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Evaluation of Groundwater Quality Characteristics in Lagos-City

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Abstract: Most of the water requirement for Lagos is met from surface and ground water supplies. Lagos an industrial and highly populated city located in the Southwest Nigeria has urban migration problems and resource limitations. However, as found in many cities, a certain proportion of the population is forced to rely on the well water as sources of drinking water, a poor drinking water quality that may have health consequences. A study was therefore carried out to gain an idea of the inorganic quality of the water in the wells penetrating the shallow (< 20 m thick) alluvial aquifer in the city. Results from this study revealed that some of the ground water quality constituents exceeded the World Health Organization (WHO) standards for drinking water irrespective of the sources of pollution: the total dissolved solids limit in 50%, the conductivity limit in 27.8%, the lead limit in 38.9%, the pH limit in 44.4% and the sodium and calcium limits in 11.1% of the samples. Thus, ground water from some of these wells requires further purification to ensure its fitness for human consumption.

Key words: Aquifer, ground water, water quality constituents, wells

INTRODUCTION

Nigeria is the largest country on the west coast of Africa with an estimated population of 140 million and about 43% of the populace currently live in cities or urban areas (World Bank, 2000a). The rate of urbanization in Nigeria is alarming and the major cities area growing at rates between 10-15% per annum.

Pollution of ground water has been reported for a number of urban aquifers throughout the world (Table 1) because of its overwhelming environmental significance. A wide range of pollutants has been recognized including heavy metals, N-species, chlorinated hydrocarbons, phenols, cyanide, pesticides, major inorganic species and bacteria. Their impact on ground water continues to raise concern and have become the subject of past and recent investigations (Ikem *et al*., 2002; Ahmed and Sulaiman, 2001; Fatta *et al*., 1999; Kjeisen *et al*., 1998; Bjerg *et al*., 1995; Loizidou and Kapetanios 1993; Gallorini *et al*., 1993; Robinson and Gronow 1992; Khan *et al*., 1990).

In the city of Lagos, potable water from the water supply boards are inadequate for the teeming population and fears of contamination of the municipal drinking water supply is high since water treatment and distribution is facing many problems. According to the World Bank (2000b), only 39% of people that live in cities have improved water source. Thus, a large percentage (over 70%) of the population of the neighbourhoods studied depends on groundwater from their private wells as the main source of drinking water. Therefore, it became necessary to ascertain the water quality since poor water quality may have adverse health impact. With this in mind, a study of the quality of the Lagos ground waters has been undertaken to determine variations in physical and chemical concentrations. It was hoped that the studies would provide a useful addition to the sparse literature on urban ground water pollution in developing countries.

Lagos and the lagos aquifer

Climate: The climate of Nigeria, including that of the study area is tropical with an annual rainfall of approximately 1408 mm (57.7 inches). Eighty percent of the annual rainfall (1160 mm) falls during the south west monsoon, (April-October) and the remaining twenty percent (250 mm) falls during the northeast monsoon (November-March). The air is very humid throughout the year, with monthly average temperatures ranging from 28°C in July/August to 32°C in February/March.

Sewage, waste disposal and industry: As a result of the over stressed sewerage system, most of the canals are often little better than open sewers. In addition, the improper disposal of solid and liquid wastes near residential areas poor wastes collecting and handling, access roads and the state of physical infrastructure contribute to the sewage problems. In all these cases, it is expected that direct input of organic species of biological origin, major and minor inorganic species and bacteria will occur in the aquifer.

Table 1: Some urban ground-water pollution case histories

Author	City/Region	Country	Reported analyses
Cavallero *et al.* (1985)	Milan	Italy	Org
Cross (1980)	Halifax	Canada	Cl in deicing salts
Cruickshank *et al.* (1980)	Merida	Mexico	Bacteria
Dummer and van Straaten (1988)	Bielefeld	W/Germany	Org, EC, H, Mn, Cl, COD
Eisen and Anderson (1980)	Milwaukee	USA	Cl, SO_4, bacteria
Flipse *et al.* (1984)	Long Island	USA	NO_3
Foster (1988)	Various	S/America	NO_3, bacteria, metals, org
Gosk *et al.* (1990)	Coventry	UK	CHS
Handa *et al.* (1983)	Faridabad	India	Cr
Kakar and Bharnagor (1981)	Ludhiana	India	Metals
Katz *et al.* (1980)	Nassau County	USA	NO_3
Philips *et al.* (1997)	Oklahoma	USA	No_3
Somasundarama *et al.* (1991)	Madras	India	metals, majors
Ikem *et al.* (2002)	Lagos/Ibadan	Nigeria	COD, metals

Org = Organic determinand, EC = Electrical conductivity, Metals = Heavy metals, Majors = Na, K, Ca, Mg, Cl, SO_4, HCO_3, COD = Chemical Oxygen Demand, TOC = Total Organic Carbon, H = Hardness and CHS = Chlorinated Hydrocarbon Solvents

Most of the domestic and industrial wastes generated were used in reclaiming land, a considerable quantity is dumped within the city. Such wastes will provide pollutants ranging from CI-through N-species and metals to organic species associated with putrescible materials.

