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Keywords: groundwater sources, physicochemical properties, heavy metals toxicity, spatial distribution, safe water, maximum contaminant levels.

I. Introduction

It had been reported that one of the most important environmental issues is groundwater contamination (Vodela *et al.,* 1997). Water sources have been put under great pressure by population increases in developed and developing countries, through pollution by agricultural, domestic and industrial waste, and by environmental change (WHO, 2000). A primary concern of people living in developing countries is that of obtaining clean drinking water. In Africa and Asia, most of the largest cities utilize surface water but many millions of people in peri-urban communities and rural areas are dependent on groundwater (Obiri-Danso *et al.,* 2009).

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Water pollution problem both in the rural and mostly in the urban cities with teaming population have been observed to be the major cause of diseases and death. As a measure to the daily shortage of water, especially in most of our urban centers, attention has been shifted to open dug wells for groundwater resources (Gbadebo and Akinhanmi, 2010). Water sources, including groundwater, contain heavy or trace metals in concentrations depending on geology and contamination from varying anthropogenic sources. Although many heavy metals are necessary in small amounts for the normal development of the biological cycles, most of them become toxic at high concentrations. Heavy metals are introduced into the environment through natural phenomena and human activities, such as agricultural practices, transport, industrial activities and waste disposal (Kamarudin *et al.,* 2009).

Marcovecchio *et al.,* (2007) observed that between the wide diversity of contaminants affecting water resources, heavy metals received particular concern considering their strong toxicity even at low concentrations. Metals like calcium, magnesium, potassium and sodium had been known as essential metals in order to sustain life while cobalt, copper, iron, manganese, molybdenum and zinc had been needed at low levels as catalyst for enzyme activities (David and Joel, 2004). Excess exposure to heavy metals had been, however, reported to result in toxicity. Heavy metals had been known to produce their toxicity by forming complexes with proteins, in which carboxylic acid (-COOH), amine ($-NH_2$), and thiol (-SH) groups are involved; and these modified biological molecules had also been known to lose their ability to function properly, which resulted in the malfunction or death of the cells (Momodu and Anyakora, 2010).

Water resources containing contaminants, such as heavy metals and toxic metalloids, that pose a threat to health, had been reported to increase worldwide (Anazawa *et al.,* 2004). It had been observed that the presence of metals in water resulted from two independent factors: the first involving the weathering of soils and rocks (Bozkurtoglu *et al.,* 2006; White *et al.,* 2005) with its products being transported by air, (Rubio *et al.,* 2006) and water (Das and Krishnaswami, 2007),

Global Journal of Science Frontier Research (H) Volume XVIII Issue II Version I Year 2018

and the second involving a variety of anthropogenic activities that have created a societal health risk in rivers that received a substantial amount of waste from such activities (Espino *et al.,* 2007; Rubio *et al.,* 2004). Different studies have revealed that the presence of toxic heavy metals iron, lead, mercury reduce soil fertility and agricultural output (Lokhonde *et al.,* 1999). Also Cd, Cr, As, and Pb are proved detrimental beyond a certain limit (Bruin *et al.,* 2000).

In most town and cities in Nigeria, groundwater in form of shallow or deep wells, borehole and springs are significant sources of drinking water supplies to a large proportion of the communities. The qualities of these groundwater sources are affected by the characteristic of the media through which the water passes on its way to the groundwater zone of saturation (Shittu *et al.,* 2008). Thus, the heavy metals discharged by industries, municipal wastes, hazardous waste sites, as well as from fertilizer for agricultural purposes and accidental oil spillage from tankers can result in a steady rise in contamination of groundwater. (Igwilo *et al.,* 2006). Garba *et al.,* (2010) reported a mean Arsenic concentration of 0.34mg in drinking water from hand dug wells, boreholes and tap of Karaye Local Government Area, Kano State. The Zamfara State lead poisoning epidemic occurred in Nigeria in 2010. At least, 400 children died from the effect of lead poisoning due to the acute lead (Pb) poisoning from illegal processing of lead rich ore for gold extraction taking place inside houses and compounds in these areas.

The health problem of heavy metals poison is believed to be a global one. While some countries have been able to identify the magnitude of the problem and are already making efforts at putting it under control, Nigeria and most other African countries (particularly the under developed ones) are yet to identify the extent of the health problem associated with groundwater contamination by heavy metals and provide information for policymakers. Hence the objective of this study was to assess heavy metals in groundwater from selected communities in Sagamu Local Government Area, Ogun State, Nigeria.

II. Materials And Methods

a) *Study design*

The study involved a cross-sectional descriptive survey and laboratory analytical procedures. The experiment employed a complete randomized design with three (3) replicates of each of the samples.

b) *Study location and population*

The study was carried out in Sagamu Local Government Area, Ogun State, located within Southwestern Nigeria. It is bounded by Odogbolu Local Government to the East, Ikenne Local Government to the North, Obafemi-Owode Local Government to the West and Lagos State to the South respectively. It farthest point on the top left is 6 50 42.59N/ 3 28 20.67E, farthest point top right is 6 57 26.83N/ 3 36 36.09E. Lower left 6 38 57.35N/ 3 26 37.56E and lower right 6 41 05.34N/ 3 40 55.18E. The Local Government has an area of 614km^2 and a total population figure of 253,421 people, comprising of Yoruba, Hausa and Igbo background according to the National Population Census conducted in 2006. Sagamu Local Government Area is a Cosmopolitan Area that is divided into fifteen political wards. These include ward 1 – Oko, Epe & Itunle 1, ward 2 – Oko, Epe and Itunla II, ward 3 Aiyegbami Ijoku, ward 4 – Sabo 1, ward 5 – Sabo II wards 6 – Itunsoku Oyebayo, ward 7 Ijagba, ward 8 – Latawa, ward 9 – Odelemo ward 10 – Ogijo/Likosi, ward 11 – Surulere, ward 12 – Isote, ward 13 – Simawa ward 14- Agbowa, ward 15-Ibido/Itun-alara.

The purposively selected wards of interest for this study included Sabo 1, Sabo II and Ogijo/Likosi. They were chosen because of the indiscriminate waste disposal practices and high industrial activities in these communities. The industries in the study area are oil and gas depot and mostly metal, iron steel and battery lead recycling companies etc.

c) *Sampling procedure*

A three stage multi-sampling procedure was carried out. Fifteen wards were identified from the local government area, out of the fifteen wards, 3 wards were purposively selected based on the high industrial activities and indiscriminate waste disposal practice. From the three wards selected, seven communities were purposively selected based on high industrial activities and indiscriminate waste disposal practices, a practice predisposing heavy metal contamination in soil and water. From the seven communities, households were selected using systematic sampling method. This involves sampling of every 3rd houses in each locality and their groundwater source.

d) *Sample location (coordinates acquisition)*

Fifty groundwater samples were purposively collected for analysis in the laboratory. Samples locations were collected using a Global positioning system (GPS) Garmin 60 on site at groundwater source location. The GPS was put on and allowed to receive signals from the navigational satellite. Once full signals were received, the coordinates of the groundwater source was marked and saved on the GPS unit to be downloaded and inserted into data base to generate map showing samples location across the study area. In order to keep track of each unique location, the way points were saved to correspond to the names of each groundwater source site.

e) *Sample collection and transport*

The water samples were collected in a 500ml sterilized bottles. The pH, TDS and conductivity of the groundwater samples were determined immediately using pH meter. Concentrated hydrogen trioxonitrate (V) (HNO_3) was added to water samples for preservation and transported to the laboratory for analysis of Heavy metals [Arsenic (As), Cadmium (Cd), Chromium (Cr), and Lead (Pb)].

