the "Harmattan" conditioning, vegetation to reduce moisture. There is a relative high temperature and humidity in this area, resulting to an average annual temperature of about 27^{o}C with relative humidity value about 80^{o}C generally, the climatic conditions promote rain forest vegetation like trees, herbs and grasses with vibrant green colors in the area (Anderson, 1966).

The Study area (figure 1) and its environs is characterized by the sedimentary rock of the Niger Delta underlain by Akata Formation which is Paleocene in age and also the oldest, the Agbada Formation belonging to the Eocene age and the youngest Benin Formation which is Miocene – Recent in age. The Benin Formation which is the aquiferous formation consists of coastal plain sand which is unconsolidated and dominantly sandy. The sand is friable in nature with clays occurring as streak of discontinuous lenses. The sand textures appears to range from fine to coarse grained, with poorly sorted beds of pebbles found as lenses (Onyeagocha, 1980). The forming of the so called Proto-Niger Delta may have occurred at the second depositional cycle (Campanian-Maastrichtian), while the forming of the Modern Niger delta may have been during the third and last phases of deposition of the southern Nigerian basin which began during the Paleocene. Three tertiary lithostratigraphic units can be distinctively identified in the Niger delta basin. The major water bearing formation of the area under study is the Benin formation (Nwankwoala and Amadi, 2013). It is about 2100 meters thick of the basin Centre and consists of coarse to medium grained sand stones, thick shale and gravel (Short and Stauble, 1967). The upper parts of the Benin formation consists of quaternary deposits which are about 40 – 158 meters thick and comprise of sand and silty/clay with later becoming increasingly more obvious seawards (Merki 1970). The formation consists of mostly fresh water continental friable sands and gravel that have excellent huge areas of underground water with occasional intercalation of clay stone/shale (Olobaniyi and Owoyemi 2006). All the water wells within the study area are drilled into the Benin Formation which consists of fluvial and lacustrine deposits.

The Study Area is underlain by a thick unconfined aquifer of regional extent. Ventricular clays and shales overlie high yielding lower aquifers. Most of the boreholes tap from the unconfined aquifers Atmosphere precipitation is the major source of recharge for aquifers in the area. The lithology of the Benin Formation include sand silts, gravel clayey intercalation the sands are fine. Coarse grained gravelly, poorly sorted and sub angular to well rounded. The rocks of the Benin Formation are made up of about 95 – 99% quartz grains; Na + K – Mica 1 – 2.5%, feldspars 0.51% and dark minerals 2.3% (Udom *et al.*, 2002). The main source of recharge is through direct precipitation, the water infiltrates through the highly permeable sands of the Benin Formation to recharge the aquifer. The average depths of borehole in Aba area are 35 and 65 meters. Deep boreholes in the area tap water from depth up to about 200m or more. The static water level in the area ranges from 0.4m during the rainy season and 2-6m during the dry season.

