IMPACT OF URBAN ACTIVITIES ON GROUNDWATER QUALITIES IN ABEOKUTA SOUTHWESTERN, NIGERIA

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ABSTRACT

Pollution of groundwater has become a major environmental problem. Anthropogenic impacts on groundwater within different zones of Abeokuta, Southern Nigeria were evaluated. The study area was divided into four zones; Crowded, Market, Residential and Industrial areas. Groundwater samples were randomly collected from hand dug wells and boreholes and analysed for pH, electrical conduitivity (EC) and total dissolved solids (TDS). The samples were also analysed for selected trace metals using ICP-NS and major anions and cations. Results of the Physicochemical parameters were in the range of 67 – 649 ppm for TDS; 6.6 – 8.9 for pH, and 103.07-984.61 μScm^{-1} for EC respectively. Elemental analysis revealed mean concentrations in decreasing order of Na > Ca> K > Mg > Fe> Mn >Zn > Pb> Cd > As> Cu for cations and Cl^- > SO_4^{2-} > NO_3^- for anions. Cations occurred within WHO permissible limits for potable water except K, Pb, and Ca, while among the cations Cl^- and NO_3^- were above the permissible limits. The high values of Cl^- and NO_3^- were most probably due to the influence of tie and dye production in the study area. The contamination factor (C.f) and geo- accumulation Index (Igeo) revealed no contamination due to the cations except for Cd and Pb from the effect of fuel combustion and quarry activities behind the residential area. The study concluded that the groundwater in the industrial and crowded zones of the study area was more contaminated than in the residential zone.

Keywords: Anthropogenic, Leachates, Seepages, Accidental Discharge, Zones

INTRODUCTION

Groundwater is of great importance in many countries of the world especially where most drinking water comes from aquifers (Forster *et al.*, 1998). Aquifers have provided inexpensive drinking water, a fact that can be associated with improvement in public health. Nevertheless, at present the most important challenge is attaining sustainable management of groundwater in places where the quality of water is threatened. Groundwater quality degradation is related primarily to what the land is being used for and this could be industry (food, clothe or drug), agricultural plantation, mechanical workshop, and many other anthropogenic activities resulting in the emission of fuel combustion into the atmosphere. Such emission is often precipitated as acid rain directly or as water run-offs, infiltrate into the underlying aquifer thereby polluting the aquifer. These aquifers are mostly tapped to serve as alternatives to the existing but unreliable public water supply in different countries that rely on them, examples of such is Nigeria (Gbadebo *et al.*, 2010). Groundwater increases through percolation of water from rain, streams, lakes and springs into the soil and weathered bedrocks and gets stored underground in the pores spaces of rocks and soil particles. Groundwater contamination can either be natural (mineral deposits in rocks) or manmade (Anthropogenic). The contamination of groundwater by anthropogenic sources has long been recognized (Hem, 1989; Butow *et al.*, 1989; Alloway and Ayres, 1997; and Clark, 2006).

Groundwater contamination associated with man occurs from different sources such as leakages from underground storage tanks, chemicals and waste dump sites, effluents, sewage pits, land spreading of sludge, brine disposal from the petroleum industry, mine waste, animals feed, radioactive waste, highway- run-offs and acidic rain which has being found to be associated with various deadly diseases (Naidu *et al.* 2011; Lenntech 2012).

Several works have been carried out on the impact of both natural (soil leaching, rock weathering) and anthropogenic (leaching of chemicals used to make battery and clothes, indiscriminate dumping of refuse, inadequate toilet facilities) influx on the groundwater quality in the study area (Punmia and Jain, 1998; Sridhar, 2000; Ikem *et al.*, 2002; Akujieze *et al.*, 2003; Gbadebo *et al.* 2010). However, little or no work has been done on the segregation of the areas according to the activities found in the study area.

