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Characteristics of groundwater in Port-Harcourt local Government area

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A B S T R A C T

The study was carried out in Port Harcourt Local Government Area, during the dry season. The quality of groundwater in the area was studied using existing deep water well (borehole) constructed with steel casing and screens. Also shallow wells (hand dug) were investigated. Water samples from the groundwater were collected directly from the wells for a period of five weeks and analyzed. The results in all cases showed that pH was acidic (less than 6.5) as against the WHO tolerance limits of 6.5 – 8.5. Iron appears to be relatively higher (0.38mg/l) in borehole groundwater at station 1, Bundu as against WHO – specified maximum value of 0.3 mg/l. Iron is leached by the acidic and corrosive ground waters (pH less than 6) from the steel well-structured and iron pipe network, laterized soil cover that are in vertical continuity with the aquifer and iron rich sediments, particularly iron coated and stained sand and pebble grain. Neither odour nor taste was noticed in all the groundwater sampled. Also there were no fecal coliform and other coliform organisms present during bacteriological analyses. Water treatment involving demineralization (acid medium removal) and iron removal are necessary in order to improve the quality of ground waters under study.

Capsule Summary: The quality of groundwater in the area was studied using existing deep water well (borehole) constructed with steel casing and screens from Port Harcourt Local Government Area were studied. It was observed that demineralization and iron removal are necessary in order to improve the quality of ground waters under study.

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INTRODUCTION

Water is the most important, precious and versatile substance on earth because all forms of life needs it for survival. Therefore, adequate supply of potable water is essential for any meaningful developmental programme of any nation. To achieve this noble objective, governmental efforts should be geared towards the proper location, efficient development, conservation and management of the efficient development, conservation and management of the country's water resources (Abam, 1996; Gobo, 1990; Emongor, 2005; David, 2006; Harrisob, 2004; kielv, 1996; Bhatia, 2006 & Cobbit, 1998). This realization has led the Federal Government of Nigeria to establish the Federal Ministry of Water Resources which serves as a national coordinating agency to manage all water resource development programmes in the country. To effectively achieve these goals, River Basin Development Authorities were established in the country (Harrisob, 2004; kielv, 1996). Their Functions include the Following: undertake comprehensive development of groundwater resources for multi-

Fig. 1: Map of Rivers State Showing Port Harcourt Local Government Area Climate

purpose uses, to construct and develop wells and boreholes and to provide and supply water to the urban and rural communities of their areas of jurisdiction. State water boards were also established to translate and concretize the water policies of the Federal Government "water for all" into reality (Narayanan and Emeka, 1997; Nwaogazie, 2006).

The activities of all these corporate bodies have generated a lot of hydrological and hydro-geochemical information on the water resources potentials of Nigeria. These data, however, are generally poorly managed and interpreted. In view of this, they are rarely used in the water planning and management programmes of Government. The reason for this is partly related to the lack of well trained professional staffs to properly interpret these data (Akintola, 1986; Amajor, 1986; Leton, 2004).

In Rivers State almost 50% or more of the population live in the reverie area where communities live in isolated barrier island, beaches, and other emergent land areas separated by tidal flats, channels and swamps. The water environment is characterized by brackish water which is not good for human consumption. The lack of potable water in this area is further compounded by saline water intrusion into fresh water aquifers in the coastal areas (Akintola, 1986; Amajor, 1986; Leton, 2004; Narayanan and Emeka, 1997; Nwaogazie, 2006, Onveagucha, 1980; SPDC, 1995; Gobo, 1988; Etueffeotor, 1981 & Ross, 1997).

About thirty percent of groundwater consists of fresh water, most of which are inaccessible, unusable or may be obtained at great expense of energy. Only three tenth of one percent of total freshwater can be truly considered as renewable. The water from rainfall, seeping into the soil to nourish plant and tree growth and lakes flow into the ocean and evaporating into the atmosphere in a natural hydrological cycle that will produce more rain. Without clean water, people's health and livelihoods can be severely affected. The international community has set ambitions millennium developmental goals to reduce by half the number of people without clean water by 2015 (United Nation, 2003). In this context, the need for sustainable development of groundwater cannot be overemphasized. Across the globe, Africa, South America and Asia, groundwater provides the realistic water supply option for meeting dispersed rural demand. Alternative water resources can be unreliable and expensive to develop. Surface water (if available) is prone to contamination and often seasonal (Sharma, 2006).

