IMPACT OF OIL EXPLORATION AND ENVIRONMENTAL POLLUTION ON GROUND WATER QUALITY IN SELECTED LOCAL GOVERNMENT AREA OF RIVERS STATE

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ABSTRACT

Groundwater remains one of the most important and reliable sources of water supply for man's use. In its natural form, groundwater is considered pure and unpolluted. However, anthropogenic activities such as crude oil and natural gas exploitation and production introduce foreign materials (contaminants) to groundwater which render it unfit for use. In this study, groundwater quality in oil bearing LGAs of Khana and Obio-Akpor in Rivers State was assessed. Water samples from existing boreholes were analyzed in the laboratory to ascertain their physicochemical characteristics. Results show that groundwater in the study areas are acidic and do not meet the World Health Organization (WHO) standard for drinking water which is a pH range of 6.5 – 8.5. While Khana has a pH range of 4.72 – 6.16 with a mean value of 5.23, Obio-Akpor recorded a pH range of 4.31 – 6.18 and a mean value of 4.79. The study traced the acid contamination to severe environmental pollution of the study areas as well as poor effluent and waste management practices. The study recommends adequate treatment of groundwater in the study areas before use to eliminate water borne diseases and corrosion/clogging of water facilities. It further recommends regular assessment and monitoring of groundwater in these areas to ascertain level of contamination and the likely method and technique for treatment and remediation.

1.0 INTRODUCTION

Groundwater is an important source of water for agricultural and domestic use in developing countries like Nigeria (Agbalagba, et al, 2011). Groundwater naturally contains dissolved minerals/salts/gases and other substances but only in concentrations that fall within the tolerable limits for human use. These substances are picked up as water flows from the surface through soil and rock strata/formations into the underground aquifer. When harvested in its natural form through drilling of wells/boreholes, groundwater is generally considered pure and uncontaminated.

However, groundwater does not exist in isolation. Hydrological cycle studies show that while groundwater can be recharged from surface water bodies – lakes, streams, swamps, rivers, seas and oceans, it can equally discharge into these bodies depending on the prevailing circumstances. This interaction is a major source through which groundwater can be contaminated. In the Niger Delta region water table is shallow and vulnerable to pollution from anthropogenic activities, mainly crude oil and natural gas exploitation and production. Groundwater can also be contaminated through salt water intrusion as well as other activities of man in Agriculture, industrial manufacturing, waste disposal, mining activities and oil exploration.

Rivers State is a coastal state which has a direct contact with the Atlantic Ocean (saline water). Fresh surface water, generally, is difficult to come by (about 0.3% of the earth's total fresh water) and even when available is highly vulnerable to pollution due to numerous industrial activities within the area. Potable water, therefore, must be sourced from groundwater which accounts for 30.1% of the earth's total fresh water. This scenario, therefore, puts so much pressure on groundwater resources in Rivers State including the areas of our case study – Khana and Obio-Akpor LGAs.

Rivers State is highly endowed with crude oil and natural gas reserves with a lot of upstream, midstream and downstream activities in the sector**.** High level of oil/gas exploitation, exploration, production, processing, distribution and utilization take place in the state all year round with their concomitant environmental hazards.

Oil spills, gas flaring, industrial effluent discharges into the environment are some of the consequences of oil exploration activities, which have impacted negatively on the environment and the quality of both surface and groundwater in the study areas. The famous UNEP Report of the devastation of Ogoni land by oil production activities is a case in point. The story is not different in the other parts of the state and indeed the entire Niger Delta region.

The ugly situation is made worse by recent developments in which angry youths of the region (Rivers State inclusive) by way of protests are engaging in crude oil theft, pipeline vandalization and illegal refining of stolen crude oil, causing even more pollution and degradation of the ecosystem. Remote sensing revealed the rapid proliferation in the past two years of artisanal refining whereby crude oil is distilled in makeshift facilities *(UNEP Report on Ogoni land, 2011).* The study found out that this illegal activity is causing pockets of environmental devastation in Ogoni land and neighbouring areas and endangering lives. Groundwater, no doubt, is among the victims of this environmental pollution and devastation.

Gas flaring is still a regular feature in the landscape of Rivers State including the study areas of Khana and Obio-Akpor Local Governments. Gases such as carbon dioxide, oxides of sulphur and nitrogen which are usually injected into the atmosphere produce *acid rain* in a state that records heavy rainfall for most of the year.

Rivers State has two refineries with a total installed/production capacity of 210,000 barrels of crude oil per day representing about 47% of Nigeria's total refining capacity, a petrochemical plant, a fertilizer plant that is presently moribund but that has left in its wake tremendous environmental damage; not less than four gas plants, two very busy sea ports in Onne and Port Harcourt, numerous active oilfields/wells including offshore, many industrial/manufacturing companies, all of which exert environmental pressure on the state by way of pollution. It is instructive to note that the two refineries, the petrochemical plant, the moribund fertilizer plant, the Onne sea port, and quite a number of oil fields/wells are sandwiched between Khana and Obio-Akpor LGAs which are our study areas.

Water is an indispensable and essential requirement for the existence of any form of life, just like air. The availability of a water supply adequate in terms of both quantity and quality is essential to human existence (Peavy, et al, 1985).The importance of water can, therefore, not be over emphasized. While man can survive for a long time without food, he can hardly do the same for the same period of time without water. Water is needed by man for domestic purposes including cooking, washing, drinking and sanitation. Water is also required by man for agricultural activities - irrigation, growing of crops and processing his farm products; industrial manufacture of goods and production of power for energy. Water quality, therefore, must be ascertained to ensure it meets the required standard that can guarantee its safe use for both domestic and industrial/agricultural purposes.