Abeokuta metropolis, the study area, was divided into four zones: Crowded zone of Labaiwa and Olose area; Industrial zone of Itoku; Market zone of Kuto area and Residential zone of Elega Housing area, which all fall within the Basement Complex of Southwestern Nigeria. The study area lies within the Southeastern part of Abeokuta in Ogun State of Nigeria, between latitudes $07^{0} 08^{'}$N and $07^{0} 13^{'}$N of the equator and longitudes $003^{0} 20^{'}$ E and $003^{0} 23^{'}$ E of the Greenwich meridian (Fig. 1). The study area is located in the moderately hot humid tropical climate zone of South Western Nigeria with two distinct seasons namely the dry season which last from October/November till March / April and the wet season which lasts for the rest of the year from March/April till October/November. The mean temperature ranges from 24 to 30°C, with a mean temperature of about 27°C. The study area contains two major rock types: Biotite Granite which covers approximately 10% of the study area, (found mostly in the North–Eastern part of the study area) and Porphyroblastic Gneiss which covers about 90% of the study area (Fig 1).

The major factors that seem to have contributed to contamination or observed problems in the study area are the use of chemicals in the making of tie and dye at the industrial zone and generating sets that produce combustion effect through the release of carbon monoxide (CO) into the atmosphere within the Crowded and Residential zones respectively.

This study aimed at assessing the impact of anthropogenic activities on groundwater in crowded, market, residential and industrial zones; and to determine the sources of groundwater pollution in the study area.

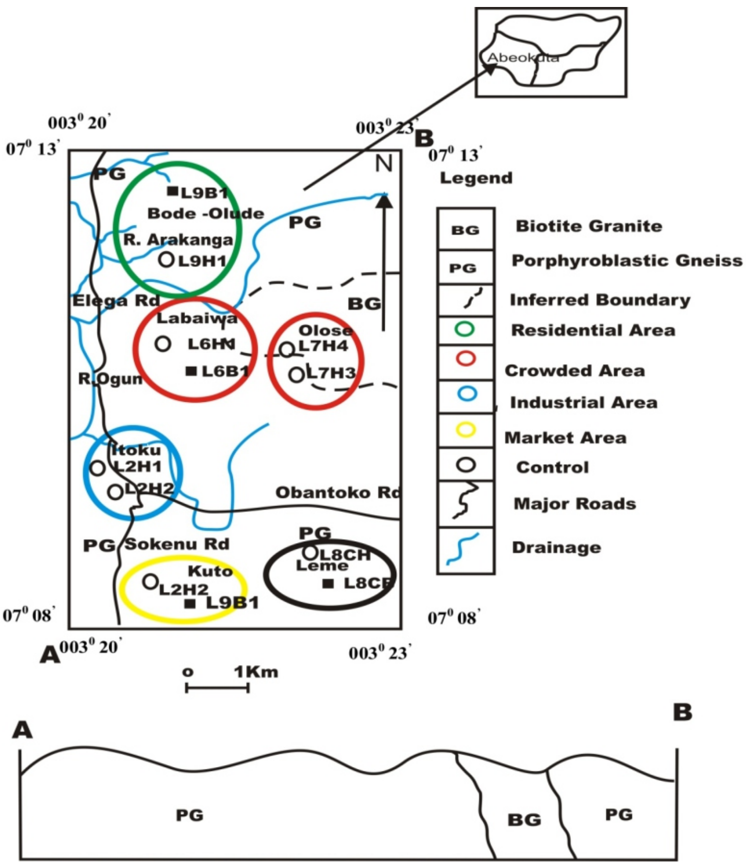

Figure 1: Map Showing Location of Boreholes, Hand Dug Wells, Geology, Drainage and Major Roads in the Study Area (Courtesy Geological Research, Ibadan).

MATERIALS AND METHODS

The study area was divided into four zones namely: Crowded, Industrial, market and residential zones (Table 1). Groundwater samples were collected randomly from hand dug wells and boreholes and analysed for pH, total dissolved solids (T.D.S) and electrical conductivity (EC) in-situ. Selected trace metals were analyzed for at Acme Analytical Laboratory, Vancouver, Canada, North America, using the inductively coupled plasma- mass spectrometry, while major anions (Cl^{-1} and No_3) were determined at the University of Ibadan (U.I) Ibadan, Laboratories.