Rainwater harvesting can be expensive and require good rainfall throughout the year. Groundwater however can be found in most environments with appropriate expertise. Groundwater can be difficult to find in some areas. For example in Sub-Sahara Africa alone, up to 300 million rural people live in areas where finding groundwater is difficult and special techniques are required to help locate groundwater close to the community (Narayanan, 2006; Offordile, 1992; Oteri, 2005; Walton, 1970; Swingle, 1967; Scruton, 1960; Short and Stauble, 1967; Howarit and McGillivary, 2001; Papadaki, 1961 and Wilson and Fredrick, 1999). Following the above discovery the quantity, quality, regularity and forms of water supply become central relevant and form a key variable. In the present study, this key variable is accepted as surrogate for assessment of the status of Port Harcourt groundwater. In most part of the world, it is known as necessity in human life. Port Harcourt and other parts of the country in general require potable water supply. The quality is usually high since residents' carryout modern and traditional economic activities, most of which require regular supply of fresh water. Water is required for most forms of normal food processing in Port Harcourt including other parts of the country. Water uses from fermentation of cassava to packaged food processing. Water is required for traditional medicine for health care, body hygiene, domestic cleanliness and protection against fire outbreak, water also provides transportation, fishing and modernized aquatic and recreational activities (Veissman and Hammer, 1993; Anis, 1978; Altman and Parizek, 1995; Simpson, 1954).

Objectives of the Study include: to investigate the physicochemical and biological parameters of the groundwater within the study areas, attempt to establish and determine the source(s) of pollution in the ground water and compare the results of the study with World Health Organisation (WHO) in order to determine their suitability for domestic use. Scope of the study include: data collection, data Analysis Results will be compared with water quality standard of who to determine how potable the groundwater under study were and attempt would be made to plot a distribution of the various concentrations of the dominant anions and cautions in the study areas.

The research shows the status of groundwater in the study location. Food and beverage industries can utilize the information on the various locations of the groundwater to site their companies in order to minimize cost of water treatment.

MATERIAL AND METHODS

Study area

The study area is Port Harcourt (P.H) city otherwise known as Port Harcourt City Local Government Area (PHALGA) shown in figure 3.1 and is situated approximately on latitudes 4^o 40^1 N – 50^1 N and between longitude 70.00^1 E – $7^0 10^1$E. It has a land area of about $70.31km^2$ approximately. The Local Government and Obio/Akpor Local Government make up Port Harcourt Metropolis, the capital of Rivers State. It is one of the towns in the Niger Delta State. It is one of the towns in the Niger Delta States. Port Harcourt City is bounded in the north by Obio/Akpor Local Government Area, in the East, it shares common boundaries with Eleme Local Government Area and with Okrika Local Government Area in the south stretching to the East. In the West, it is bounded by Asari – Tori Local Government Area.

Port Harcourt City displays climatic characteristics that could be classified as humid, semi-hot equatorial type (Papadaki, 1961: Gobo, 1990). The area experience heavy rain fall from March to October and even the dry months of November, December, January and February are not free from occasional rainfall (Gobo, 1988). The mean annual rainfall is about 2,500mm (Akintola, 1986). With the extensive rainfall and the consequent reduction in the infiltration capacity of the soil due to its low permeability, flooding is commonly experienced in most homes during the rainy season which wash the soil below the earth and into the drainage system.

Topography and draining

The city has a flat topography with inadequate drainage facility. Its elevation varies between 3m and over 15m above mean sea level. The low relief of the area is gently inclined towards the sea; thus discharges are into the major natural drainage, through the Bonny River.

The drainage network of rivers, streams and creeks of the study area include Bonny River, the New Calabar River and Okpokar rivers while the Creeks are Elechi, Woli, Amadi, Diobu and Dockyard. The streams are south flowing streams, which are turbid during the wet season due to the discharge of clay and silt into the drainage channels. In the dry season however, the discharge and turbidity are highly reduced (Abam, 1996).

Regional geology of the study area

Geologically, the rear lies within the Niger Delta, and the surface is classified as part of the Benin formation (Simpson, 1954). The geology of the Niger Delta has been well described by various authors (Abam, 1996). Sedimentological evidence suggests that the geometry of the delta has remained essentially the same since its inception (Short and Stauble 1967). The stratigraph of the Delta consists of three major units: the Akata, the Agbada and the Benin formations from base to top. The Benin formation is an extensive stratigraphic unit in the southern Nigeria sedimentary basin. The formation has a southern Nigeria sedimentary basin. The formation has a variable thickness of up to 1,400m (Onyeagocha, 1980). It is predominantly sandy with a few clay and shale intercalation Short and Stauble, 1967). The sands and poorly cemented sandstones are generally coarse-grained, with grains sub-angular to well round. The materials are believed to be deposited in a continental fluviatile to deltaic environment (Onyeagocha, 1980). The Benin formation is overlain by the coastal plain sands, deltaic plain sands, abandoned beach ridges, mangrove and freshwater swamps, meander belts and alluvium, and range in ages from Oligocene to Holocene (Etueffeotor, 1981).

Data collection

Both field and laboratory studies were employed to obtain data needed for the study. The field survey involved reconnaissance survey and collection of data on existing groundwater supply systems.

Field study

In this study, it is very important that the groundwater samples collected is fairly represented. Five (5) boreholes sampling stations were established along the study zone (Port Harcourt) and designated station one (STN_1) to five (STN_5). The locations and their respective designation are represented in Table 1 and Figure 2.