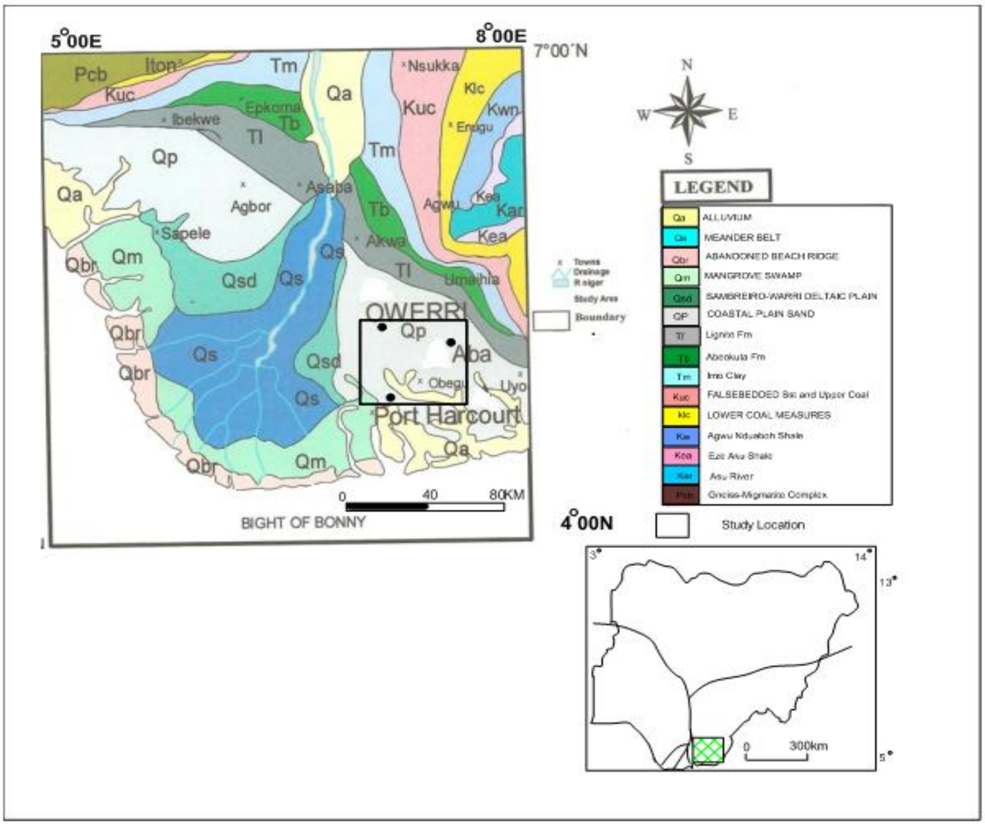

Fig1. *Geologic Map Showing Study Area*

METHODS OF STUDY

Field Sampling and Analysis

Samples were gotten from the various boreholes after pumping for 5 minutes to make sure of a true representation of the aquifer. Samples for metal analysis were obtained separately and acidified at site. One sample was obtained a little distance away from dumpsites, which serve as control sample. Samples were taken as close to the wellhead as possible to make sure water sampled is not that which has gone through the treatment unit already. All samples were obtained using a tightly covered good quality polyethylene container and immediately moved to the laboratory at a low temperature condition in ice-packed coolers for the relevant laboratory analysis.

Unstable parameters such as pH, temperature and electrical conductivity were determined in the field using pH meter, mercury thermometer and conductively meter respectively. Table 1 shows the sampling locations and geographic coordinates while Figure 2 shows the sampling locations. The locations of the boreholes were obtained with a handheld global positioning system (GPs).

Statistical analysis results such as mean, the standard deviation (SD) as well as coefficient of variance was computed for each of the measured parameters for the 15 locations and values compared with standard parameters such as World Health Organization WHO and United States Environmental Protection Agency (USEPA) thus allowing for easy comparison of data derived from each water well.

Table1: Sampling locations and Geographic Coordinates

S/N	SAMPLE LOCATION	GEOGRAPHIC CO-ORDINATES
1	Faulks Rd Market	N 05^{o} 06’ 449” E 007^{o} 20’ 13. 9
2	Faulks Rd Chemical Market	N 05^{o} 06’ 43.1” E 007’ 20’ 22.2
3	Fly Over by Mechanic Market	N 05^{O} 03’ 449 E 007^{o} 19’ 44.4
4	MEFCO Filling Station Fly Over Mechanic	N 05^{o} 03’ 49.6’ E 007^{o} 19’ 38.2”
5	Ehi Rd by Old Court	N 05^{o} 06’ 17.9 E 007^{o} 22’ 04.5”
6	Ogbor Hill (River Layout)	N 05^{o} 06’ 58.2” E 007^{o} 22’ 45.0”
7	War Front by Ikot Ekpene Rd	N 05^{o} 06’ 58.2” E 007^{o} 22’ 45.0”
8	Bakassi Junction by Borrow Pit	N 05’ 06 59.5 E 007^{o} 19’ 37.5
9	Ahia Aba Village by Borrow Pit	N 05^{o} 06’ 49.5 E 007’ 19’ 36.1”
10	Faulk Rd by Ukwu Mango	N 05^{o} 06’25.1” N 007^{o} 20’ 01.2”
11	Four-Square Avenue Ngwa Rd	N 05^{o} 05’ 37.8” E 007^{o} 23’ 13.6
12	Emelogu by Ehere Off Opobo	N 05^{o} 06’ 09” E 007^{o} 23’ 44.3
13	Cemetery Market Junction by Rail	N 05^{o} 06’ 08.9” E 007^{o} 21’ 18.7”
14	Panamas Street Off Emelogu (Ehere)	N 05^{o} 06’ 10.0” E 007^{o} 23’ 29.5”
15	Umuocham Rd Aba Owerri Rd	N 05^{o} 08’ 15.1” E 007^{o} 21’ 02”