The physical and hydro-chemical data collected were interpreted and compared with the WHO 2006; SON 2006; EPA 2008, guideline for drinking water. Contamination factor (C.f) (Hakanson, 1980), Degree of contamination (C.D) and Geo – accumulation Index (I-geo) were also used to estimate the rate of pollution in the study area while the water type and water flow were derived by the use of Piper Trilinear diagram (Piper, 1944) and Piezometric map (Plummer *et al.* 2011)

Table 1: The Major Zones and Activities within the Study Area

Zone Area	Section of Study Area	Activities
Industrial	Itoku	Dying of Adire (Tie and dye), use of chemicals (dye)
Market	Kuto	Major Market where the selling of food items such as fruits, meat, rice, beans, garri, ; use of generating sets within the area; Domestic use of firewood.
Crowded	Labaiwa, Olose	Domestic use of firewood, washing of clothes and use of generating sets.
Residential	Elega Housing Estate (Bode - Olude)	Use of generating sets; Quarrying of Porphyroblastic Gniess directly behind the estate.

Determination of Factors and Indices

Contamination Factor (C.f),
(1) Cf = mean value of metal/W.H.O standard

Geo Accumulation (Igeo)
I geo = Log_2 (Cn/ 1.5 x Bn) (Cn = measured concentration , Bn = World Health Organization standard)

Degree of Contamination (Cd)
C.d = sum total of contamination factor (C.f)

RESULTS AND DISCUSSION

Physicochemical Parameters
TDS, pH and Electrical Conductivity (EC) (Table 2) occurred within the WHO, 2006; SON, 2006; and EPA, 2008, permissible standards for potable water with values ranging from 67 to 649 ppm and a mean value of 268.17 ppm for TDS; 6.6 – 8.9 with a mean value of 8.16 for pH, and 103.07-984.61 μScm^{-1} and mean value of 405.79 μScm^{-1} for EC respectively.

Table 2: Physical Parameters of the water samples

PHYSICAL PARAMETER	RANGE	MEAN	EPA (2008)	SON (2006)	WHO (2006)
TDS(ppm)	67-649	269.17	500	500	500
EC(μScm^{-1})	103.07-984.61	405.79	1400	1000	1400
pH	6.6-8.9	8.16	6.5-8.5	6.5-8.5	6.5-8.5
Temp (^{o}C)	26-29	27.12	-	-	-
SAL (‰)	0.01-0.06	0.03	-	-	-

Hydrochemical Results

The concentrations of all the metals across the zones (Table 3) were found to occur within the permissible limits of WHO 2006; SON 2006; EPA 2008 for drinking water with the exceptions of Ca in the market zone, Mn and Pb in the crowded and residential zone and Fe in the residential zone. The elevated level of Ca may be due to the Ca rich food items (such as bones of animals) thrown about indiscriminately and or from leachates of weathered Ca-rich feldspar found within the market zone. The high Mn and Pb values observed in the crowded and residential zones may be due to the effect of fuel combustion from domestic use of firewood, and emission from generating sets into the atmosphere which later gets precipitated into the ground water system. The elevated values of Fe above the permissible limits of WHO 2006; SON 2006; EPA 2008, in the residential zone maybe due to the reaction of rusted pipes within the watering system which later gets leached into the ground water system. The concentration of chloride (Cl^-) found above the permissible limits of WHO 2006; SON 2006; EPA 2008, in the industrial and market zone may be due mainly to the release of chloride ion which occurred as major constituent in the chemical used in making tie and dye material. On the other hand, the elevated values of NO_3^- observed in the crowded zone may be due mainly to the inappropriate dumping and burning of refuse in the zone leading to emission of fuel combustion. High nitrate levels in underground aquifers can cause methemoglobinemia or blue baby syndrome, in infants and pregnant women (Self and Waskom 2013).

The crowded, residential and market zones were contaminated with Mn, Pb and Ca with contamination factor above one (cf >1), while the other metals occurred below the contaminated factor less than 1, (cf < 1) (Table 4). Geo-accumulation index as indicated in Table 5 showed contamination only in the industrial zone with Cd with all the other zones showing practically no contamination (Figs. 2 & 3). Salinity and sodium hazard (Fig. 4) showed a generally low-medium sodium and salinity hazard except for the industrial and market zones which had a high sodium and salinity hazard.