Two hand dug well water sampling stations were equally carried out in the zone and designated stations were equally carried out in the zone and designated station six (STN_6) to seven (STN_7) as presented in Table 2. Before the sampling commenced, the following precautionary steps were taken during borehole and hand dug well waters sampling.

Water sample bottles and containers were thoroughly washed with detergent solution, rinsed in tap water, then soaked in chromic acid to remove organic materials and subsequently rewashed and rinsed with distilled water before collecting the sample.

Only analytical grades of reagents were used for analyses. Equipment was calibrated/standardized before actual measurement for result reproducibility. Sampled boreholes and hand dug wells were chosen to reflect the ground waters of the zone. Permission to collect water samples was obtained from the groundwater owners. This was possible and easy because they were convinced that it necessary and to their advantage. Sampling was done for a period of five months. Each of the borehole from which water sample was collected was pumped and allowed to run for about 20 minutes before 1 litre of water sample container was used for collection. This method prevents iron contamination by wall structure and flushes out all the fine and suspended sediments in the borehole sump and aquifer (Amajor, 1986).

Samples from the hand dug wells were collected by means of 1 litre of plastic bottle tied to a rope. Water samples were taken from the water outlet at the borehole site to minimize contamination by the galvanized pipeline distribution network. Each water sample collected was properly identified with appropriate labels indicating location, water temperature, date, sample number, time collected.

To minimize sample deterioration and therefore avoid unrepresentative analytical results, only one or two ground waters were sampled per field visit. In situ measurement of sampled groundwater temperature was taken in the field during sampling with mercury in glass thermometer. The pH, turbidity and Total Dissolved Solids were all measured using the multi-meter Horiba U-10 water checker. Each sample was immediately taken out from the groundwater source and the equipment dipped into it. Turbidity sample was gently agitated after collection in order to ensure a representative measurement. All samples were immediately stored in an ice cooled box and transported to the laboratory for analysis.

Laboratory analyses

Table 1: Borehole Sampling Stations

Designation	Locations
STN_1	Bundu
STN_2	Aggrey Road
STN_3	Diobu
STN_4	Abuloma
STN_5	Trans Amadi

Table 2: Shallow Hand Dug Well Sampling Stations

Designation	Locations
STN_6	Bundu
STN_7	Aggrey Road

This phase of the study methods covers essentially the physicochemical and biological parameters of water quality. The physicochemical parameters analysed include pH, turbidity, total dissolved solids, chloride, Iron, conductivity, copper, magnesium, Nitrate and sulphate while bacteriological parameters are faecal coliform and other coliform organisms.

pH: The multi-meter Horiba U – 10 water checker was used in determining the pH of the water samples. The measurement was made by immersing the electrode into the beaker containing the water sample and the reading taken.

Conductivity: This was determining using the multi-meter water checkers. The electrode was immersed into the beaker containing the samples and the samples and the readings taken.

Turbidity: Turbidity of water samples was also determined using the multi-meter water checker. The electrode was immersed into the beaker containing the water sample and the reading taken.

Nitrate ($N0_3$): Nitrate was analysed by Brucine method. A 2ml of water sample was measured in a standard rack and turned into a conical flask. Also 2ml of sulphuric acid (H_2S0_4) was measured and added into the sample and allowed for 20 minutes to cool. Then 0.2ml of the brucine sulphate was added. The sample was heated in a water bath to cool down. Then absorbance blank reading was taken with a corresponding absorbance reading of the sample in a spectrophotometer at a wavelength of 410nm.

Sulphate ($S0_4^{2-}$): The turbidmetric method was adopted in determining sulphate concentration in water sample. 50ml of water sample was added to 2.5ml of conditioning reagent (made up of 50ml glycerol with a solution containing 300ml distilled water. 100ml of 95% ethyl alcohol and 75g NaCl) and it was mixed by swirling before a quarter spoonful of Barium Chloride was added and swirled for exactly 1 minutes. The contact was placed into 1cm curvette after 5 minutes and absorption read off at 420nm in a spectrometer 21D model.

Similar procedures involving different reagents were adopted in analyzing other water samples for chloride iron, copper. The individual metal content was determined respectively by aspirating the samples into Perkin Elmer atomic Absorption spectrophotometer (AAS) model 3110.

The water samples for the determination of odour and taste were collected in 2.5 liters clean plastic container and analyzed in the laboratory. Bacteriological analysis for the determination of fecal coliform and other coliform organisms' samples was carried out using sterilized wide mouth plastic bottle, preserved and analyzed in the laboratory.

RESULTS AND DISCUSSION

The results of laboratory analyses on groundwater samples from the borehole and dug wells in Port Harcourt presented in table 1 and 2 were plotted against time on rectangular scales using chart wizard in excel doc. The limited value of each of the water quality parameters specified in the WHO standard for drinking water were also plotted on the scale in each case. This enabled for easy comparison between the results obtained and those in the WHO guidelines, and particularly to determine;

1. The trend in the values of parameter over time.
2. The parameters whose values (concentrations/levels) are off WHO specified limits.
3. Which of the parameters call for treatment of water to improve its quality?