2.0. STUDY AREA

This study was carried out in two local government areas of Rivers State namely Khana and Obio-Akpor. Rivers State is located in the oil rich Niger Delta Region, South-South geopolitical zone of Nigeria. It is bounded on the south by the Atlantic Ocean, on the north by Anambra, Imo and Abia states, on the east by Akwa Ibom state and on the west by Bayelsa and Delta states. It has a topography of flat plains with a network of rivers and tributaries. These include New Calabar, Orashi, Bonny, Sombreiro, and Bartholomew rivers.

2.1. Khana Local Government Area.

Khana is one of the 23 Local Government Areas of Rivers State. It is situated on the coordinates $4^0$42'N, 7^0 21'E. Bori serves as its administrative headquarters as well as the traditional headquarters of the Ogoni ethnic nationality spread across four LGAs namely Khana, Gokana, Tai and Eleme. It also serves as the commercial nerve centre for the Ogoni, Andoni, Opobo, Nkoro, Anang and other ethnic nationalities of the Niger Delta region of Nigeria.

Khana people are spread across 560 square kilometres with a population of 294,217 according to 2006 census figures. It shares boundaries with Oyigbo in the north, Tai and Gokana in the west, Andoni and Opobo/Nkoro in the south and the Atlantic Ocean in the east. Khana has a very rich arable land and is surrounded by rivers, creeks, and marshland. The traditional occupation of the people is farming, fishing and petty trading all at the level of mere subsistence.

2.2 Obio/Akpor Local Government Area.

Obio-Akpor has a total land mass of approximately 260 square kilometres and shares boundaries with Emohua (west), Ikwerre & Etche (north), Oyibo & Eleme (east) and Port Harcourt (south). By 2006 census records, Obio-Akpor had a total population of 878,890. Based on the national average population growth rate of 2.82%, Obio-Akpor's current population is projected at over one million people.

Obio-Akpor is rich with natural resources such as oil and gas, clay, sand, and gravel. It is one of the major centres of economic activities in Nigeria. Obio-Akpor has a high industrial base location as most of the companies in the state including key oil and gas companies are located in parts of the Local Government Area. It has a vast arable land, forest reserves and forest based resources such as fruits and vegetables and is surrounded by rivers, creeks, marshland, and semi-forest zones from where various fishes and other sea foods are sourced mainly for subsistence.

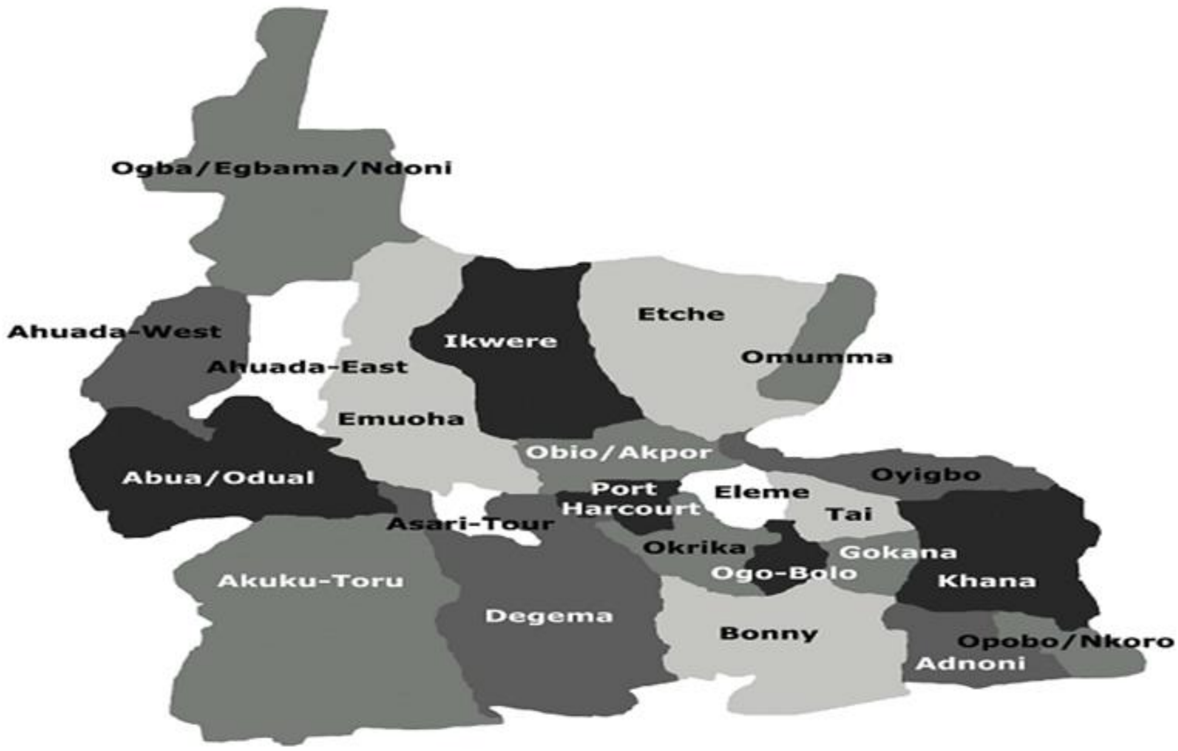

Fig.1. Physical map of Rivers State showing the 23 LGAs including Khana&Obio-Akpor.

3.0 RESEARCH METHODOLOGY

3.1 Field Collection of Samples

Groundwater samples were collected from different boreholes from different locations/communities in both Local Governments according to international best practice for sampling protocols. All collected samples were preserved in coolers and taken to the laboratory for analysis within 24 hours of collection to minimize interference and contamination of the physico-chemical properties of the samples.