The study area falls within g – class of the Piper diagram, and the groundwater there can be classified as alkaline water-predominantly SO_4^{2-} - Cl^- water (Sulphates or Chloride). This was governed by alkali rich Biotite rocks (Biotite Granite and Porphyroblastic Gneiss), found in the study area. As alkali rich Biotite rocks gets weathered the weathered components react with water and are then leached into the groundwater (Tijani *et al.*, 2006) (Fig 5).

Piezometric Map (Plummer *et al.*, 2011) of the investigated samples can reveal the general flow direction of water in the study area which was observed to be along North East-South west direction (Fig. 6). Contaminated water flowing westward and southward in the crowded area may get leached and thus, affecting the aquifers of industrial area, and this could enhance the rate of contamination of the area.

Table 3: Comparison of the Mean values of Investigated Groundwater Chemical Parameters with Sonme Regulatory Standards

Parameters (ppm)	Mean	Range	WHO (2006)	EPA (2008)	SON (2006)
K	19.05	1.74-88.91	13.48	-	-
Ca	49.11	17.07-86.63	75	-	-
Mg	8.78	3.14-18.60	200	-	0.2
Fe	0.99	0.01-10.01	-	0.03	-
Cu	0.00	0.00-0.00	2	1.3	1
Pb	0.00	0.00-0.02	0.01	-	0.01
Cl^-	168.33	60.00-350	200	-	-
NO_3^-	28.08	16.72-46.01	25	-	-
Mn	0.19	0.00-1.27	0.4	0.05	0.2
Na	47.48	8.81-168.6	200	-	200
Zn	0.03	0.01-0.04	3	5	3

Table 4: Contamination Factors of Groundwater Sources for Trace and Major Elements.

Zones	Cu (ppm)	Mn (ppm)	Pb (ppm)	Zn(ppm)	Na(ppm)	Ca (ppm)	Mg (ppm)
Industrial	0.00	0.08	0.23	0.01	0.65	0.91	0.14
Market	0.00	0.00	0.10	0.01	0.40	0.85	0.11
Crowded	0.00	0.55	0.26	0.01	0.25	0.46	0.07
Residential	0.00	1.83	0.15	0.02	0.16	0.57	0.06
Control	0.00	0.01	0.59	0.02	0.22	0.57	0.09
W.H.O (2006)	2.00	0.40	0.01	3.00	200.00	75.00	100.00
C.D	0.00	6.02	2.94	0.17	3.88	7.64	1.06

Table 5: Geo- accumulation Index of Groundwater in the Study Area

Zones	As	Cd	Cu	Mn	Pb	Zn
Industrial	-3	0.65	-17.5	-3	0.49	-7
market	-2.7	-0.5	-17	-14.5	-7	-7.5
Crowded	-7.5	0.55	-18	-2.4	-2.5	-7.25
Residential	-4	0	-15.5	-2	-3.5	-6.5
control	-6.5	0.05	-18	-6	-3	-7.5

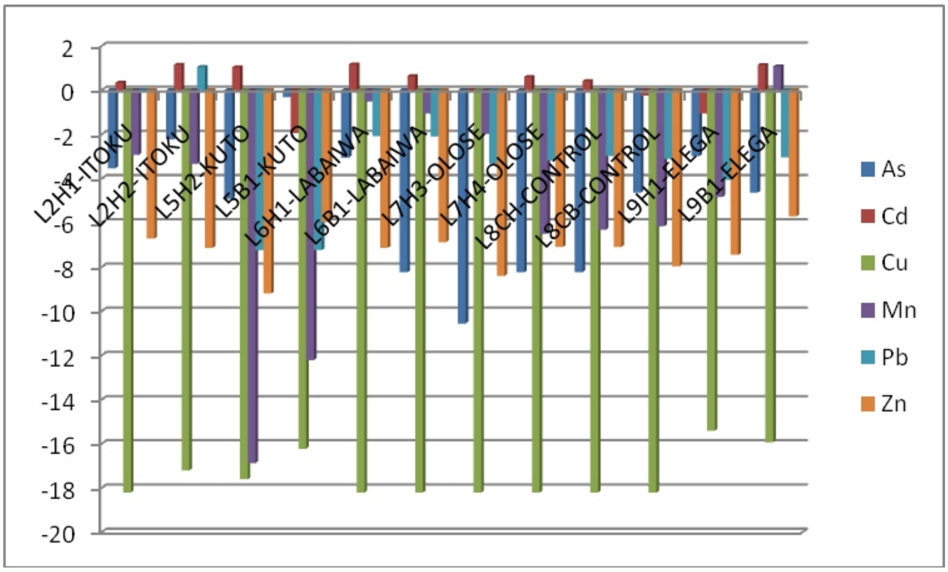

Figure 2: Geo Accumulation Index of Heavy Metals in the Study Area.