The pH results were unsteady with values that range from 5.3 to 6.3, indicating that the groundwater was all acidic. The acidity value was highest at station 5, (Trans Amadi) with a pH of 5.3 as presented in Figure 3. This is where the slaughter house is located. It is likely that the slaughter effluents are being discharge into river with its high concentration of organic waste, percolates into the water aquifers contributing to the low pH value obtained at the station. This is in agreement with Swingle, (1967) who reported that organic waste reduced the pH of water to acidic level. According to Walton, (1970) groundwater with pH values between 4 and 6 are associated with small amount of mineral acids from sulphide sources a /or organic acids. Tyres used for roasting the meat contains sulphur which is acidic contribute to the acidity of the groundwater during infiltration. Also in Bhatia, (2006), it is emphasized that acidity generally results from the presence of weak acids, particularly CO_2 but sometimes, including protein and fatty acids. The high microbial activity at station 5, which may result from the breakdown of organic matter by bacteria, could contribute to high CO_2 in the groundwater. WHO, (2006) prescribes pH of 6.5 as the least desirable level for drinking water 8.5 as the maximum permissible level? None of the groundwater study attains this standard. Station 4, Abuloma has acidic value of 5.8.

There is no marked difference between the pH of Trans-Amadi (5.5) and that of Abuloma (5.8). The cause of the low pH of the groundwater sources in the areas are the activities, including the rain water which carries with it dissolved gases that contribute to the formation of various kinds of acid whether in the atmosphere or in the soils beneath. Station 3, Diobu has a pH of 6.3, indicating acidity. It has a higher pH than all the other stations sampled. This could be as a result of geologic formation of the soil such as reduction in acidic level resulting from ion exchange in the soil or soils are not sufficiently enriched with acid forming nutrients.

Stations 1 and 2 (Bundu and Aggrey road) have pH values of 5.4 and 5.6 respectively, also indicating acidity. The two stations have high acidic groundwater. These could be as results of sea water intrusion which account for the relatively high chloride contents. The highest chloride values 98.7 mg/l and 60.2 mg/l for Bundu and Aggrey road respectively are found in these stations. With a poorly defined northwesterly trend from Bonny through Okrika to south of Port Harcourt, this trend correlates with higher conductivities and is thought to be suggestive of sea water intrusion. Also the only two hands dug wells found in the stations Bundu and Aggrey indicate acidic content of ground water, resulting from brackish water intrusion (Table 2). In summary, the groundwater in Port Harcourt is generally acidic.

The total dissolved solid (TDS) of the groundwater under investigation is low and within acceptable range. The presence of iron and other anions and cations in water contribute to the amount of solids in it. Hence a drop in pH resulted in increase in acidity level which in turn caused corrosion of metallic materials leading to increase in TDS. But since materials of construction such as well

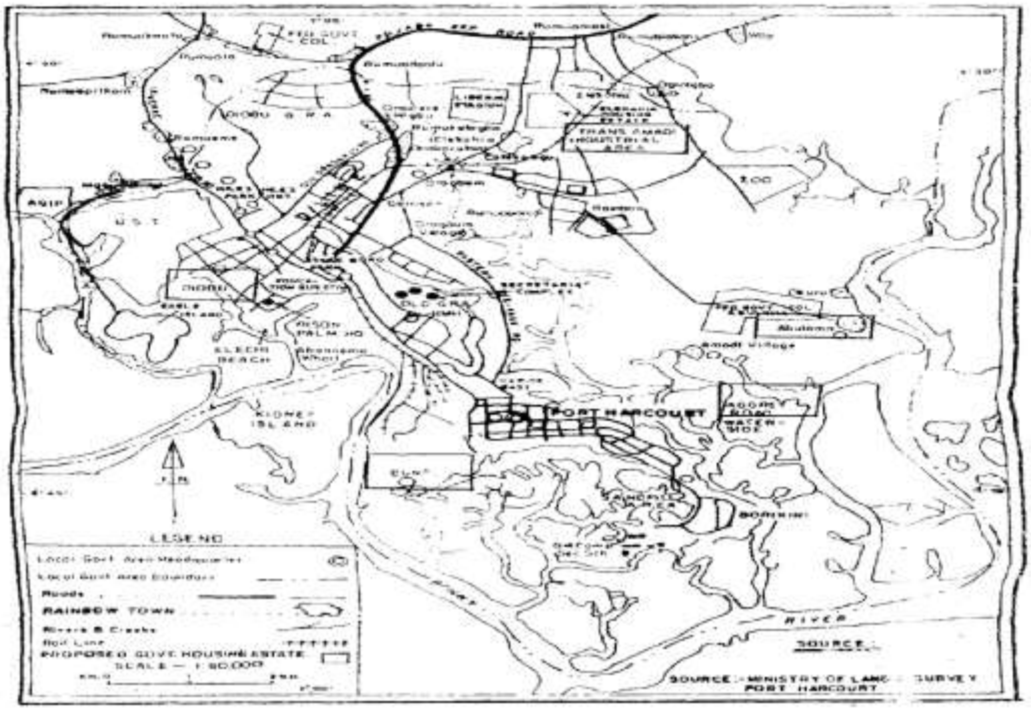

Fig. 2: Map of Port Harcourt Local Government Area Showing Sampled Ground Water Stations