f) Procedure for laboratory sample

i. *Physicochemical analysis*

The Physicochemical parameters of the groundwater such as the temperature, conductivity, Ph and Total Dissolved Solids (TDS) were determined using a combined conductivity, TDS, temperature, pH meter (Hanna HI 9811-5 model). The already switched on meter was inserted into 500ml sterilized bottle with the tip containing the electrode touching the water. The result was read when a constant reading was attained. The procedure was repeated for each of the fifty water samples.

ii. *Heavy metals analysis (As, Cd, Cr and Pb)*

The concentration of heavy metals in the groundwater samples was determined following the methods described by the Association of Analytical Chemists (A.O.A.C). The samples were digested in concentrated nitric acid (HNO_3). After digestion, the samples were analysed using Perking 3300 AAS at different wavelengths (As – 193.7, Cd – 228.8, Cr – 357. 9, Pb – 283.3). Perkin Elmer MHS-10 hydride generator was used with the system for the determination of As. Blank and Standard for each of the metals were also analysed under the same analytical conditions. The concentration of metals in each sample was calculated using the read out from the AAS, volume of sample taken for analysis and volume of extract viz;

$$\text{Metal (mg/L)} = \frac{\text{The result – Blank) x Vol. of extract}}{\text{Vol. of Sample taken}}$$

g) Data management and analysis

The results obtained from the physicochemical and heavy metals analysis were summarized using descriptive statistics such as proportions, percentage, mean and standard deviation.

III. Results

a) Physicochemical analysis of water samples

Table 1 shows the mean values of physicochemical parameters analysed as compared with World Health Organization (WHO) and Standard Organization of Nigeria (SON) standards. The pH value of sample analysed ranged from 3.8 – 7.9 with a mean value of 4.79±1.6. The temperature value ranged from 27.7 – 34.5°C with a mean value of 30.09±3.6°C. The conductivity value ranged from 010-750 μ^2/ cm with a mean value of 81.25±5.8 μ^2/ cm. TDS value ranged from 0010-0360 mg/L with a mean value of 50±3.9 mg/L.

Table 1: Shows the physicochemical analysis on water samples

Parameter	Range	Means / SD	WHO 2011 / SON 2008
Ph	3.8 – 7.9	4.794 ± 1.6	6.5 – 8.5
Temperature (°C)	27.7 – 34.5	30.093 ± 3.6	Ambient
Conductivity (μ^2/ cm)	010 – 750	81.25 ± 5.8	500
Total Dissolved solids (mg/L)	0010 - 0360	50 ± 3.9	1000

b) Level of arsenic concentration in groundwater samples

Table 2 shows the levels of arsenic concentration in groundwater samples. A total number of 50 samples were analysed. The Arsenic (As) value ranged from <0.0001 – 0.0089 mg/L with the mean concentration of 0.002±0.002 mg/L. One hundred percent (100%) of As detected are within the WHO/SON maximum containment level.

Table 2: Levels of arsenic concentration in groundwater samples

Parameters	Borehole water	well water	Both
Number of total samples	41	9	50
Number of arsenic detected groundwater within WHO/SON limit (MCL)	43	7	50
Percentage of arsenic detected groundwater within WHO/SON limit (MCL)			
Number of arsenic detected groundwater above WHO/SON limit (MCL)	86%	14%	100%
Percentage of arsenic detected groundwater above WHO/SON limit (MCL)			
	0	0	0
Minimum concentration detected in the groundwater (mg/L)			
	0	0	0
Maximum concentration detected groundwater (mg/L)	<0.0001	<0.0001	<0.0001
WHO/SON Maximum Contaminant Level (MCL) (mg/L)	0.0089	0.00061	0.0089
Mean	0.01	0.01	0.01
	0.002	0.002	0.002

c) Level of cadmium concentration in groundwater samples

Table 3 shows the levels of cadmium concentration in groundwater samples. The cadmium value ranged from <0.01-0.43 mg/L with the mean concentration of 0.08±0.11 mg/L. 48% are above the WHO/SON MCL, while 52% are within the MCL. The minimum concentration detected is <0.01 while the maximum concentration detected is 0.43 mg/L.

Table 3: Shows Level of Cadmium Concentration in Groundwater Samples

Parameters	Borehole water	well water	Both
Number of cadmium detected groundwater within WHO/SON limit (MCL)	19	7	26
Percentage of cadmium detected groundwater within WHO/SON limi (MCL)	38%	14%	52%
Number of cadmium detected groundwater above WHO/SON limi (MCL)		1	24
Percentage of cadmium detected groundwater above WHO/SON limi (MCL)	23	2%	48%
Minimum concentration of cadmium detected groundwater (mg/L)	46%		
Maximum concentration of cadmium detected in the groundwater (mg/L)			
WHO / SON MCL (mg/L)	<0.01 0.43	0.12 0.12	<0.01 0.43
Mean			
	0.003 0.08	0.003 0.08	0.003 0.08

d) Level of Chromium Concentration in Groundwater Samples

Table 4 shows the levels of chromium concentration in groundwater samples. The chromium value ranged from <0.001-0.215 mg/L with the mean concentration of 0.03±0.05. 22% are above the WHO/SON MCL while 78% are within WHO/SON MCL. The minimum concentration detected is <0.001 mg/L and the maximum concentration detected is 0.215 mg/L.

Table 4: Shows Level of Chromium Concentration in Groundwater Samples

Parameters	Borehole water	well water	Both
Number of chromium d detected groundwater within WHO/SON limit (MCL)	32	7	39
Percentage of chromium detected groundwater within WHO/SON limit (MCL)	64%	14%	78%
Number of chromium detected groundwater above WHO/SON limit (MCL)	11	-	11
Percentage of chromium detected groundwater above WHO/SON limit (MCL)	22%	-	22%
Minimum concentration detected groundwater (mg/L)	<0.001	-	<0.001
Maximum concentration detected groundwater (mg/L)	0.215	-	0.215
WHO/SON MCL (mg/L)	0.05	0.05	0.05
Mean	0.03	0.03	0.03

e) Level of Lead Concentration in Groundwater Samples

Table 5 shows the levels of lead concentration in groundwater samples. The lead value ranged from <0.01-3.26 mg/L with the mean concentration 0.51±0.71. 12% are within the WHO/SON MCL while 88% are above the WHO/SON MCL. The minimum concentration detected is <0.01 mg/L while the maximum concentration detected is 3.26 mg/L.

Table 5: Shows Level of Lead Concentration in Groundwater Samples

Parameters	Borehole water	well water	Both
Number of lead detected groundwater within WHO/SON limit (MCL)	6	-	-
Percentage of lead detected groundwater within WHO/SON limit (MCL)	12%	-	12%
Number of lead detected groundwater above WHO/SON limit (MCL)	37	7	44
Percentage of lead detected groundwater above WHO/SON limit (MCL)	74%	14%	88%
Minimum concentration detected groundwater (mg/L)	<0.01	0.13	0.01
Maximum concentration detected groundwater (mg/L)	3.26	3.12	3.26
WHO/SON MCL (mg/L)	0.01	0.01	0.01
Mean	0.51	0.51	0.51

Distribution of Heavy Metals in Groundwater of Ogijo/Likosi and Sabo 1 and 2 Using Geographical Information System (GIS)

There is low concentration of arsenic across the study area both in Ogijo/Likosi and sabo 1 and 2. There is low concentration of chromium across the study area with one or two occurrence of high concentration in the northern part of the map close to NNPC depot, Monarch and steel companies. There is a general trend of low concentration of chromium in the southwest part of the study area whereas there appears to be high concentration of chromium in the north east part.

In Ogijo/Likosi cadmium is predominantly low with spars occurrence of high concentration of cadmium in the southern part of the study area. In the upper northern part, there is a significant high concentration of cadmium especially the areas closed to industries. In Sabo, there is a significant occurrence of high concentration of cadmium across the area with only spars occurrence of low concentration of cadmium in the southwest area, but the northwest region shows a significant level of high concentration of cadmium. A map showing lead concentration distribution in Ogijo/Likosi shows that there is predominantly high concentration of lead across the study area with just spars appearance of low concentration in the southern area and also in Sabo lead concentration is predominantly high across the area.