3.2 Laboratory Analysis of Collected Water Samples

All the samples collected were analysed using internationally accepted standard laboratory methods as indicated in Table 1.

Table1. Laboratory Analytical Methods Used for the Physico-chemical Analyses.

Parameter	pH	Temp	Elect. Cond.	TDS	Cl	Fe	Ca	Mg	Pb	Cu	Zn
Analytical Method	ASTM D3921	ASTM D3921	Electro metric	APHA 208D	APHA 408C	APHA 301A	APHA 301A	APHA 301A	APHA 301A	APHA 301A	APHA 301A

4.0 RESULTS AND DISCUSSION

4.1 Results

The results show that all the groundwater samples analyzed are acidic with their pH below WHO's limit of >6.5 < 8.5 for potable water (Fig.2). However, all the physico-chemical properties analyzed and heavy metal presence in the samples are within WHO's permissible limit and are, therefore, acceptable for drinking and other domestic, commercial and agricultural purposes (Figs. 3 – 9)

4.2 Discussions

The acid contamination of the analyzed groundwater samples can be attributed to severe environmental pollution and degradation of the study area and the entire Niger Delta region as a result of oil exploration and production activities. Both Khana and Obio-Akpor have heavy presence of oil production activities including gas flaring which injects acidic gases - carbon dioxide, sulphur dioxide, oxides of nitrogen among others into the atmosphere. Nigeria is reported to flare more natural gas associated with oil extraction than any country in the world. Wikipedia Report (2007), show that natural gas in Nigeria's Niger Delta is flared into the environment at a rate of 70 million cubic metres per annum. Being a zone of heavy rainfall almost throughout the year, these gases are washed down to the soil as *acid rain*. Consequently these acid rain seep through the soil and percolate into the underground aquifer and contaminate groundwater.

Nwankwoala & Walter (2012), stated this much in their assessment of groundwater quality in Okrika Local Government Area of Rivers State: *Gas flaring in the area generates CO_2 which could have been dissolved in precipitation which percolates into the groundwater to reduce the pH.* Similar study by Nwankwoala &Amadi (2013) for groundwater in Port Harcourt, Eastern Niger Delta, showed that pH in Rumuolumeni and Elelenwo were respectively 5.90 and 5.93 and acidic. This study confirms the acidic nature of the groundwater in these areas and in fact indicate a deterioration of the acid contamination to pH of 4.50 and 4.90 respectively. This is an indication of three things:

a) No remediation actions have taken place since the 2013 study

b) The activities that lead to increase in pH are still continuing

c) The situation will get even worse if no remediation actions are taken.

The simple reason for the deterioration is that there have not been any coordinated effort by any government agency or the private sector to address the issue of environmental pollution and in particular water contamination and degradation. The much publicized UNEP Report of Environmental Assessment of Ogoni land is still gathering dust in Government files without any concerted effort to address the issue by implementing the recommendations. Instead, the matter has been politicized with the various stakeholders trading blames, accusations and counter accusations on each other and in the process abandoning the task of cleaning the environment and water supply sources to alleviate the challenges of the people.