casing are only related to occurrence of iron in the water, the effect of corrosion could not significantly affect the TDS values. The low TDS values occurring with equally low chloride also supports the assertion that the principal constituents of TDS are chloride, sulphate, magnesium, calcium and bicarbonates (Environment Canada, 1984).

Station 1, Bundu has the highest value, 240mg/l of total dissolved solid than other stations. This could be as a result of presence of more ionic substances, salt and is located towards the sea which in turn influenced it. The reason suggested for borehole waters are also applicable to hand dug wells. The value of TDS in hand dug well is higher 300mg/l than that of borehole well water because hand dug wells are constantly open and their limitation involves the ease of their pollution by surface water, airborne materials or objects falling or finding entrance into the wells as presented in Figure 4.

The range of total dissolved solids is from 120mg/l to 300mg/l. These values are far below the WHO regulation that allow tolerance limit of 500mg/l. Generally, the relative high TDS does not affect the groundwaters under investigation.

Highest iron concentration occurred at station 1 (0.38m/I) while station 6 has the least iron concentration of 0.1mg/I.

Iron in the borehole water was higher than the shallow hand dug well. This could have resulted from large amount of iron in the soil and geologic formation or picked up from steel materials used for well water construction (e.g casing). Thus, in addition to the amount of iron naturally present in the ground, more iron is introduced into the water as the borehole, casings are corroded by the acidic water resulting from low pH, and iron is leached out.

The open shallow hand dug well has the least iron content (0.1mg/I) when compared to borehole waters. This sharp disparity between the open shallow well and the drilled (borehole water) could be attributed to the fact that the open shallow hand dug well was constantly exposed to the atmosphere from which large amount of oxygen was obtained to oxidize the soluble ferrous iron to insoluble ferric iron. In the case of borehole, the supply of oxygen is limited or inhibited, little or no oxidation took place hence the soluble ferrous iron remained thereby contributing to higher concentrations as presented in Figure 5. Only station 1 (0.38mg/I) exceeded the permissible limit of WHO value of 0.3mg/I.

The conductivity of a substance is its ability to conduct electricity (electrical conductivity). This property of water is dependent upon temperature and concentration levels of the various ions present. Conductivity level decreased from station 1 (450 μs/cm) to station 4 (200 μs/cm) and then rose again to 350 μs/cm at station 6 (Bundu shallow hand dug well). David and De Wiest (1966), Bhatia S.C. (2006) suggested that normal groundwaters should have conductance of 30 to 2000 μs/cm. According to these authors, the highest conductance values may be related to the presence of sodium chloride waters while the lowest values may be a reflection of the presence of calcium bicarbonate and calcium sulphate ions. Bundu is closer to the sea; the relative highest value (430μs/cm) is an assertion that there is presence of more sodium chloride than other stations. Unesco and other (1992) suggested that water body receiving large quantities of large runoff is associated with high conductivity level. Stations 6 and 7 (Hand dugs wells which have high conductivity values of 395ps/cm and 320 μs/cm support this assertion as presented in Figure 6. However, if the maximum tolerance limit of WHO is l250μs/cm, then all the groundwater under investigation are potable.

Copper concentration of less than 0.4mg/l was obtained at all the stations. The highest value (0.3mg/l) and lowest values (0.01m/l) were obtained at stations 2 and 3, 4 respectively. The values are in accordance with of WHO tolerance limit of 1.0mg/I. Low values of copper concentrations indicate that the groundwater contain permissible inorganic salts of copper metal as presented in Figure 7.