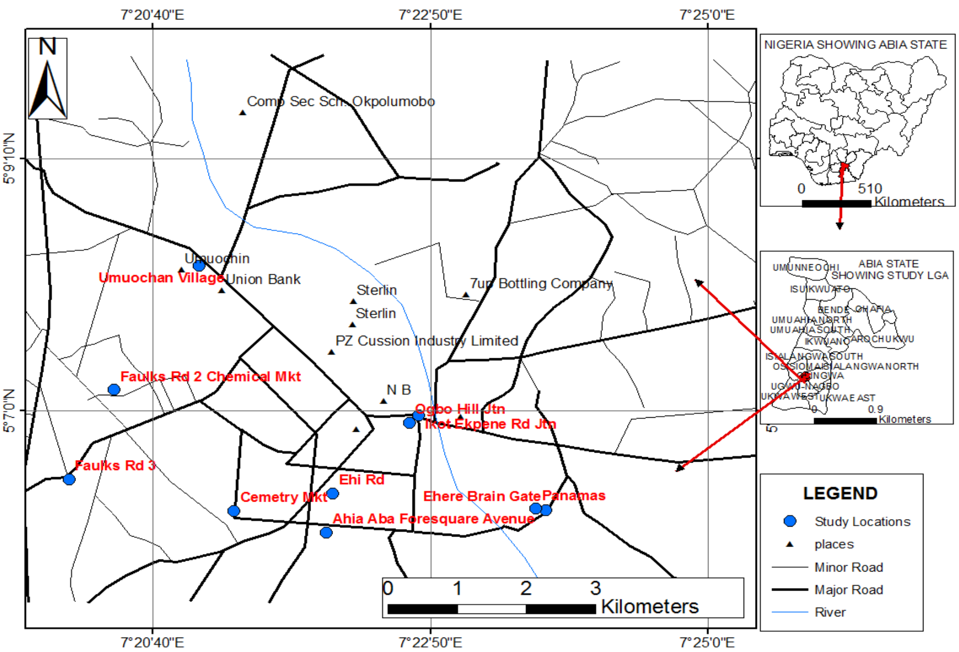

Fig2. *Map of Aba Showing Sample Locations*

RESULTS AND DISCUSSION

Table 2 shows the analytical results of metals including descriptive statistics of the mean, median, minimum and maximum values of the parameters. The concentration of Chromium (Cr) in the samples varies from 0.01mg/l to 0.10mg/l. Results show that four locations which represent about 15% of the total sample have values greater than the WHO (2006) limit of 0.05mg/l. In the blood, sugar levels are regulated by insulin and chromium is an essential mineral that help the insulin play such role. Chromium has been found to decrease haemoglobin when in high concentration and also increase white blood cell count, thus can negatively affect liver tissues.

The concentration of lead (Pb) was found to be below detection level of the equipment used. Lead was not found at concentrations above the WHO (2006) standard of 0.01mg/l in the entire fifteen locations which represent the total sampled location. Lead found as a result of huge mechanic villages where carbides are used for panel biting works. If found at concentration of lead calls for immediate action since lead is a more deadly element which is detrimental to the skeleton of the human body. Thus, could replace calcium in bones. Lead exposure has also been related to retard of neurobehavioral development (Lidsky, and Schneider, 2003; Coccini, and Manzo, 2013). Lead which is present in little quality on the earth crust is distributed all around our surroundings. Most of it is as a result of direct activities carried out by humans, like manufacturing, mining, and the incineration of fossil fuels such as coal, natural gas and oil.