Table 6: Distribution of Heavy Metals in Groundwater Using GIS

1. **Describe the distributions of heavy metals in groundwater (GIS)**	Pb (mg/L)	Cd (mg/L)	Cr (mg/L)	As (mg/L)
Presence of heavy metals	44	24	11	0
Absence of heavy metals	6	26	39	50

Global Journal of Science Frontier Research (H) Volume XVIII Issue II Version I Year 2018

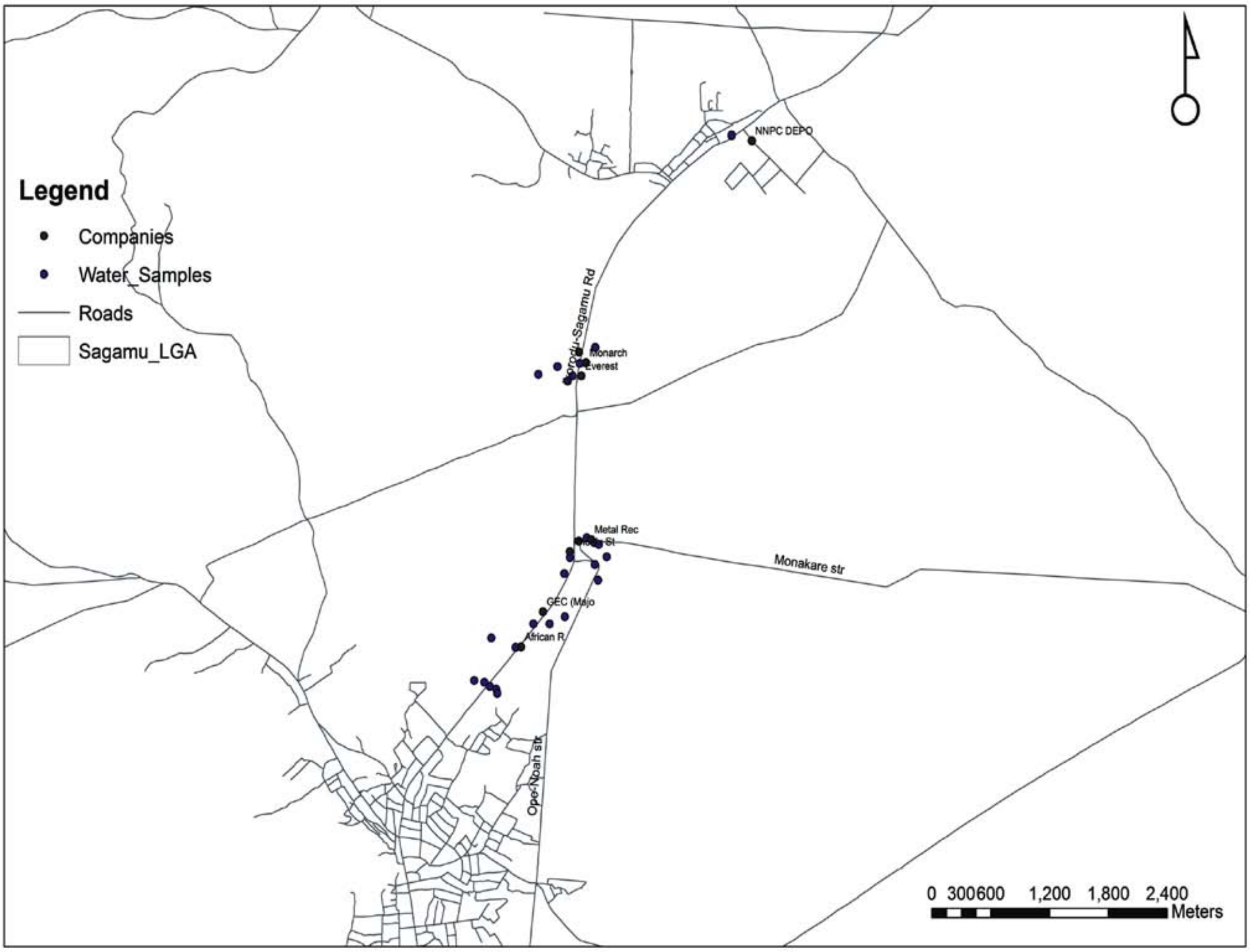

Fig. 1: Map Showing Sample Locations In Ogijo/Likosi Ward 10

Global Journal of Science Frontier Research (H) Volume XVIII Issue II Version I Year 2018