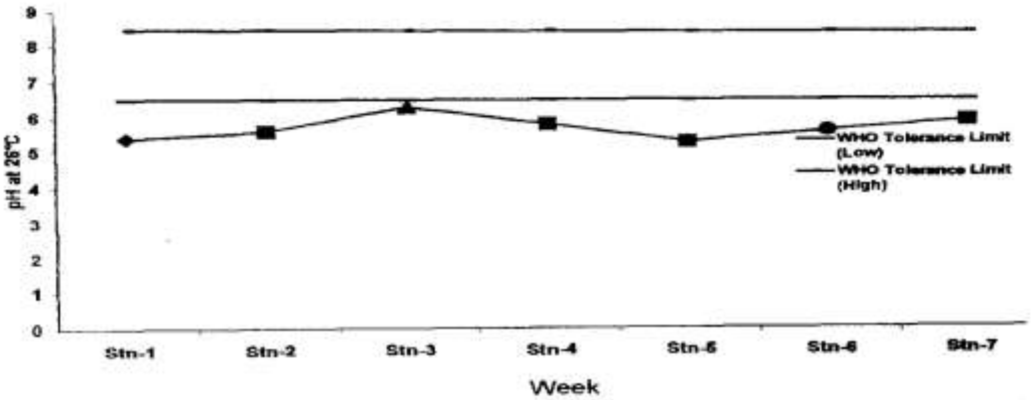

Fig. 3: Transient pH at 26 ^{0}C of ground water at different stations and time

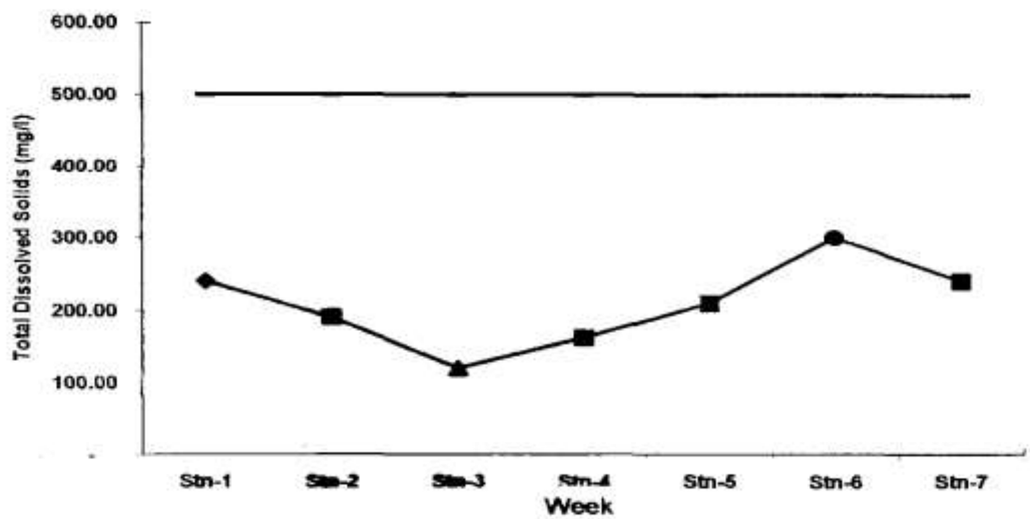

Fig. 4: Total dissolved solids (mg/l) in ground water at different stations and time

Concentrations of magnesium ranged from 0.1 to 0.41mg/l. when compared to WHO standard of 30mg/l, the groundwater in Port Harcourt are generally potable as their concentration are low as presented in Figure 8.

Nitrate concentration was unsteady in all the sampled stations. Concentrations ranged from 2.4 to 15.3 mg/l. The highest value 15.3mg/l was obtained in the shallow well at station 6. This could be as a result of likely contamination from private privies or septic tanks in the neighborhood. Presence of high nitrate concentration of more than WHO tolerance limits of 50mg/I is an indication of high presence of nutrients that could likely stimulate algae growth in shallow wells. The relatively high value recorded in the shallow well could also be as a result of possible infiltration of sea water Sharma, (2006). However, the concentrations of nitrate in all the sampled stations are below the WHO tolerance limit. They do not significantly affect the groundwater quality even though they vary in concentrations with time as presented in Figure 9.

Sulphate concentrations ranged from 2.8 to 14.0 mg/l at the established sampled stations. Sulphate concentrations were unsteady with its highest value (14.0mg/l) recorded at station 7, the shallow hand dug well at Aggrey. The shallow well is liable to intermittent pollution by air borne materials and objects falling or finding entrance into the wells. Concentration in excess of WHO tolerance limit of 250mg/l makes water unpleasant to drink. Harrison, (2004) emphasized that high sulphate concentration pose special problem in the conditioning of water, for it generally means extreme hardness, high sodium salt concentration and high acidity as presented in Figure 10.

Generally, all the sampled groundwater stations compiled with WHO regulation as their sulphate concentration are below the WHO tolerance limit 250mg/l.

Possible iron sources

1. Sharma (2006) noted that groundwaters with ranges from 5-8 are sufficiently reducing to carry much as 50mg/l of ferrous ions at equilibrium if bicarbonate activity does not exceed 60mg/l. This phenomen is thought to obtain in Bundu area Harcourt because the ground water when initially drawn from the borehole was usually clear but later become cloudy and then brown due to the precipitation of ferric hydroxide resulting from aeration of the water. It should be noted that under reducing conditions (pH less than 7). Iron exists in the soluble ferrous state. On exposure to air (i.e addition of oxygen, 0_2), ferrous iron is oxidized to the insoluble ferric state and may hydrolyse to form insoluble hydrated ferric oxide.