Table2. *Analysis Results in Study Area*

S/N	SAMPLE LOCATION	GEOGRAPHIC CO-ORDINATES	Cr	Pb	Ni	Cu	Zn	Cd	Co	Fe	Mn	pH
1	Faulks Rd Market	N 05° 06’ 449” E 007° 20’ 13. 9	0.09	ND	ND	0.40	4.50	0.08	0.03	2.40	0.30	4.80
2	Faulks Rd Chemical Market	N 05° 06’ 43.1” E 007’ 20’ 22.2	0.05	ND	1.25	5.98	6.00	0.01	0.01	0.05	1.05	6.00
3	Fly Over by Mechanic Market	N 05° 03’ 449 E 007° 19’ 44.4	0.02	ND	0.03	2.10	2.50	0.08	0.10	0.05	1.05	6.00
4	MEFCO Filling Station Fly Over Mechanic	N 05° 03’ 49.6’ E 007° 19’ 38.2”	0.10	ND	0.10	ND	2.60	0.01	1.00	0.35	0.60	6.90
5	Ehi Rd by Old Court	N 05° 06’ 17.9 E 007° 22’ 04.5”	0.08	ND	1.00	0.90	2.10	0.02	ND	0.01	1.00	5.00
6	Ogbor Hill (River layout)	N 05° 06’ 58.2” E 007° 22’ 45.0”	0.03	ND	1.20	1.40	1.90	0.06	1.00	2.80	1.00	5.90
7	War Front by Ikot Ekpene Rd	N 05° 06’ 58.2” E 007° 22’ 45.0”	0.05	ND	0.10	2.60	0.90	ND	0.70	2.40	ND	7.10
8	Bakassi Junction by Borrow Pit	N 05’ 06 59.5 E 007° 19’ 37.5	0.02	ND	0.50	1.06	2.40	0.10	0.20	2.30	0.30	6.90
9	Ahia Aba village by Borrow Pit	N 05° 06’ 49.5 E 007’ 19’ 36.1”	0.01	ND	0.20	2.20	5.10	0.01	0.21	2.10	ND	6.10
10	Faulk Rd by Ukwu Mango	N 05° 06’25.1” N 007° 20’ 01.2”	0.02	ND	0.50	2.50	4.10	0.03	ND	0.60	1.00	5.80
11	Four-Square Avenue Ngwa Rd	N 05° 05’ 37.8” E 007° 23’ 13.6	0.07	ND	0.01	2.00	2.00	0.04	0.25	0.30	0.50	4.90
12	Emelogu by Ehere off Opobo	N 05° 06’ 09” E 007° 23’ 44.3	0.10	ND	0.01	3.00	5.50	0.04	0.01	ND	0.10	7.01
13	Cemetery Market Junction by Rail	N 05° 06’ 08.9” E 007° 21’ 18.7”	0.10	ND	0.02	3.10	ND	0.06	0.10	1.10	0.06	7.40
14	Panamas Street off Emelogu (Ehere)	N 05° 06’ 10.0” E 007° 23’ 29.5”	0.60	ND	0.10	4.50	3.35	0.03	1.01	2.07	1.01	8.00
15	Umuocham Rd Aba Owerri Rd	N 05° 08’ 15.1” E 007° 21’ 02”	0.02	ND	ND	2.50	2.50	0.05	0.02	0.06	0.06	7.00
	W.H.O (2006)		0.05	0.01	0.02	2.0	3.0	0.03	0.01	0.3	0.5	
	MINIMUM		0.01	0	0.01	0.4	0.9	0.01	0.01	0.01	0.1	
	MAXIMUM		0.10	0	1.25	5.98	6.0	0.10	1.0	2.8	1.0	
	MEAN		0.092	0	0.38	2.44	3.03	0.04	0.35	1.13	0.61	

The concentration of nickel (Ni) is high in six of the location above the WHO (2006) limit of 0.02mg nickel occurs in large quantities on the earth surface; frequently found in all soils, it is also found to be emitted from volcanic vents. With oxidation number of 0 and 2, Nickel can be useful as an alloy in the making of steel, electroplating, Ni/Cd batteries, arc-welding, rod, pigment for paints and ceramics, surgical and dental prosthesis(artificial jaws, arm, leg, etc.), molds for ceramics and glass vessels, computer parts and catalysts for chemical reactions (Bradi, 2005). At minute quantities, Ni is considered as an extremely important trace metal (Silvaperumal *et al.*, 2007). In the body system, some enzymes are activated with the presence of Ni but its poisonous quality at higher levels is more well-known. High quantities of Ni in the blood level can cause respiratory problems and it is carcinogenic. Possible source of nickel comes from chemical industries where it comes out as by-products.