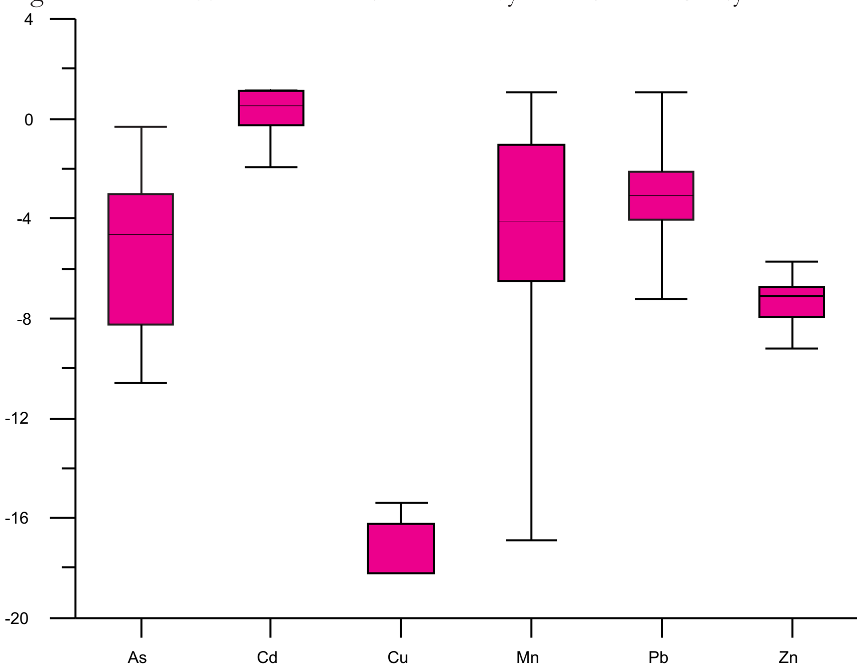

Figure 3: Box Plot for Igeo of Trace Elements

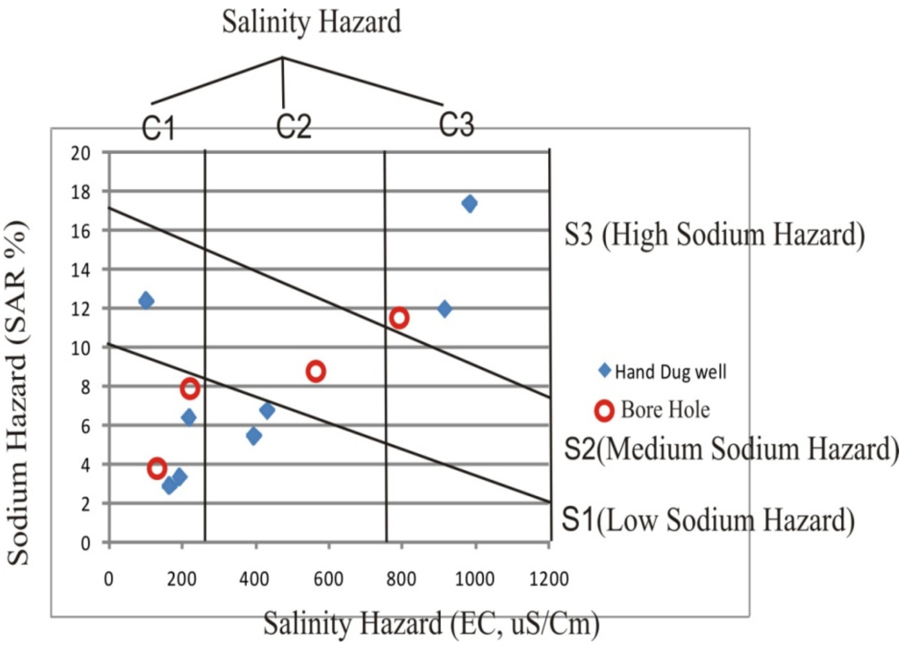

Figure 4: Salinity and Sodium Hazard within the Study Area

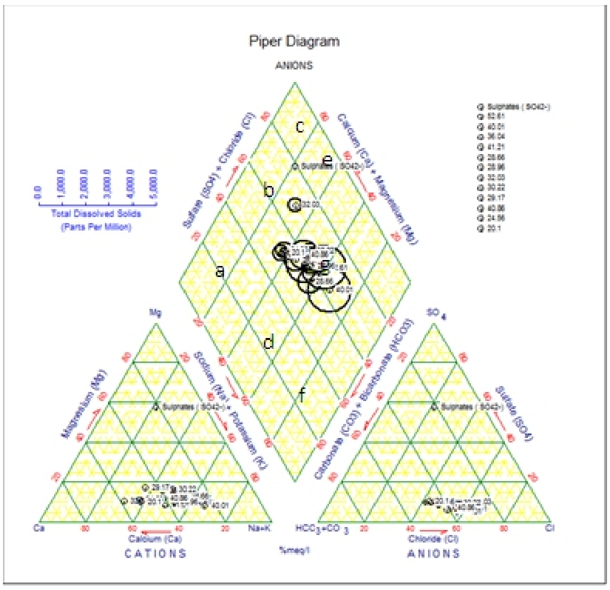

Figure 5: Piper Diagram of the Study Area (Piper, 1944)

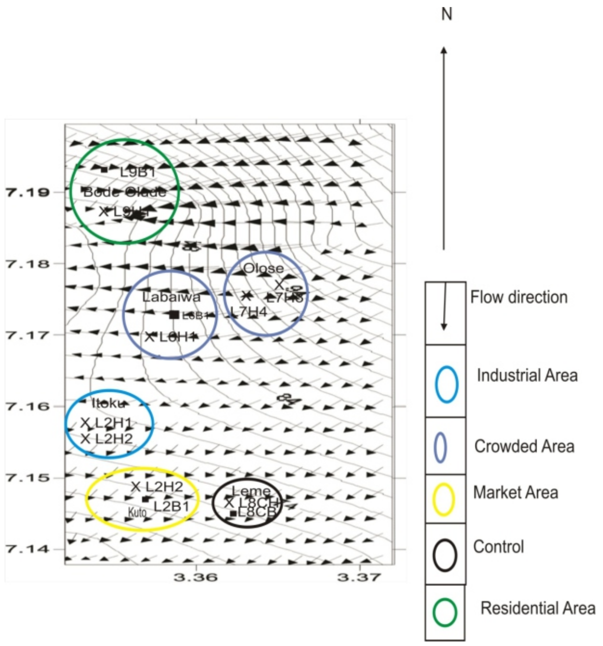

Figure 6: Piezometric Map of the Study Area

CONCLUSION

The geochemical analysis of groundwater from different zones of the study area (market area, crowded area, Industrial and residential) showed the mean concentration of major cations in the decreasing order of Na > Ca > K > Mg while the trace elements or heavy metals occurred in the order of Mn > Zn > Pb > Cd > As > Cu.

The order of contamination in the four zones was industrial > market > crowded > residential. Contamination was related to tie and dye factories in the study area, food items rich in Na, domestic activities with metal laden wastes and fuel combustion found within the area. Also quarrying activities that exist behind the housing estate could serve as another influencing factor.

Based on contamination factor (C.f), the trace or heavy metals had a low C.f except Cl^{-} Mn Pb and Ca in the industrial, crowded and market zones while other metals have little or no contamination in the various zones.

The groundwater type in the study area can be classified as alkaline water- SO_4^{2-} - Cl^- water (sulphates or Chloride) type mostly influenced by the alkali rich (biotite granite and porphyroblastic gneiss) rock types in the study area.

Although, the general quality of drinking water across the zones in the study area was safe, there is however, a need for continuous geochemical analysis of the groundwater over time. This will help to maintain and regulate the rate of contamination in all the zones of the study area.

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