The city has a wide range of industries ranging from large scale textile factories, foods and pharmaceuticals, tanneries and motor assembly plants, to roadside one-man vehicle repair garages. Some wastes are disposed through the sewer system or via the surface water courses. Many of the small premises do not have access to any disposal system other than allowing wastes to soak into the ground.

Industrial contaminants can also gain access to the local aquifer either via interaction with the surface water bodies or directly through infiltration. Pollutants to be expected range from metals and other inorganic species to industrial organic compounds.

Geological features: Geologically, the Lagos area is made of sedimentary deposits with alluvium formation covering the entire study area and overlies the coastal plain sand formation. The flow of material and pollutants is through pores.

MATERIALS AND METHODS

Ground water samples were collected in polyethylene bottles from 18 different wells across the city during the months of August to October 2004 using polyethylene bucket. These months were chosen by practicalities. Ikem (1996) has shown that seasonal water quality and patterns in an aquifer are variable and dependent upon local conditions. The samples were analyzed in duplicate and the average values were recorded.

Standard methods were used for the determination of the chemical and physical characteristics of the water (APHA 1998). The parameters analyzed were alkalinity, total hardness, Total Dissolved Solids (TDS), nitrate, phosphate, sulphate, chloride, calcium, magnesium, potassium, sodium, lead, zinc, pH, conductivity and temperature. Titration methods were used for alkalinity and total hardness measurements. Chloride was determined using the Mohr Argentometric Method. The pH and conductivity were measured at the time of samples collection using Suntex TS-2. Sodium, calcium and potassium were determined by flame photometer while lead and zinc were carried out using Buck Scientific 200A atomic absorption spectrophotometer.

Samples were unfiltered and as such, the concentrations reported were probably in excess of true dissolved values but close to the total concentration imbibed by the consumers. Unfortunately, no facilities were available to carry out analyses for organic pollutants. Prior to each analysis all instruments were calibrated according to manufacturer's recommendations. All the reagents used in the analysis were of research grade.

RESULTS AND DISCUSSION

The results show high values of TDS, conductivity, hardness and lead (Table 2). The ranges are 79-1343, 120-1860, 24-289 and nd-4.9 mg L^{-1}, respectively. There are several factors which may contribute to the degradation in the quality of ground water in Lagos. Human activities as well as municipal waste disposal can cause variation in concentration of ground water within Lagos city. The statistical results of ground water quality data as well as classification and comparison of the data with WHO drinking water standards are presented in Table 3 (WHO, 1991a, b). Temperature values obtained ranged from 24.9-26.8°C with a mean of 25.8°C. Water at high temperature contains less dissolved gases and tastes. Ipinmoroti (1993) reported that the temperature of water from subterranean springs was little affected by

Table 2: Analyses of water Samples from the Lagos ground water (concentration in mg L^{-1})