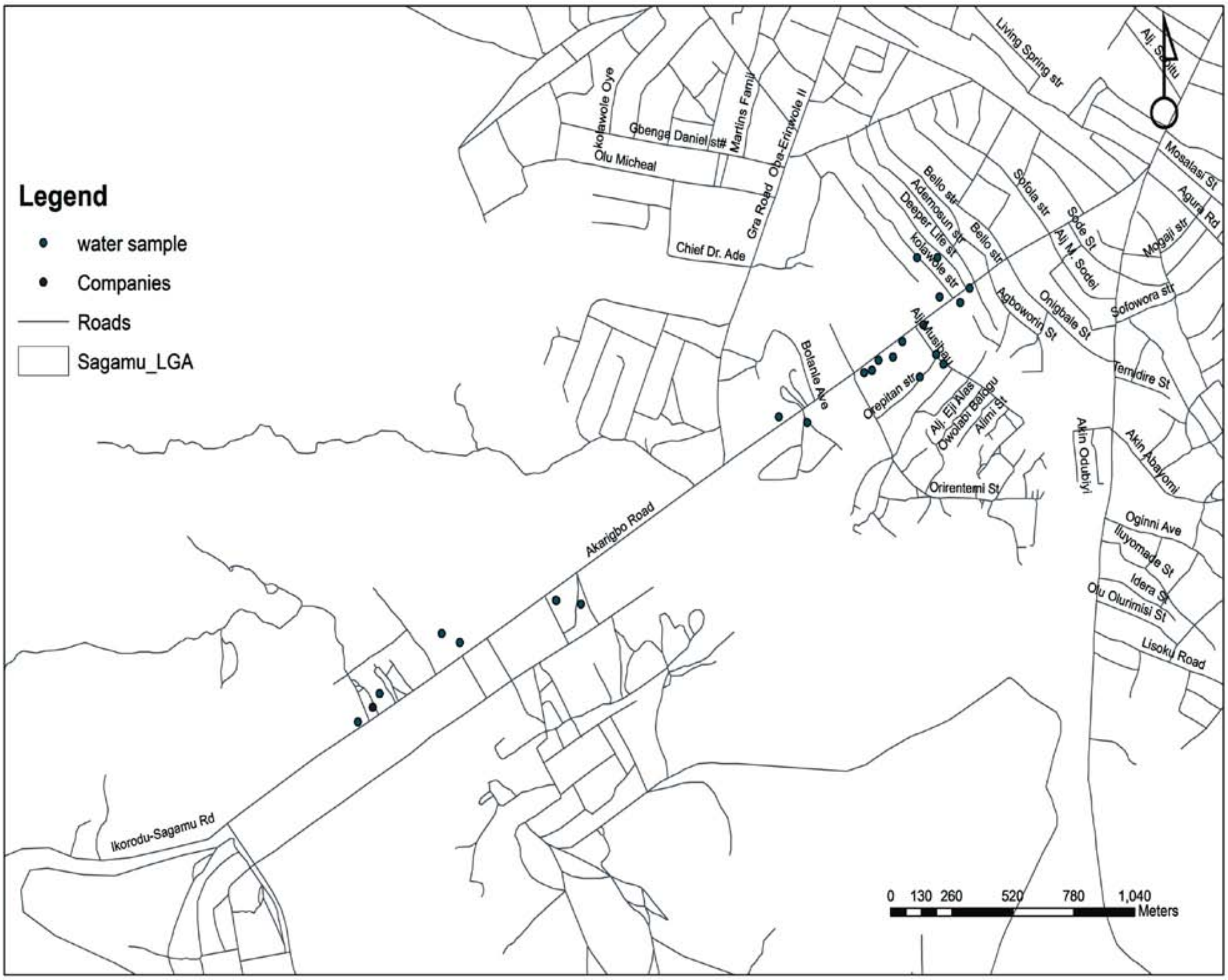

Fig. 2: MAP Showing Sample Locations In Sabo Ward 4 & 5

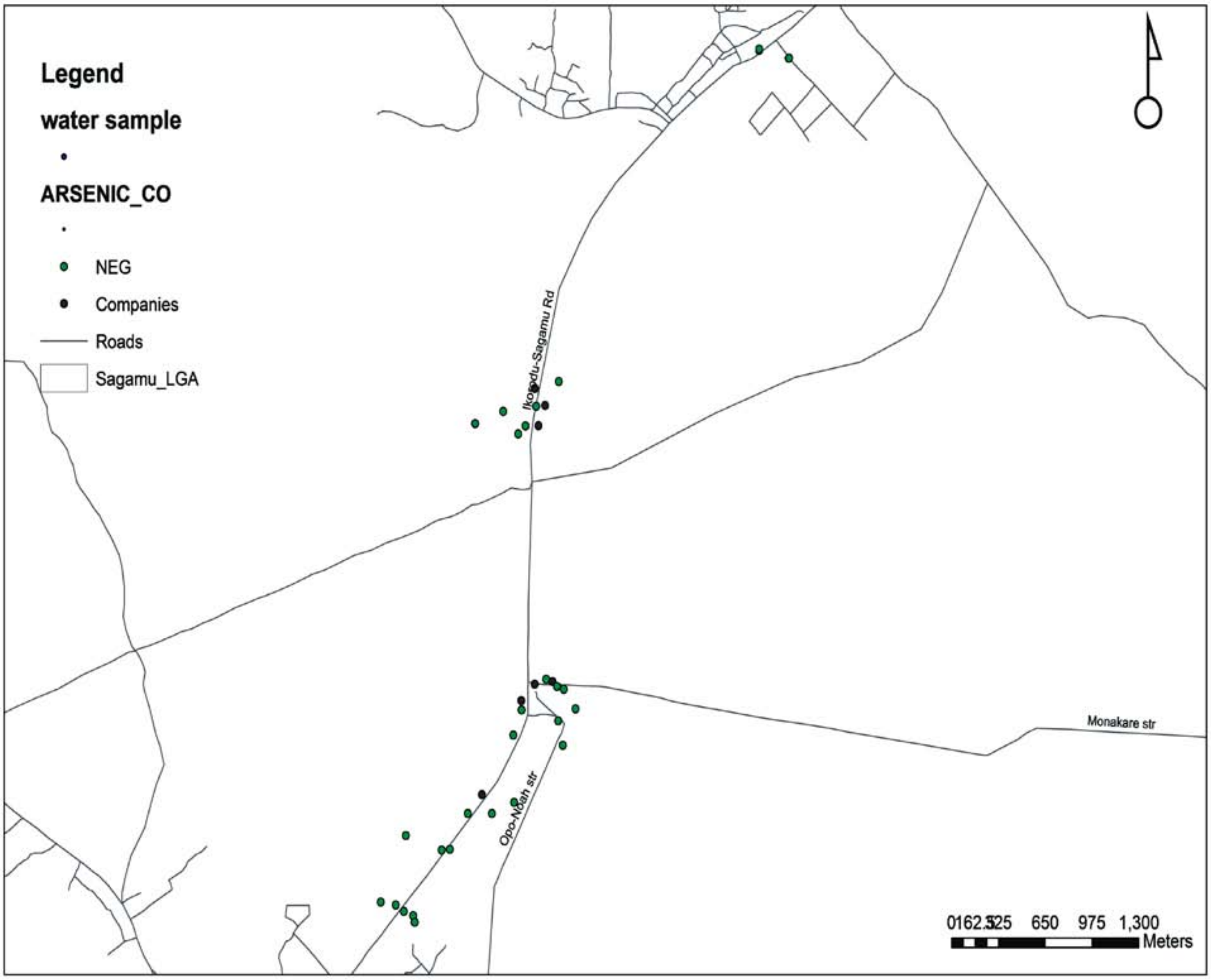

Fig. 3: MAP Showing Arsenic Concentration Distribution in Ogijo Likosi Ward 10

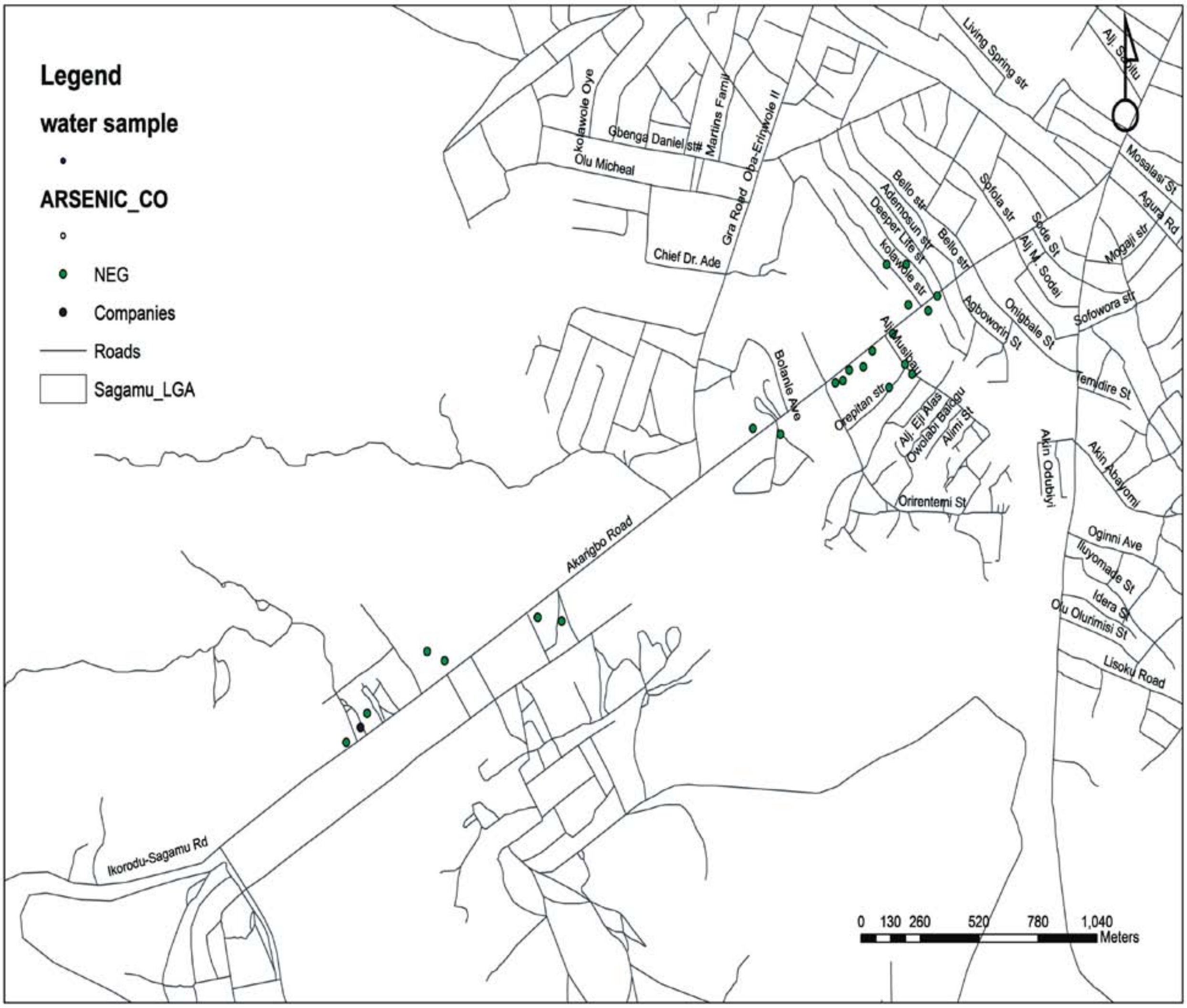

Fig. 4: MAP Showing Arsenic Concentration Distribution In Sabo Ward 4 & 5