2. **Well structure and piping network**

The pH values of the groundwater in Port Harcourt have already been established to be acidic and corrosive. Therefore in situations where the welt structure (pump, cables, casing, screens) and piping

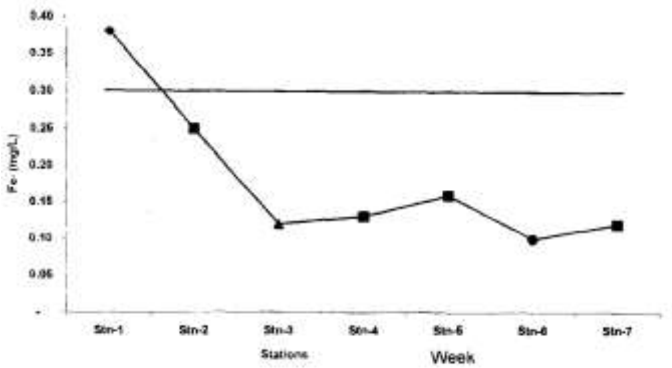

Fig. 5: Transient Fe (mg/l) content in ground water at different stations and time

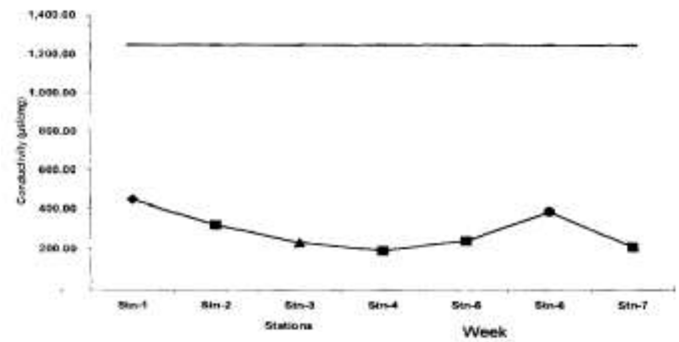

Fig. 6: Conductivity (μs/cm) of ground water at different stations and time

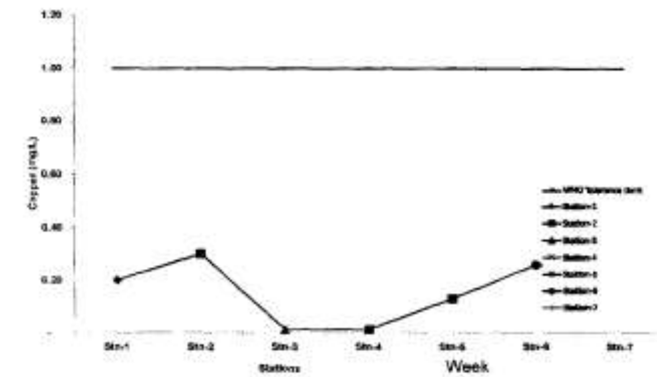

Fig. 7: Transient Copper (mg/l) content in ground water at different stations and time

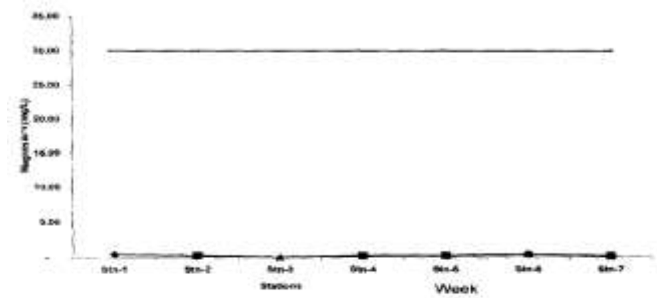

Fig. 8: Transient Magnesium (mg/i) content in ground water at different stations and time

network for water, gas are composed of iron, It could be easily leached and entrained into the groundwater system in the soluble ferrous state. Evidence in support of this iron source is manifested by the brownish or reddish brown water produced from taps when water is first drawn from the well after a few days of not running the pump.

3. **Leaching of Iron from sedimentary rocks**

The soils formations could contain much peat, lignite, organic matter and clay inter-beds. These are commonly pyritic, Amajor (1986). According to Scruton (1960), this type of lithologic sequence typifies detals all over the world. Therefore, iron could be leached out of the sediments and pyrite and entrained into the groundwater system in the following reactions (Davies and De Wiest, 1966; Hem, 1970; Bouwer, 1978).

$2FeS_2 + 7\ 0_2 + 2H_20 \rightarrow 2Fe\ S0_4 + 2H_2S0_4$

$4FeS0_4 + 0_2 + 10H_20 \rightarrow 4Fe\ (0H)_2 + H_2S0_4$

$4Fe(0H)_2 \rightarrow 4Fe0 + 4H_20$

Where the pyretic sediments are abundant and extensive, this could lead to the liberation of a high quantity of iron into the groundwater system, thereby contaminating it.

4. **Bacterial Action**

The chemical reduction of sulphur from S^{6+} (Sulphate to S^{2-} sulphide) occurs in groundwaters in the presence of certain types of bacteria. The solid products formed like iron are carried away to permit the reaction to go to completion. This may be another way in which iron can be added to the grounder system, particularly in very shallow aquifers.