The concentration of copper (Cu) ranges from BDL to 5.98mg/l and this is well above the WHO (2006) limit of 2.0mg/l. Copper finds its way into drinkable water through copper pipes, as well as from substances or chemicals added to control the growth of algae. Vessels made out of copper alloy such as tea kettles and other cooper cookware could be potential sources of copper toxicity if used frequently over a prolonged period of time. Copper is considered as an extremely important constituent of metallo-enzymes of living organisms and is needed in haemoglobin synthesis and in catalysis of metabolic reaction (Dural *et al*., 2007). In normal case scenario, copper is bound in the blood to ceruloplasmn (95 percent) and albumin. Body organs where copper could accumulate in high quantity may include the liver, brain, heart and kidneys. However, excess copper can accumulate in almost every organ of the body. It causes astringent taste in water. Deficiency of Cu is responsible for anaemia in children, or may result in liver damage (Nwankwoala *et. al*., 2011). The important ores of Cu are chalcocite ($CuFeS_2$), Cuprite (Cu_2O) and malachite [$CuCO_3$. Cu $(OH)_2$]. Copper is widely used for wire production and in the electrical industry. Its main alloys are brass (with zinc) and bronze (with tin). Other applications are kitchenware, water delivery systems, and copper fertilizers (Bradi, 2005). It plays a crucial role in many biological enzyme systems that catalyze oxidation/reduction reactions and if found at relatively high concentrations in the environment, toxicity to humans may occur.

The concentration of Zinc (Zn) ranges from BDL to 6.0 mg/l which is above the WHO (2006) permissible limit of 3 mg/l. Zinc is an essential element for the life of animals and human beings. It is also essential for male reproductive activities. Zinc is widely distributed in the body – in bones, teeth, hair, skin, liver, muscle, white blood cells and testes. It is a component of more than 100 enzymes, including those involved in the formation of RNA (Ribonucleic Acid) and DNA (Deoxyribonucleic Acid). Excess amount of zinc can cause system dysfunctions, impairment of growth and reproduction. The clinical signs of zinc toxicities have been reported as vomiting, diarrhea, bloody urine, icterus (yellow mucus membrane), liver failure, kidney failure and anemia (Duruibe *et al.*, 2007). In the study area possible sources of zinc include steel industries, mechanics and rod market where zinc comes in contact with soil.

The most common minerals of zinc are zinc sulphide (ZnS), zincite (ZnO), and smithsonite ($ZnCO_3$). Zinc is used in many industries in the manufacture of dry cell batteries, production of alloys such as brass or bronze, producing a galvanized coating (Momtaz, 2002). Cadmium (Cd) concentration ranges from below detectable limit to 0.10 mg/l, which is above the WHO (2006) limit of 0.003 mg/l for drinking water. Excess amount of cadmium may cause prostate enlargement, low birth weight, still birth and spontaneous abortion. Excessive cadmium may also weaken the body immune system and causes lung cancer. Prolonged effect to cadmium may lead to damage of the heart arteries. In production industry it is an important constituent in the manufacture of batteries (Ni-Cd batteries of mobile phones), paint making, electroplating and for making plastics. It can often times be used in the production of many other things mainly as alloys. Cd finds its way into the air from mining, industry, and burning of fossil fuel such as coal and municipal wastes. Its particles can travel a long distance in air before falling to the ground or water (Momtaz, 2002). Cadmium is scattered throughout although at low levels in our environment and is not an important trace metal for the wellbeing of humans, animals and plant life. In the location, possible source of cadmium is paint and plastic industries where cadmium could be as by product.