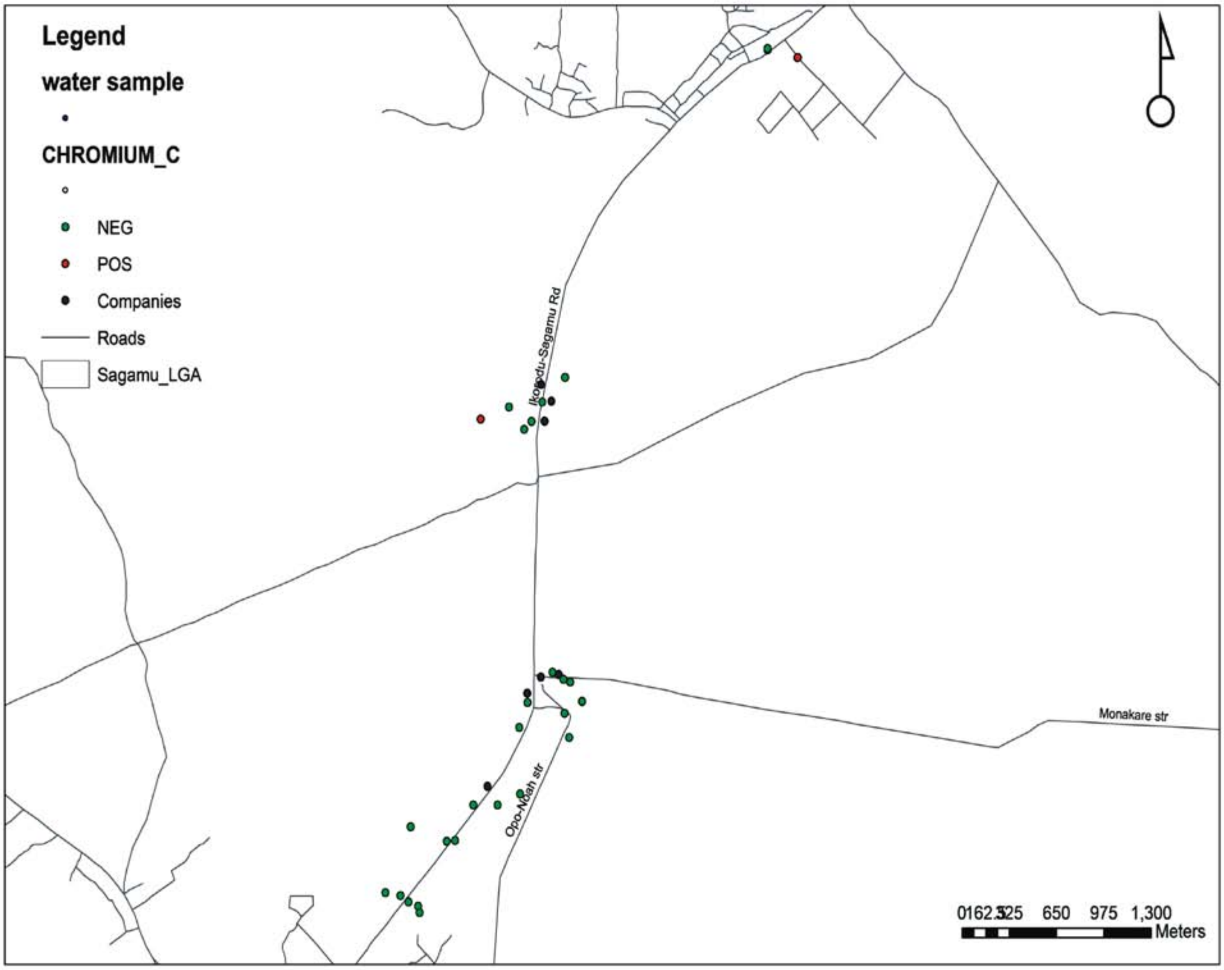

Fig. 5: MAP Showing Chromium Concentration Distribution In Ogijo/Likosi Ward 10

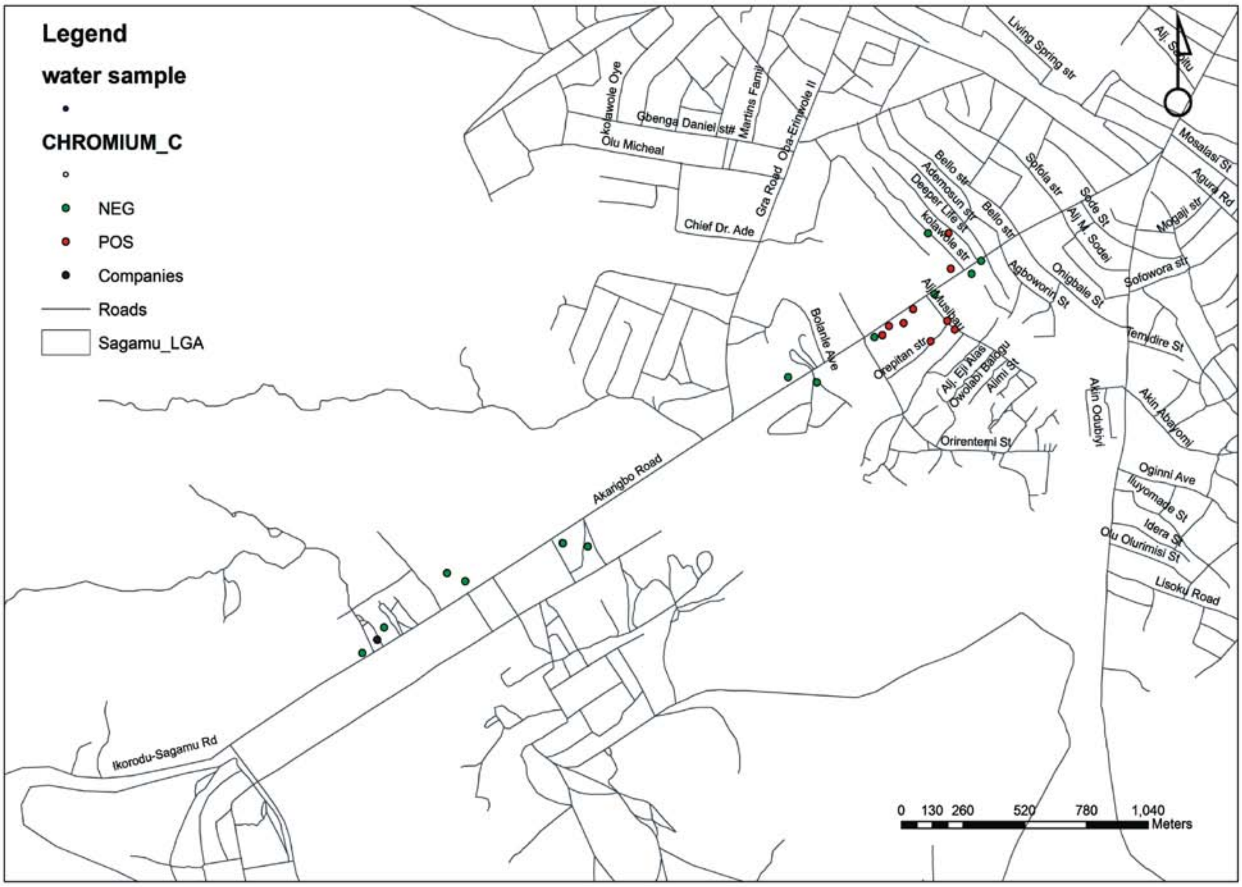

Fig. 6: MAP Showing Chromium Concentration Distribution In Sabo Ward 4 & 5

Global Journal of Science Frontier Research (H) Volume XVIII Issue II Version I Year 2018