Location reference No.	pH	Ca^{2+}	Temp	Na^{2+}	K^{+}	Cl^{-}	SO_4^{2-}	NO_3^{-}	PO_4^{3-}	EC	TDS	TH	TA	Pb	Zn
GW_1	6.93	102.0	26.3	26.2	11.4	30.0	2.0	0.2	1.1	578	464	104	81.5	nd	0.14
GW_2	6.55	133.5	26.2	154.0	27.5	90.3	2.9	0.5	0.2	1253	878	137	57	nd	0.11
GW_3	6.66	158.5	26.2	29.4	17.5	49.0	1.8	0.3	0.05	911	558	161	118	nd	0.0
GW_4	6.19	130.9	26.0	34.1	15.4	63.3	3.8	0.5	0.07	1093	794	141	40	nd	0.04
GW_5	5.72	68.4	26.1	34.1	13.4	51.0	2.0	0.4	0.01	703	521	71	14.5	nd	0.06
GW_6	5.13	128.3	26.2	165.0	24.3	116.0	2.0	1.2	0.0	324	917	132	12.5	nd	0.01
GW_7	5.78	17.4	26.1	25.7	3.2	26.3	0.0	0.2	0.01	244	164	18	11.0	0.1	0.05
GW_8	6.96	144.6	25.9	11.7	4.8	5.3	0.0	0.02	0.0	394	187	145	127	nd	0.22
GW_9	6.35	86.6	26.1	28.9	5.9	23.0	0.0	0.6	0.01	530	383	89	38.5	nd	0.0
GW_{10}	6.82	43.4	26.4	174.8	112.7	166.5	0.2	0.5	0.0	1756	577	47	56.5	nd	0.01
GW_{11}	6.47	45.4	26.8	26.3	37.2	18.5	1.3	0.05	0.04	699	172	47	72.0	nd	0.02
GW_{12}	5.97	23.1	26.3	8.0	3.0	15.5	0.0	0.05	0.02	602	398	24	21.5	0.03	4.2
GW_{13}	6.61	246.8	25.0	177.6	35.2	104.0	2.3	1.5	0.01	825	571	253	163	1.3	0.14
GW_{14}	6.29	27.8	24.9	24.7	5.8	19.0	1.1	0.2	0.0	133	86	35	35	1.8	0.01
GW_{15}	6.51	143.1	25.0	29.4	7.4	35.0	2.9	0.2	0.06	1055	750	146	109	4.9	0.04
GW_{16}	6.77	273.7	25.0	237.9	26.3	224.0	2.7	0.05	0.02	1860	1343	289	292	nd	0.2
GW_{17}	6.64	110.2	25.0	205.4	27.5	114.0	2.7	0.8	0.03	620	406	117	80	1.0	0.03
GW_{18}	6.53	23.7	25.0	18.9	3.4	5.0	0.04	0.2	0.01	120	79	28	27	2.1	0.06
Range	5.13-6.96	23.1-273.7	24.9-26.8	8.0-273.9	3.0-112.7	5.0-224.0	0.0-3.8	0.05-1.51	0.0-1.13	120-1860	79-1343	24-289	11-292	nd-4.9	0.0-4.2
Mean	6.38	105.9	25.8	78.5	21.2	64.2	1.98	0.40	0.01	761	513.8	110	75	1.6	0.3
SD±	0.47	73.8	0.63	80.1	25.5	60.6	1.04	0.42	0.27	497	333.3	75.9	70	1.7	0.1

Table 3: Classification of Lagos groundwater quality data and comparison with guidelines

Parameters	Classification	Comparison with classification (% Samples)	WHO guidelines
Conductivity (µS cm^{-1})	<500	27.8	1000
	500-1000	44.4	
	>1000	27.8	
Alkalinity (mg L^{-1})	<100	72.2	200
	100-200	27.8	
Sulphate (mg L^{-1})	0-20	100.0	400
Total hardness (mg L^{-1})	0-30	16.7	500
	31-60	16.7	
	61-120	22.2	
	121-128	33.3	
	>180	11.1	
Total dissolved solid (mg L^{-1})	>500	50.0	500
Chloride (mg L^{-1})	>250	0.0	250
pH	<6.5	44.4	6.5-8.5
	6.5-8.5	55.6	
Na (mg L^{-1})	>200	11.1	200
Nitrate (mg L^{-1})	>10	0.0	10
Pb (µg L^{-1})	>10	38.9	10
Zn (mg L^{-1})	>5.0	0.0	5

seasonal variations of temperature. pH values obtained was lower than WHO standard values for drinking water in 44.4% of the samples (Table 3) with a mean value of 6.38 and maximum and minimum of 5.13 and 6.96, respectively, these values reflected the hydrogeology of the area. Alkalinity indicates the level of carbonate, bicarbonate and hydroxyl groups in water samples. Hydroxide is uncommon to natural water hence no phenolphthalein alkalinity recorded for all the water analyzed. Mean value of 75.3 mg L^{-1} $CaCO_3$ was recorded for the alkalinity; however, it was observed that water sampled had low alkalinity values reflecting low pH values.