The concentration of Cobalt (Co) ranges from 0.01 mg/l to 1.0 mg/l. Cobalt is essential to the health and wellbeing of humans due to it constitutes a part of Vitamin B12, which is very important for the human health. Cobalt, often used in the treatment of anaemia for women who are pregnant, due to its ability to stimulate the production of red blood cells. Nonetheless, at high concentration, cobalt may cause damage to the human system, health symptoms that may result from intake of high concentration of cobalt are: vomiting and nausea, vision problem, heart problems and damage of the thyroid gland (Lenntech, 2007)

The concentration of iron (Fe) ranges from BDL to 2.8 mg/l. Result revealed that seven locations which represent 50% of the total sample gave high values higher than the WHO limit of 0.3mg/l. The concentration of iron in some locations posses' the potential of staining cloths for laundry, pipes for reticulation and scaling in pipe and may give an undesirable taste. The body poorly absorbs iron, an estimated 10 - 15% only of the ingested iron is absorbed, except a case of iron deficiency which may increase the percentage absorbed.

Manganese (Mn) concentration ranges BDL to 1.0mg/l, the concentration of Mn falls above the WHO (2006) recommended standard of 0.5mg/l. manganese is a very important constituent trace metal in tissues of all living organisms. In our surrounding environment, Mn is rarely seen to occur in free-state, but mostly in combined form (Momtaz, 2002). Mn is frequently found in metamorphic, sedimentary and igneous rocks. Its average content in the lithosphere is about 1000 ppm (Momtaz, 2002). As its ionic size is similar to Ca, the two elements can replace each other in silicate minerals. Mn substitutes for Fe in magnetite. Although there are more than 100 manganese minerals such as sulphides, oxides, carbonates, silicates, phosphates, arsenates, tungstate, and borates. Manganese is an essential element and present in all living organism. Excess amount of Mn affects the central nervous system, causes liver cirrhosis and produces a poisoning called Manganese Parkinson disease (Momtaz, 2002). At high concentration, manganese also imparts a bitter taste on water, stains clothes and metal parts and precipitates in food when used for cooking and it also promotes the growth of algae in reservoirs (Todd, 1980). Fig.3 shows mean concentration against parameters, Fig. 4 is the component bar chart showing mean against the parameters. Table 3 shows the statistical analysis of studied parameters.

Table3. *Statistical Analysis of studied parameters*

PARAMETERS	MINIMUM	MAXIMUM	MEAN	Standard Deviation	Coefficient of Variance	NIS(2007) mg/l	USEPA(2010)mg/l	WHO 2006
Cr	**0.01**	**0.10**	**0.092**	**0.01**	**3.44**	**0.05**	**0.10**	**0.05**
Pb	**0**	**0**	**0**	**0**	**0**	**0.01**	**0.15**	**0.01**
Ni	**0.01**	**1.25**	**0.38**	**0.13**	**4.00**	**0.02**	**0**	**0.02**
Cu	**0.40**	**5.98**	**2.44**	**1.18**	**3.82**	**0.01**	**1.00**	**2.00**
Zn	**0.90**	**6.00**	**3.03**	**1.18**	**3.82**	**0.10**	**2.00**	**3.00**
Cd	**0.01**	**0.10**	**0.04**	**0.0004**	**3.63**	**0.003**	**0.005**	**0.03**
Co	**0.01**	**1.00**	**0.35**	**0.08**	**4.10**	**0.01**	**0**	**0.10**
Fe	**0.01**	**2.80**	**1.13**	**0.59**	**3.80**	**0.30**		**0.30**
Mn	**0.10**	**1.00**	**0.61**	**0.62**	**4.16**	**0.20**	**0.05**	**0.50**