Finally, the cumulative effect of these iron contamination sources is to enrich the groundwater system with iron. Poor well construction is also thought to be responsible for producing iron in groundwaters. This is because suspected horizons of contaminants (e.g Laterized soil, organic beds, brackish water interval) are never cemented off to prevent the contaminant from direct contact with the aquifer waters through the annulus of the borehole.

Water treatment

From the results of water quality analyses conducted on the various groundwater under study, pH and Iron contents were off WHO tolerance limit for potable water. To ensure safe drinking water, the sources of groundwater have to be treated for these water quality parameters- pH and iron. Thus the treatment process required to improve the quality of the produced groundwater to acceptable standard should involve pH correction and Iron-removal.

1. **pH (Acid medium) removal**

This involves the demineralization of water. Sharma (2006) defined demineralization of water as the removal of cations and anions of the substances dissolved in it. The water to be demineralized is first passed through hydrogen cation exchanger units for removal of cations, then through an anion exchange bed to replace the anions of acids by the exchange anion.

2. **Removal of iron**

Removal of iron in the water involves the introduction of strong oxidizing agent like chlorine in the treatment plant. The chlorine oxidizes Fe^{2+} ion to Fe^{3+} ion. Chlorine also helps to kill pathogens/bacteria that may find their way into the groundwater through leaching. Flocculation unit should be incorporated into the water treatment plant prior to sedimentation to quicken the process. Following disinfection, the well should be pumped to waste until all traces of chlorine are removed. As a final check on the portability of the water, a sample should be collected and sent to laboratory for bacteriological examination.

CONCLUSIONS

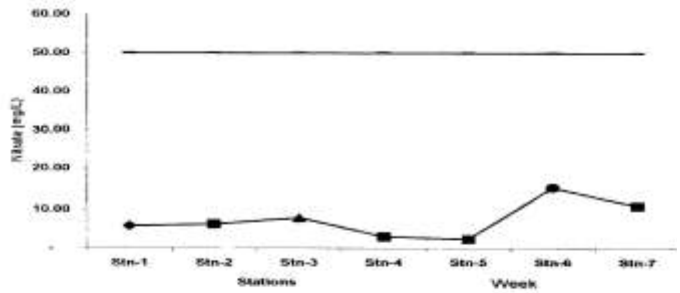

Fig. 9: Nitrate (mg/l) content in ground water at different stations and time

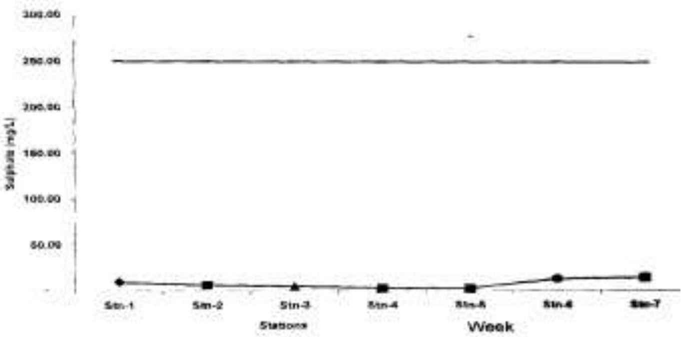

Fig. 10: Transient Sulphate (mg/l) sontent in ground water at different stations and time

It was observed that physical and chemical parameters that characterize the groundwater understudy, pH and partly iron are the major problems associated with the groundwater. The study revealed that iron in station 1 and pH in all ground waters were above WHO tolerance limits. The low pH values are characteristics of all groundwater involved in the study, thus signifying the acidic status of the sampled stations. pH values between 4 and 6 are associated with small amount of mineral acids from sulfide sources and/or organic acids, Walton (1970). Geologic formation, presence of free carbon dioxide in the ground and sea water intrusion on land contributes to acidity of groundwater. The acidic and corrosive groundwater is responsible for iron leaching from the well structure and piping network, organic sediments and entered into the groundwater system thereby causing contamination in the Port Harcourt groundwater.

In general, poor borehole construction, development and completion practices in the study area could enhance iron contamination of the groundwater system. The effect of Iron could be minimized by constructing well water with non-corrodable material such as polyvinyl chloride material. Because a well is particularly susceptible to corrosion due to acidic nature of groundwater, nonferrous metals, alloys and plastics should be used for screens in order to prolong the well life and efficient operation. The problems of groundwater supply can also be effectively tackled by providing appropriate treatment plant capable of removing pH-demineralization of water and iron-oxidizing it with chlorine. The period of the study was only for one season-dry season and may therefore not be used to make definite statements. Broader study in wide area and over a longer period covering the two seasons off the year is required for such purpose. Laboratory values obtained might not be very accurate because storage of samples prior to analysis could affect results. Cations such as Fe, Cu, e.t.c. are subject to loss by adsorption or ion exchange on the walls of the container. However, the study shows that simple and relatively data collection efforts yield basis for groundwater characterization.

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