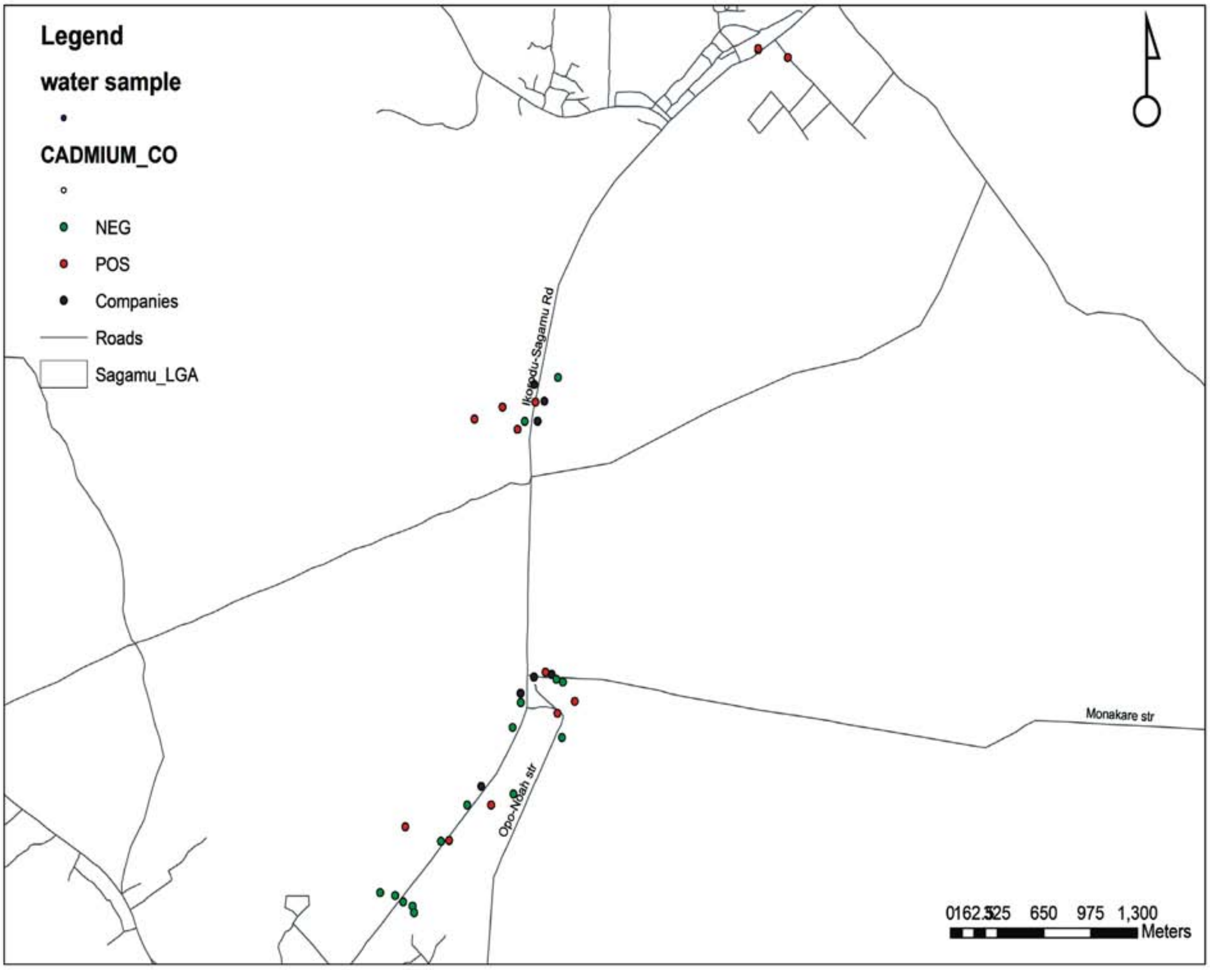

Fig. 7: MAP Showing Cadmium Concentration Distribution In Ogijo/Likosi Ward 10

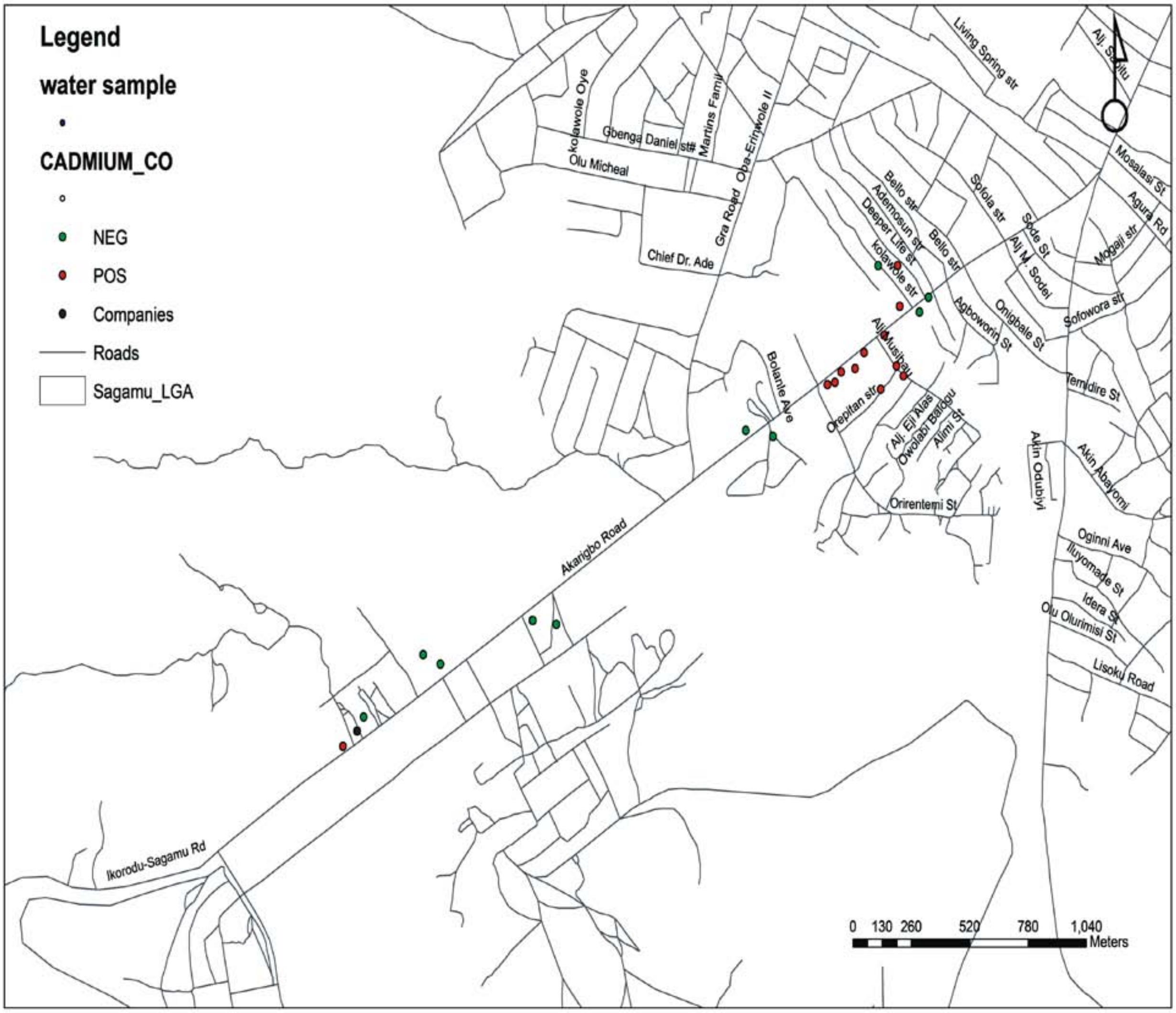

Fig. 8: MAP Showing Cadmium Concentration Distribution In Ward 10

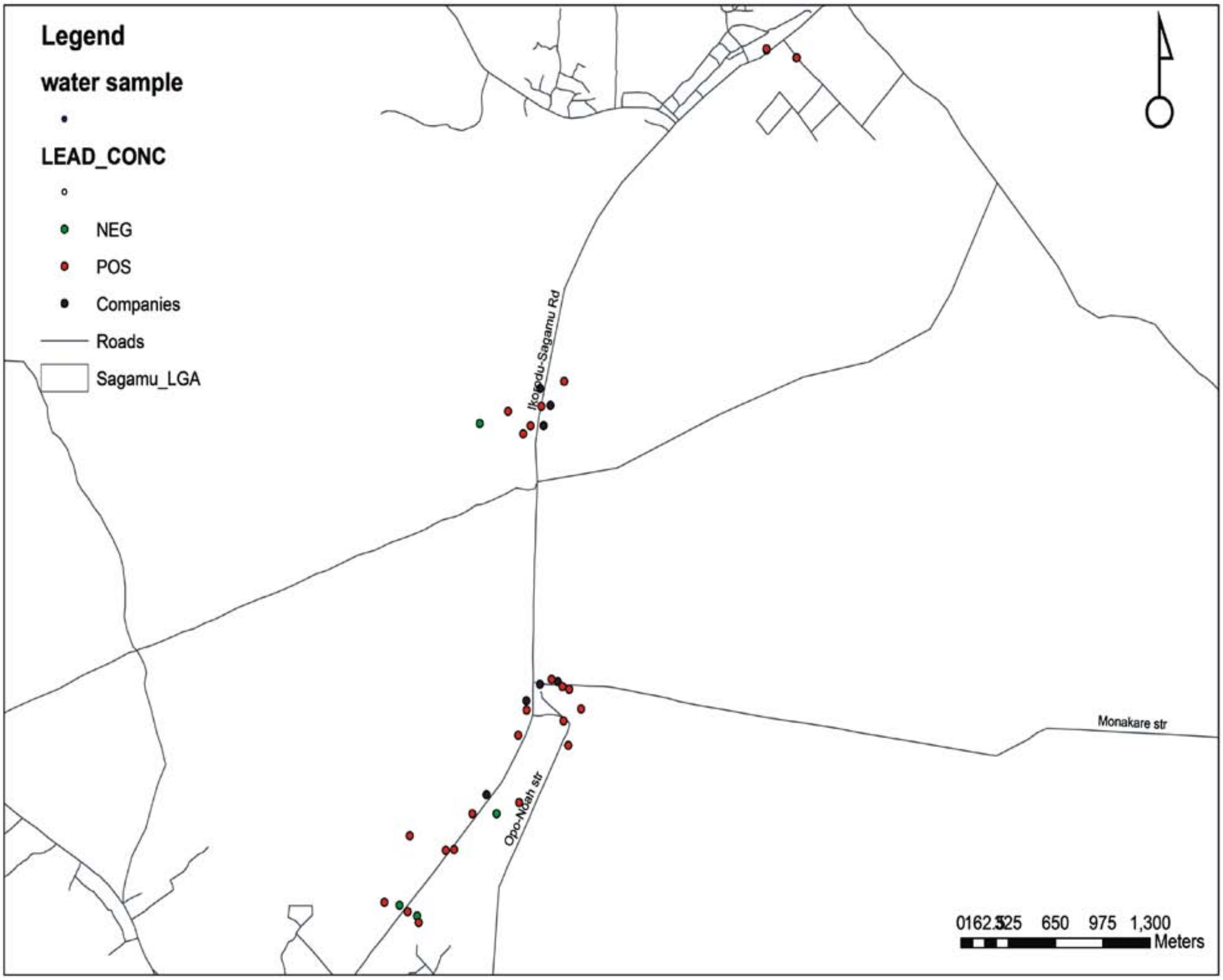

Fig. 9: MAP Showing Lead Concentration Distribution In Ogijo/Likosi Ward 10

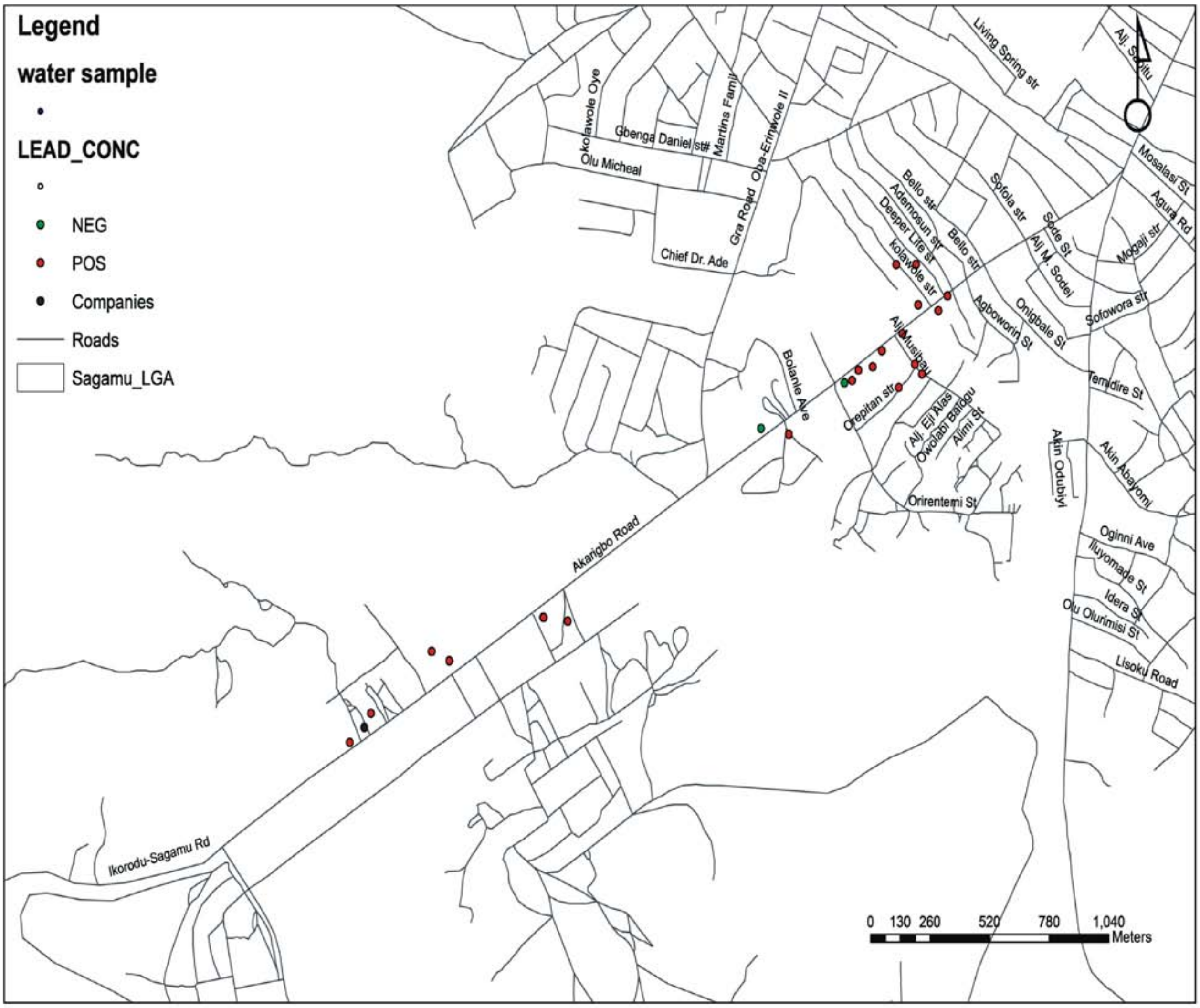

Fig. 10: Map Showing Lead Concentration Distribution In Sabo Ward 4 & 5

IV. Discussion

Ground water had been reported to be the most important source of domestic, industrial and agricultural water supply in the world (Adeyeye and Abulude, 2004). It had also been observed that rock weathering, atmospheric precipitation, evaporation and crystallization control the chemistry of water (Kayode *et al.,* 2011). The influence of geology on chemical water quality had been widely recognized (Lester and Brikett, 1999). The influence of soils in water quality had been known to be very complex and had been ascribed to the processes controlling the exchange of chemicals between the soil and water (Hesterberg, 1998). It had also been reported that the water chemistry of the groundwater consist of inorganic chemicals and suspended solids as a result of urban run-off (McGregor *et al.,* 2000).

In this study, the mean pH value of the sample water is below the recommended value by WHO/SON in drinking water, indicating that the groundwater from the study area is acidic. Past studies had reported the acidic nature of Lagos and Ogun groundwater. Longe and Balogun (2010) reported the mean pH value of 6.134 $\pm$0.67 in Lagos groundwater and Ayedun *et al.,* (2010) also reported pH value of 5.90$\pm$0.32 in Ibeshe Ogun State. The acidity is probably as a result of the industrial activities and indiscriminate waste disposal practices in the study area. The acidic water can cause corrosion of water pipes and affect gastro intestinal tract when consumed leading to perforation of intestinal tissues. In a study conducted by Anjorin (2010), to assess the physicochemical parameters of twenty (20) sample wells from three Local Government Areas in Abeokuta Metropolis, Ogun state, Nigeria. He reported that the well water in this area was almost neutral with pH (6.464$\pm$ 0.568), electrical conductivity (539.6$\pm$339.07 μscm^{-1}) and total dissolved solids (274.55$\pm$175.35 mg/L).

Four heavy metals As, Cd, Cr and Pb were analysed in groundwater of the study area. The mean value of arsenic and chromium are within the limits prescribed by WHO/SON for drinking water quality.