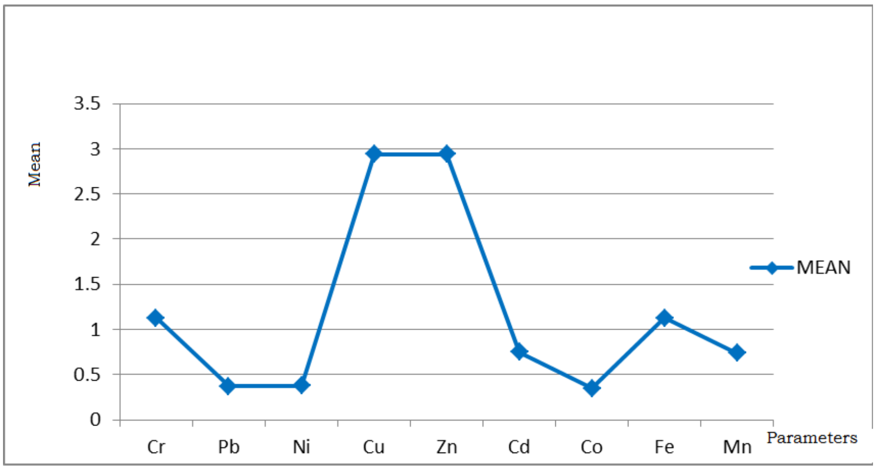

Fig3. *Plot Showing Mean Concentration against Parameters*

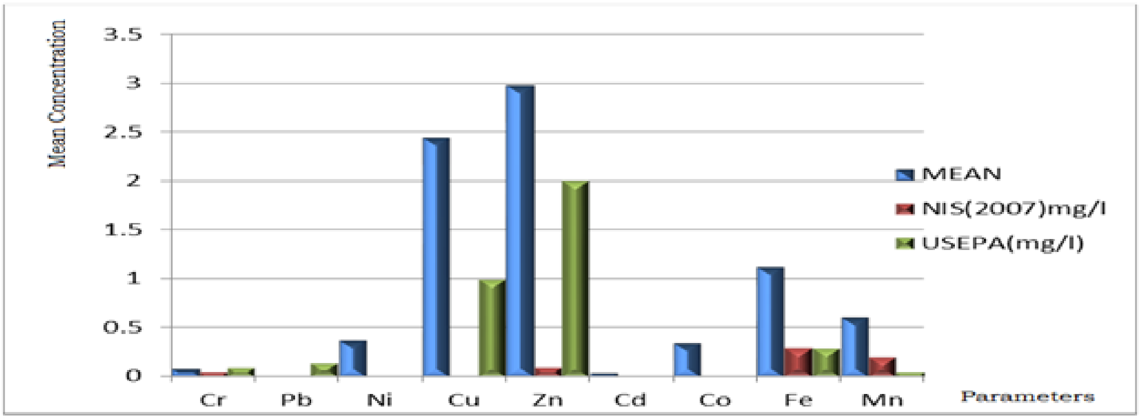

Fig4. *Component Bar Chart Showing A Plot Of The Mean Against The Parameters*

Table5. *Metal contamination factor and geo-accumulation index of metal in water from location*

Samples	C_m	B_m	C_f	IGeol	Overall summary of contamination level
C_r	1.426	122	0.009	-5.09	Uncontaminated
P_b	0	0	0	0	Not Detected
N_i	0.38	80.0	0.004	-5.75	Uncontaminated
C_u	2.94	70.0	0.04	-3.75	Uncontaminated
Z_n	2.94	132	0.02	-4.57	Uncontaminated
C_u	0.75	0.15	5.00	1.20	Slightly contamination
C_o	0.35	23.0	0.01	-4.59	Uncontaminated
F_e	1.13	400	2.80	-6.27	Uncontaminated
M_n	0.74	1000	0.0007	-7.61	Uncontaminated

CONCLUSION

Results showed that due to major factors, heavy metals showed considerably high concentration in all locations with chromium showing very high values in locations 1,2,3 and 4 as well as nickel, copper, and zinc which had the highest concentration in the area per(mg/l) of 1.25mg/l, 5.98mg/l and 6.0mg/l respectively. Component bar chart shows that Cu and Zn had the highest values with National Industrial Standards and US EPA values lower than the mean values. Metal contamination factor and Geo-accumulation index from location shows slight contamination of copper.

The results of this study show that heavy metal concentration in the ground water source in the study area are slightly high in some locations with chromium concentration from 0.01 (mg/l) to 0.10 (mg/l); lead was below detectable limit; nickel from BDL to 1.25; Zn from BDL to 6.0 (mg/l) Cd from BDL to 0.10; Co from BDL to 1.0; Fe from BDL to 2.8 and Mn from BDL to 1.0 (mg/l). The concentrations of all heavy metal were slightly higher than the WHO (2004) maximum permissible concentration in most locations and lower in other locations.

RECOMMENDATIONS

- It is important that systematic study of the heavy metal concentration in the groundwater sources of the area be carried out regularly, as the inhabitants of the area depend on groundwater for drinking and other domestic purposes.
- Mass awareness of the effect of heavy metals on groundwater quality on human health should be carried out as treatment of water recommended.

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