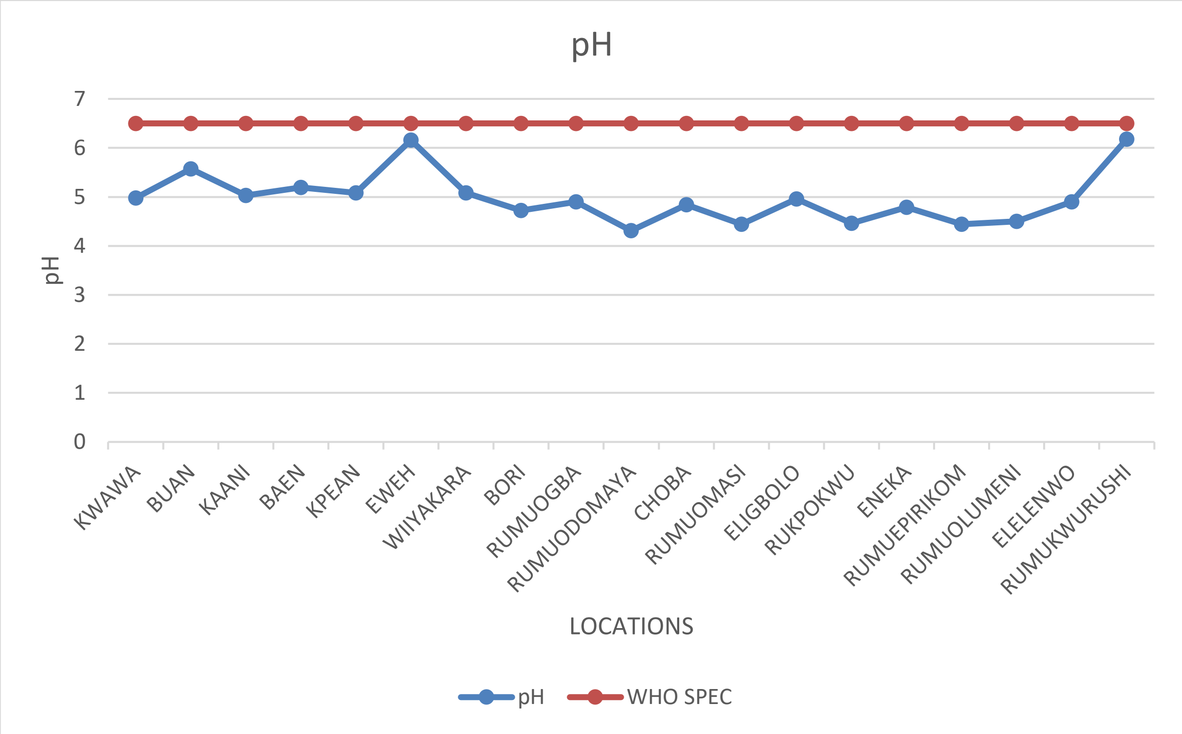

Fig. 2. Sample pH compared with WHO standards

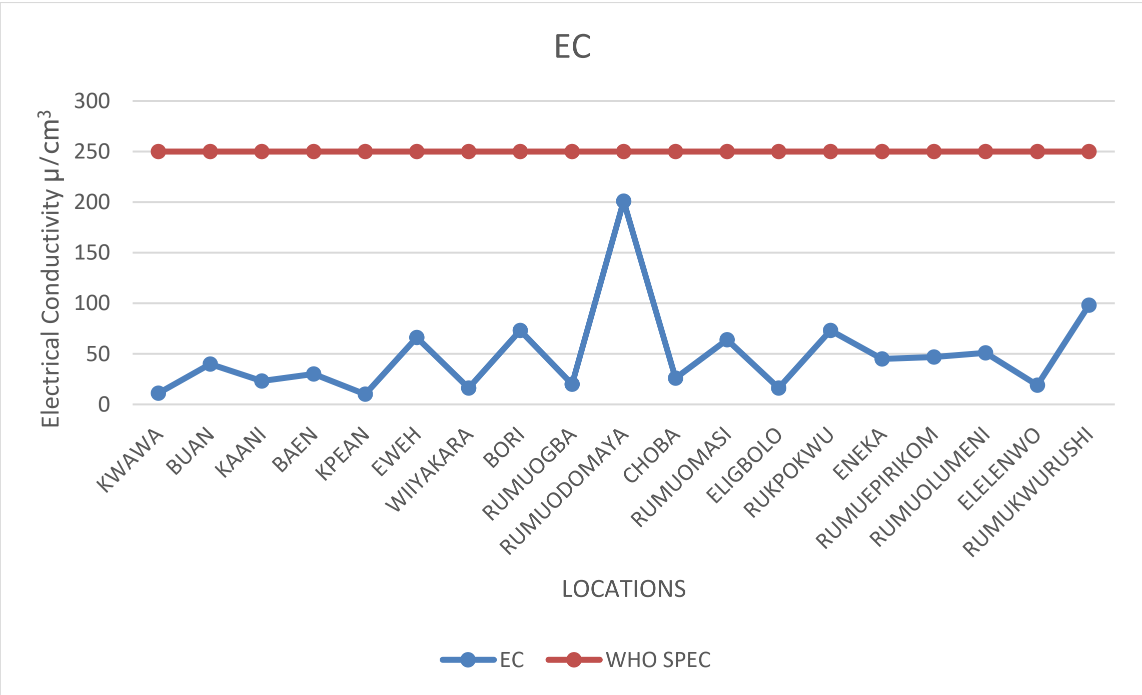

Fig. 3: Electrical Conductivity of Sample compared with WHO standards

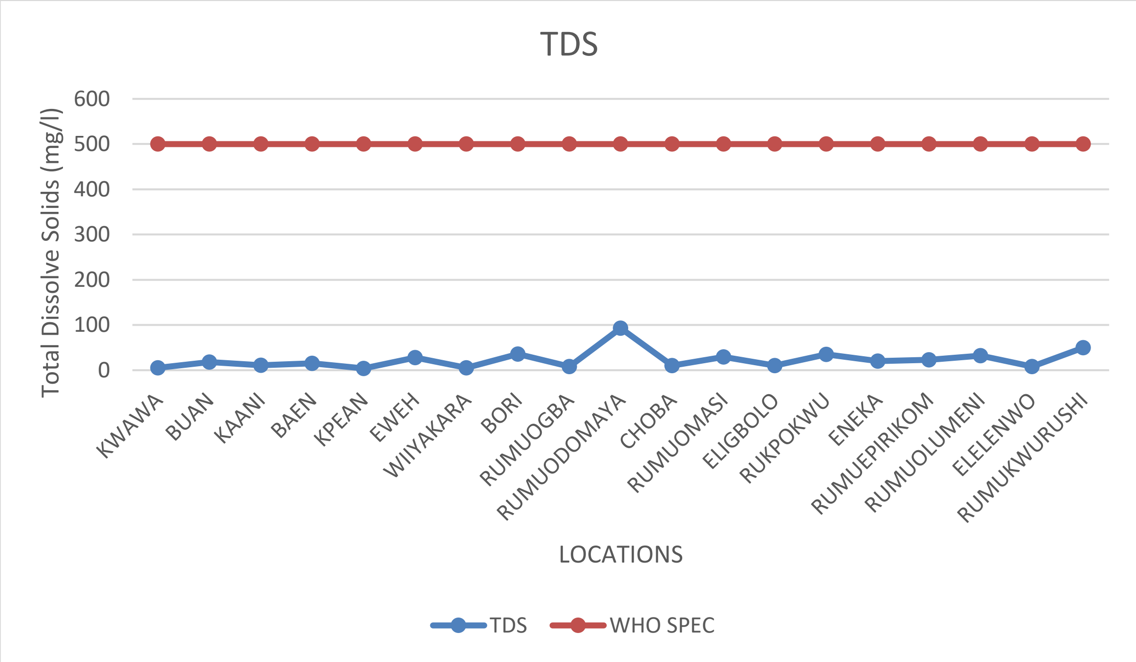

Fig. 4: Total Dissolved Solid of Sample compared with WHO Standards

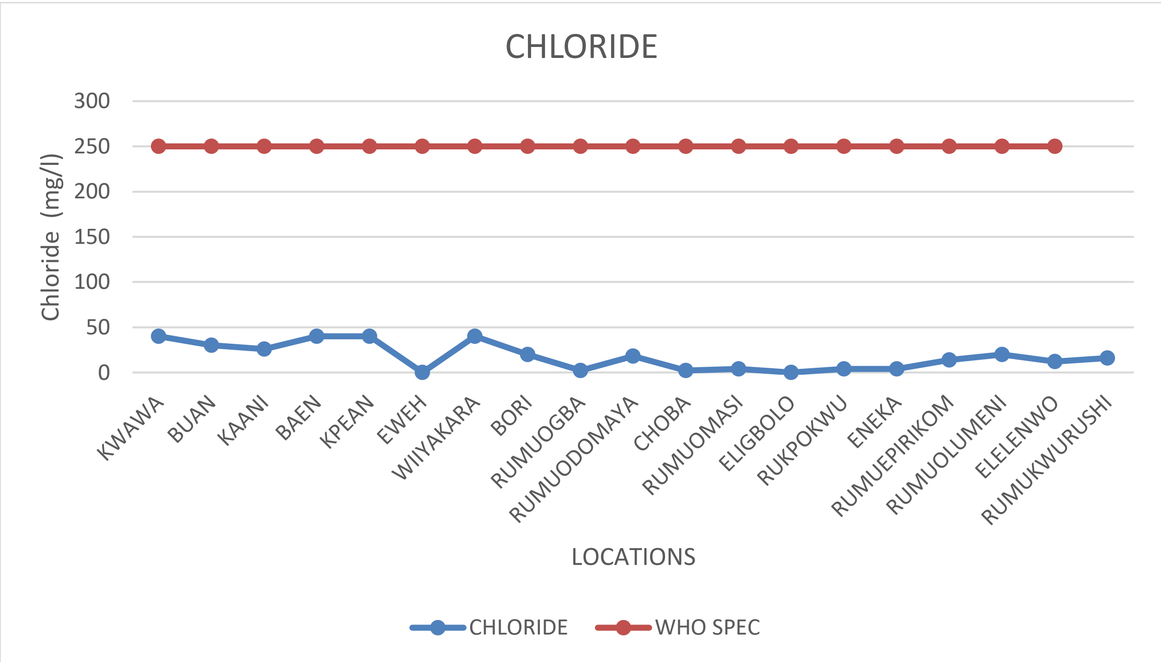

Fig. 5: Chloride Ion Concentration of Sample Compared with WHO Standards

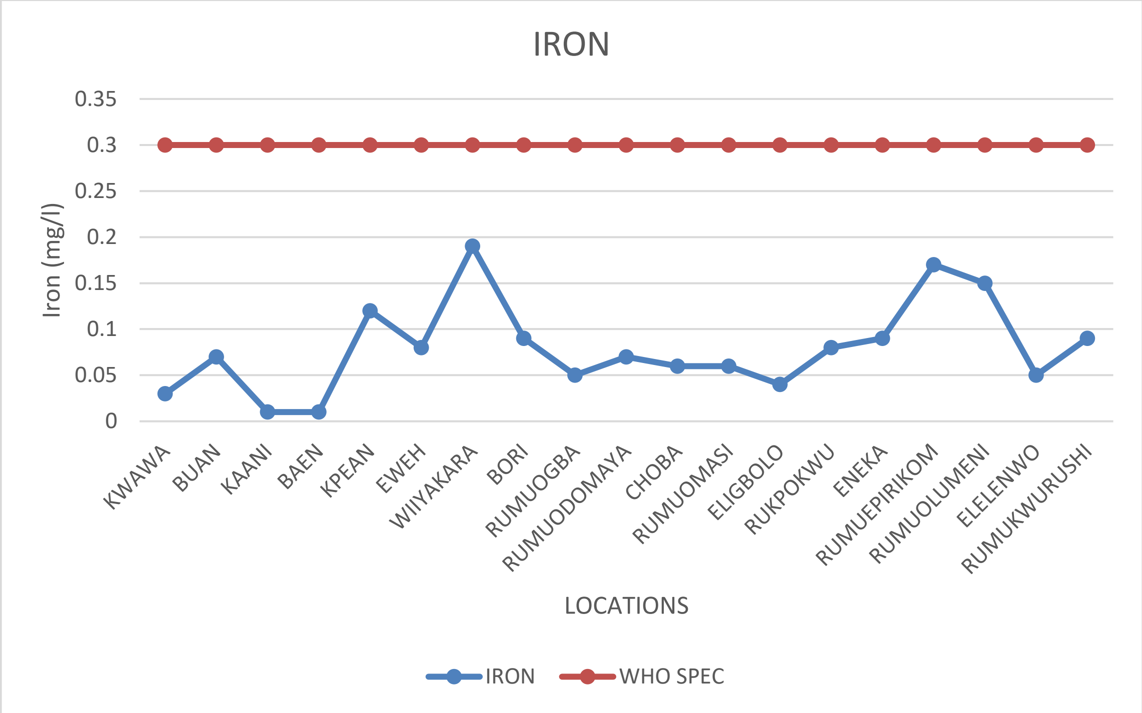

Fig. 6: Iron Concentration of Sample Compared with WHO Standards

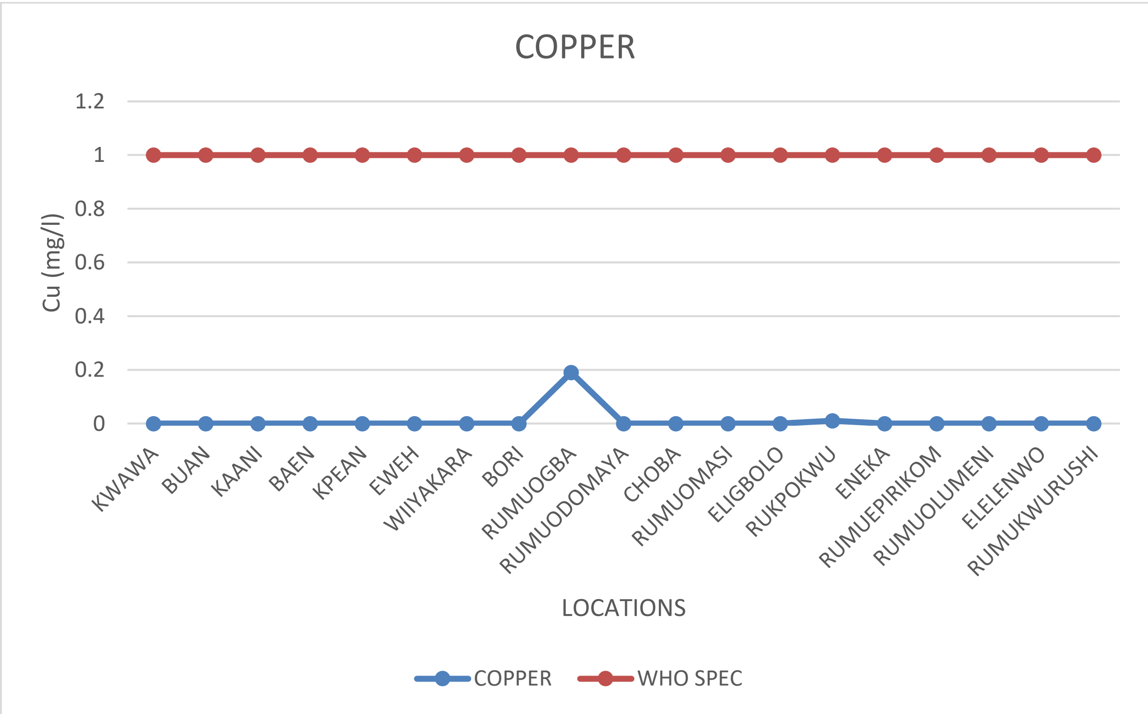

Fig. 7. Copper Concentration of Sample Compared with WHO Standards

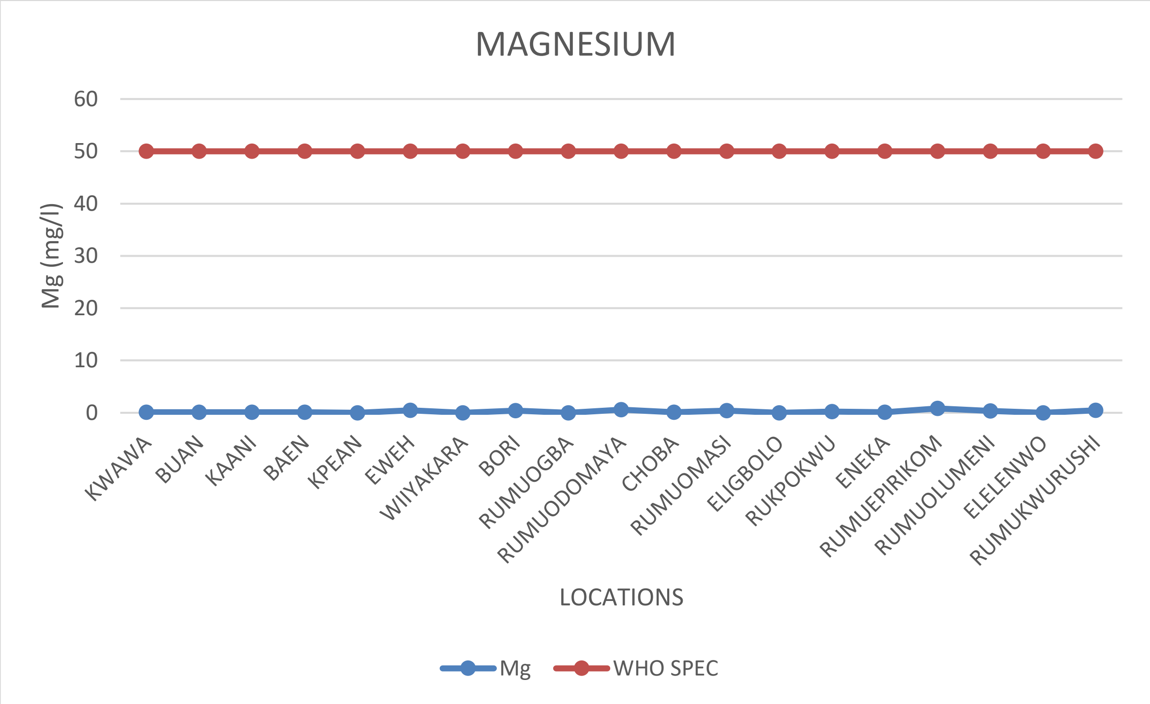

Fig. 8: Magnesium Concentration of Sample Compared with WHO Standards

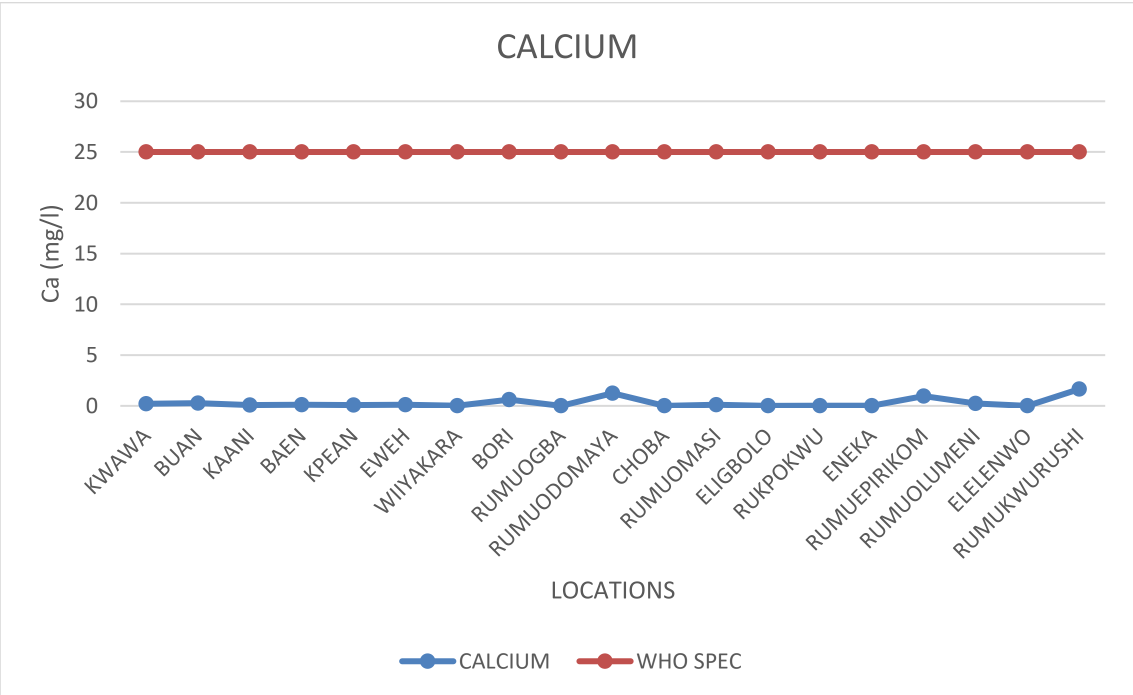

Fig. 9: Calcium Concentration of Sample Compared with WHO Standard

Besides oil and gas exploration activities, lots of other anthropogenic activities in the study area are contributing to excessive injection of carbon dioxide into the atmosphere without a commensurate amount of carbon sink available to absorb them and