However, a study conducted by Garba *et al.,* (2010), reported a high mean concentration of arsenic of 0.34mglL in drinking water from hand-dug wells, boreholes and tap of Karaye Local Government Area, Kano State. Even though the arsenic levels in the study area are within the MCL of WHO/SON, there is the possibility of bioaccumulation of arsenic in biological systems. This is important in food chain and ecosystem health. It is known that the first visible symptoms caused by exposure to low arsenic concentration in drinking water are abnormal black-brown skin pigmentation known as melanosis and hardening of palms and soles known as keratosis, further thickening (hyperkeratosis) and can lead to skin cancer (WHO 2001).

Chromium is an essential trace element, required for the metabolism of lipids and protein and to maintain a normal glucose tolerance factor. High doses of chromium cause liver and kidney damage and chromate dust is carcinogenic (SEIGH, 2001; Mugica *et al.,* 2002). Arsenic has become increasing important in environmental geochemistry because of its significance to human health. Long-term exposure to arsenic through drinking contaminated water can result in a chronic arsenic poisoning; known symptoms are: cancer of the skin, lungs, urinary blades, and kidney as well as other skin changes such as pigmentation and thickening (WHO, 2010). The concentration of arsenic in most ground waters is lower than 10g/L and often below the detection limit of routine analytical methods. The physicochemical conditions favoring arsenic mobilisation in aquifers are variable, complex and poorly understood, although some of the key factors leading to high groundwater arsenic concentrations are known (Plant *et al.,* 2004). Reducing conditions favourable for arsenic mobilisation have been reported most frequently from young (Quaternary) alluvial, deltaic sediments (Alaerts and Khouri, 2004). Recent groundwater extraction, either for public supply or for irrigation, has induced increased groundwater flow. This could induce further transport of arsenic (Harvey *et al.,* 2002).

The mean concentration of cadmium and lead found in the sample areas were above the WHO/SON recommended standards. High levels of cadmium and lead in groundwater analysed are probably the result of discharge from industrial waste or by leaching from solid waste dumped (Naik *et al.,* 2007; Singh, 2003), particularly from the iron steel and metal industries in the study area. Similar observation was reported by Eruola *et al.,* (2011) that showed high concentration of Cd (0.017±0.016) in Ilaro and high concentration of Pb (0.23±0.06) in Aiyetoro all in Ogun State. Cadmium is highly toxic, producing symptoms such as nausea, vomiting, respiratory difficulties and loss of consciousness at high doses. Chronic exposure to cadmium can lead to anaemia, cardiovascular diseases, renal problems and hypertension. (Robert and Worsfold, 1991). Waakles (2000), reported the co-existence of renal and lung damage among workers of alkali storage plant. Cadmium effects on cardiovascular system were explained by linking dietary cadmium to hypertension (Schroeder, 1965). Cadmium is released to the environment in wastewater, and diffuse pollution is caused by contamination from fertilizers and local air pollution. Contamination in drinking water may also be caused by impurities in the zinc of galvanized pipes and solders and some metal fittings (Kayode *et al.,* 2011). Food is the main source of daily exposure to cadmium and the daily oral intake is 10 to 35mg. Smoking is a significant additional source of cadmium exposure (WHO, 2010).