Total Dissolved Solids (TDS) exceeded WHO value for drinking water in 50% of the samples, thus indicating the unsuitability of some of the water for drinking purposes. High total dissolved solid can cause undesirable effects such as gastrointestinal irritation (Plunkett, 1976). Conductivity values generally reflected the TDS concentrations. Hardness of water is regarded as the measure of Ca and Mg levels present in water. The mean value of hardness in the present study was 110.2 mg $CaCO_3$ L^{-1} with a maximum of 289 mg $CaCO_3$ L^{-1} and a minimum of 18.0 mg $CaCO_3$ L^{-1}. The results revealed that in 55.5% of the samples, the total hardness values were higher than the WHO highest desirable level of 100 mg L^{-1} $CaCO_3$ and none exceeded the maximum permissible level of 500 mg L^{-1} $CaCO_3$. Environment Canada (1979) classified water having 0-30 mg L^{-1} $CaCO_3$ as very soft, 31-60 mg L^{-1} as soft; 61-120 mg L^{-1} $CaCO_3$, as moderately soft, 120-180 mg L^{-1} as hard and >180 mg L^{-1} as very hard. Based on this classification, only 33.4% of the water samples was soft. Goski and Taderz (1981), reported that water hardness ranged from 149 to 419 mg L^{-1} $CaCO_3$. Hardness renders water useless in laundry work and causes excessive scale formation. Sample GW_{16} had the highest chloride level, similar results was obtained for the same sample in conductivity, hardness and dissolved solids levels, this could be caused by nearness of the well to the waste site. The chloride in all the sampling sites were below the highest desirable level of 250 mg L^{-1}. High chloride content could cause corrosion. Normally, phosphates were absent in drinking water and the presence of measurable amounts is an indication of water contamination. The present study showed phosphate contents ranging between 0.00 and

1.13 mg L^{-1} (Table 2). The nitrate (NO_3-N) and sulphate (SO_4) values were in the range of 0.05 to 1.51 and 0.0 to 3.8 mg L^{-1}, respectively, which were lower than the recommended values for drinking purposes (Table 3).

In 38.9% of the samples, lead exceeded WHO values for drinking water, zinc however had a mean of 0.3 mg L^{-1} which is lower than the recommended values in drinking water (5.0 mg L^{-1}) for human consumption. A maximum of 200 mg L^{-1} of sodium is allowed in drinking water, only 11.1% of sodium in the water sampled exceeded WHO standard for drinking water, the levels of calcium, bicarbonate, hardness and alkalinity could be attributed to the presence of limestone formation in the study area.

Comparison with other urban pollution studies: The studies in Table 1 suggest that urban areas are characterized by high major ion concentrations, often by high metal concentrations where industries are present. The water quality in Lagos urban aquifer fits this general pattern, major ion concentrations were high but not excessively, trace metals e.g., Pb analyzed was also high. The studies in Table 1 also indicate that organic and bacteriological pollution are to be expected. For example, Gosk *et al*. (1990) found chlorinated hydrocarbon solvents at all sites investigated where organic chemicals had been used. On this basis, it is very likely that there is both organic (solvents and hydrocarbons) and bacteriological pollution in the city of Lagos.

Other studies have been carried out in Nigerian urban areas. Ikem (2002) found high major ions, nitrate and COD in ground water near two waste sites in Ibadan and Lagos. Ayejuyo (1994) found 0.01927 ppb Aldrin, 0.01842 ppb Lindane, 0.1643 ppb PCBs, 0.5156 ppb endosulfan and 2.0228 ppb DDE in groundwater from Ibadan city. However, Ipinmoroti (1993) Okoye and Adeleke (1991) found relatively good quality well waters from some selected locations in Akure. The degradation of water quality in Lagos could probably have resulted from human activities as well as municipal waste disposal within Lagos city. The comparison revealed that some of the water sampled was polluted with dissolved solids and trace metals.

CONCLUSION

There are a number of published studies on urban groundwater pollution but relatively few of these are from the developing world. However, it is often in the developing world that most reliance is placed on local groundwater supplies. This is the case for Lagos where many of the urban poor rely on dug and shallow wells for all their water needs. The citywide and local investigations reported here indicate the pollution of ground water by a range of species including trace metals and solids. The source of the pollution is, as in many other parts of the world a combination of inadequate sanitation and industrial discharge or spillage or dumping.

Irrespective of source of pollution, the analytical results revealed that ground water from these wells requires further purification to ensure their suitability for human consumption because the levels of some of the water quality parameters exceeded the WHO guidelines for drinking water. There is also need to educate well owners on the implications of inadequate well protection from storm water/runoffs and siting wells near waste sites or septic tanks. The areas need to be studied during the dry period to fully evaluate the impact of pollution on ground water and the health of the citizens in the neighbourhood. The Federal government of Nigeria has set up the States and Federal Ministry of Environment (FMEnv) to help protect the Nigerian environment from pollution in general. Some of the measures to help curtail pollution of the ground water include laws on discharge and disposal of wastes especially industrial wastes, drinking water guidelines for Nigeria, new and better designed waste sites in Lagos city.

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