mitigate their environmental impact. Some of these include automobile exhaust systems, fossil fuel combustion, forest fires and objectionable agricultural practices such as bush burning among others which are predominant in the study area.

While these activities of man produce and inject CO_2 into the atmosphere, green vegetation (a natural carbon sink) is disappearing at an alarming rate due to deforestation arising from population explosion and rapid urbanization. Apart from the environmental hazard of contributing to global warming/climate change (being a greenhouse gas), CO_2 combines with moisture/rain water in the atmosphere to form carbonic acid (H_2CO_3) a major contributor to groundwater contamination.

$$H_2O + CO_2 \rightarrow H_2CO_3 \quad (4.1)$$

Some of the carbonic acid in the rain water disassociates or break down to form bicarbonate (HCO_3^-) and hydrogen ion H^+.

$$H_2CO_3 \rightarrow HCO_3^- + H^+ \quad (4.2)$$

The hydrogen ion produced in reaction 4.2 lowers the pH of rain water. The more CO_2 present in the atmosphere, the more acidic is rain water (Nelson, 2002). Again through seepage and percolation, this acidic rain water get in contact with groundwater causing contamination.

Another factor that may have influenced the acidification of groundwater in the study area is poor waste management practices within the area. A comparison of the groundwater assessment in Khana and Obio-Akpor indicates higher acidic values in Obio-Akpor than in Khana. Obio-Akpor is densely populated (probably the highest in the Niger Delta Region) with very high rate of municipal waste/refuse generation which are equally poorly managed. In most cases these wastes are dumped in open spaces including road medians and are not removed for disposal by waste disposal contractors for upwards of 4 to 5 days or even weeks.

When rain falls the already decomposing wastes are washed off by rain water and the leachate seep through the soil and percolate into the underground aquifer causing contamination of groundwater. Even when the wastes are removed and taken to approved disposal or dump sites, the disposal practices at such sites leave much to be desired. There are usually no liners, membranes or any form of protection of the adjourning areas from leachate seepage and eventual percolation into the underground aquifer. Dumpsites at Rumuolumeni, Eneka, Eliozu, all in Obio-Akpor among others are eye sores and constitute real environmental danger to groundwater in the area. A sizeable chunk of these wastes are disused and discarded lead-acid batteries which can be a source of lead contamination of groundwater.

Khana on the other hand has better results in terms of groundwater acidity. This may, among other factors, be attributed to the fact that it is more of a rural setting than Obio-Akpor; has far less population density and generates wastes far below that of Obio-Akpor. Bori which is a semi urban area in the zone and the headquarters of the LGA has the least pH level in Khana and therefore more acid contamination. Lead and other heavy metal concentration in the area fall within WHO standards for drinking water. This again may be attributed to the fact that waste generation/disposal which follows the same trend as in Obio-Akpor is more in Bori than the other areas indicated in the study in Khana Local Government Area.