Lead is a cumulative poison, initiating hypertension, irritability, behavioural changes and impairment of intellectual functions in affected patients (Tebbutt, 1983). Long – term exposure to lead or its salt (especially soluble salts or the strong oxidant PbO_2) can affect adversely the nervous system and kidneys (Mugica *et al.,* 2002). The spatial distribution showed that there was predominantly high concentration of lead across the study area. In the upper northern part of Ogijo/Likosi and across Sabo 1 and 2, lead was predominantly high especially the areas close to industries. Lead from atmosphere or soil can end up in groundwater (Yu, 2005). Lead gets into drinking water from the corrosion of lead solder that connects the pipes or brass faucets. In US, 14-20% of total lead exposure is attributed to drinking water (Mass *et al.,* 2005). Studies have linked lead exposure even at low concentration and increases blood pressure (Zietz *et al.,* 2007), as well as encephalopathy and inability to learn fast in children (Needleman, 1985). Therefore, the presence of these heavy metals in groundwater sources for domestic use should be managed with appropriate technology that will be suitable for rural and urban dwellers. This should be geared towards improved public health status of the communities.

V. Conclusions

The purpose of this study was to assess heavy metals contamination in groundwater in some selected communities in Sagamu Local Government Area, Ogun State, Nigeria. The results show that the mean pH of the water from the borehole and hand dug wells are slightly acidic which makes the water a good medium for dissolution of heavy metals. High concentration of the heavy metals may be attributed to industrial release of hazardous waste and untreated effluents in soil leaching into groundwater. In the light of the parameters assessed, the drinking water sources may not presently have any adverse effect as far as arsenic and chromium are concerned, since their mean concentrations fell within the regulatory bodies standards, contrary to the mean concentrations of lead and cadmium. This suggests a risk of the population to heavy metals toxicity and acidic water, thereby making the groundwater sources (borehole and hand dug well) unsafe for drinking, which is raising a warning sign to the health of people settled in the communities.

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Conflict of Interest

The authors declare no conflict of interest in the publication of this research paper.

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