Domestic sewage can also be a source of acid contamination of groundwater. Due to anaerobic fermentation processes that take place in septic tanks, carbon dioxide and hydrogen sulphide (a pungent and toxic gas) are usually produced. These gases are acidic and can be a source of production of acid in septic tanks. Most homes in the study area have privately constructed septic tanks for their domestic sewage disposal. Unfortunately, most of these septic tanks are poorly designed and are not linked to any central sewage treatment facility. Permits from municipal authorities are usually not obtained nor any form of inspection from them before citing and constructing such tanks. These poorly designed tanks are in most cases located very close to water boreholes, particularly in Obio-Akpor where the population density is very high. This therefore can be a major source of contamination of groundwater in the study area.

Whatever is the source of acid contamination of groundwater, the truth remains that acidic water is unfit for domestic, agricultural, industrial and commercial use. World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) recommend pH range for potable water as 6.5 to 8.5. For our study area the closest to this range is 6.18 (Rumuokwurusi – Obio-Akpor) which falls short of the standard by WHO. For figures below or above this range it is recommended that such water be subjected to treatment/remediation and certified fit before use. Acidic water results in corrosion of iron and steel materials (pipes) and plumbing fixtures, clogging of distribution pipes and cause objectionable tastes of drinks and food and may stain clothes and rust cooking utensils (Jones, 1998). WHO guidelines for drinking water equally states that exposure to extreme pH values results in irritation to eyes, skin, mucous membranes; and exposure to low pH can result to redness and irritation of the eyes among other health and medical implications. Bertills & Sundlof (1995) further posit that acid groundwater can corrode plumbing systems and solubilize metals in the soil or in the plumbing systems. They further state that since the soluble forms of some of these metals are toxic, this trend has raised concerns regarding the effects of groundwater acidification on human health.

Acidic water increases the overall cost of provision of potable water for the citizens. Apart from the direct cost of treatment/remediation of contaminated water, there could be further cost that may arise from maintenance/replacement of materials and equipment that get damaged or deteriorated as a result of corrosion. In industrial plants, equipment like boilers, heat exchangers and water storage tanks can suffer serious damage if acidic water is used for operations without prior treatment/remediation. This again can increase the cost of production and provision of goods and services to the populace.

Solution to this deteriorating trend in acidity of our groundwater lies in remediation/treatment and improving seriously on our overall environmental management and waste disposal practices. Otherwise the trend may get to alarming proportions in the next few decades with a corresponding increase in water borne diseases and ailments.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study has shown that groundwater in the study areas is acidic [(pH of between 4.72 – 6.16 for Khana LGA) and (4.31 – 6.18 for Obio-Akpor LGA)]. Comparatively Obio-Akpor with average pH of 4.79 suffered more acid contamination than Khana with an average of 5.23. This is probably because the environmental pollution in the highly urbanized Obio-Akpor is more than in Khana. Interestingly, all the other physico-chemical properties analyzed fall within the WHO's limit for potable water.

The acidity of groundwater in the study areas is attributable to serious environmental pollution arising mainly from oil and gas production activities which are prevalent in the area and other parts of the Niger Delta region of Nigeria. The frequent rainfall in the area results in frequent *acid rain* which when dropped on the soil gradually seep into the ground and thereafter into the underground aquifer and contaminate groundwater. Fashola et al, (2013) in their study agrees with this finding when they posited that *acidity arises from gas flaring in most parts of the Niger Delta as well as the presence of organic matter in the soil.* Poor waste management and sanitation habits of the study areas may have also contributed to this high acidic groundwater. A lot of acidic liquids are regularly leached from decomposing wastes from the ubiquitous refuse dumpsites in the area and washed down the soil during rain falls and subsequently contaminate groundwater sources.

Another interesting finding from the study is that over time the pH values of the groundwater has deteriorated. Similar research work carried out around several locations in the Niger Delta region in the last decade produced the same result – *acidic groundwater*. But there has been a downward trend of pH values from average of 6.5 in the last decade to less than 5.0 as this study indicates. This trend may continue in the years ahead if no remediation measures are initiated and sustained and efforts made to eliminate or curtail the rate of environmental pollution identified in the study.

5.2 Recommendations

The research work, therefore, recommends as follows:

a) Regular recharging and dosing of groundwater sources in the area with alkaline solutions – limestone, dolomite or caustic soda. This can be done by Government in partnership with the private sector.

b) Drastic reduction in environmental pollution through gas flaring, oil spills and poor waste management and disposal practices. Government can achieve this by enforcing the relevant environmental laws and guidelines, and meting out appropriate punishments to offenders where applicable.

c) Rehabilitation of public water supply stations at Elelenwo, Rumuokwurusi, Rumuola, Rumuogba, Bori and others all located in the study areas but which have since gone moribund and install relevant water treatment units. With this in place Government can place a ban on the use of poorly constructed private boreholes as source of drinking water.

d) Enactment of a law banning the sinking of private boreholes without a mini water treatment facility. This is to ensure that only properly treated water is consumed by the public.

e) Laws should be enacted against deforestation and environmentally harmful agricultural practices such as bush burning, while the crusade for tree planting should be sustained to enhance the capacity of green vegetation to absorb excess carbon dioxide from the atmosphere.

f) Central sewage treatment systems/facilities should be built in the cities/towns/residential areas to avoid the present situation where poorly constructed private septic tanks discharge sewage to the underground aquifer and in the process contaminate groundwater.

g) Government should as a matter of urgency begin to construct properly designed sanitary landfills for efficient and effective disposal of municipal wastes.

h) Research studies such as this should regularly be embarked upon to monitor groundwater contamination and deterioration.

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