AN ASSESSMENT OF TRACE ELEMENTS IN SURFACE AND GROUND WATER QUALITY IN THE EBOCHA-OBRIKOM OIL AND GAS PRODUCING AREA OF RIVERS STATE, NIGERIA.

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ABSTRACT: This study presents the impact of surface and ground water quality on the environment in Ebocha-Obrikom oil and gas producing area of Rivers State, Nigeria. Specifically, the study examined the relationship between the physico-chemical parameters, determine the quality of surface and ground water in the study area as compared with national and international standards for drinking water, assess the quality of borehole and well water in the study area, and determine the relationship between gas flaring sites and physico-chemical parameters. This study adopted both field and laboratory experimental analysis of physical and chemical parameters. The water samples were analysed for Physico-chemical parameters using standard procedures. Physico-chemical parameters analysed for were pH, DO, BOD, TDs, Conductivity, Turbidity, Salinity, Total Hardness, Total Alkalinity, Temperature; cations and anions and TPH, Iron, Copper, Chromium, Manganese, Nickel, Lead and Zinc. The results show that ground water contained high amounts of turbidity (21.5NTU, 23.00NTU and 19.0NTU in the borehole water and well water), iron (5.3mg/l in the ground water and 6.98mg/l in the borehole water), biological oxygen demand (3.80mg/l in the surface water) and pH of all water samples were acidic in the study area. These results show that ground waters including borehole; well waters and surface water of the study area had acquired reasonable levels of pollution. Apart from these specific cases, other values were found to be lower or above and corresponded to the approved maximum permissible level (i.e. maximum permissible limits for drinking water set by NAFDAC and WHO). Pearson correlation coefficient also indicated that there was a significant correlation among the studied physico-chemical parameters in both surface and ground water. The ground waters therefore, were more impacted upon by chemical parameters than surface water. This study, recommends for the continuous monitoring of water quality in the oil producing areas to protect man and the environment. Also, there is need for bio-physico-chemical assessment extension to other new areas of the Niger Delta region of Nigeria.

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INTRODUCTION

Worldwide, water bodies have been primary dump sites for disposal of waste, especially the effluents from industries that are near them. These effluents contained toxic substances and have great influence on the pollution of water bodies, as they can alter the physical, chemical and biological nature of the receiving water body

(Adekunle and Eniola, 2008). The initial effect of waste is to degrade the physical quality of the water. Later biological degradation becomes evident in terms of number, variety and organization of the living organisms in the water (Aisien, Gbegbaje and Aisien, 2010; Adekunle and Eniola, 2008).

Safe drinking water is a basic need of human development, health and well being, and hence, an internationally accepted human right (WHO, 2001). Moreover, water has been viewed as an infinite and bountiful resource; Water is one of our most important natural resources. Without it, there would be no life on earth. The supply of water available for our use is limited by nature. Although there is about 70% of water on earth, it is not always in the right place, at the right time and of the right quality (Ogoni, 2010).

In most parts of the Niger Delta region of Nigeria, the major challenge of survival is the provision of good quality (potable) water because of environmental pollution and degradation (Efe, 2010b). In most cities, towns and villages in this region, valuable man – hours are spent on seeking and fetching water of doubtful quality to meet specialized needs (Ayoade, 2003; Kaizer, Adaikpoh, Osakwe and Obanogun-Odiete, 2001; Obasi and Balogun, 2001 and Ovrawah and Hymore, 2001).

This study examined the quality of both surface and ground water meant for human consumption in the Ebocha-Obrikom oil producing area of River State, Nigeria.

To achieve this, the following specific objectives were to:

(i) examine the relationship between the physico-chemical parameters

(ii) determine the quality of surface and ground water in the study area and compared with national and international standards for drinking water.

(iii) determine the relationship between gas flaring sites and physico-chemical parameters and

(iv) make the necessary recommendations from the findings to the residents and the general public.

General Background Information on Water Pollution

Pollution arises from the presence of materials that are foreign in the body of water being considered (Akan, 2006). Worldwide, most sources of water are not free from the influence of pollutants (WHO, 2001). Condensed atmospheric water receive air pollutants and condense same while surface and underground water bodies get contaminated by sewage and industrial effluents of different organic or inorganic chemicalized agents. Many surface water bodies receive very large amounts of pollutants either as point or non-point sources and these could make receiving source water hazardous to living organisms that depend on them (United States Environmental Protection Agency, 2008). Schueller (2006) opined that water is considered polluted if it is no longer suitable for the purpose for which it was originally put.

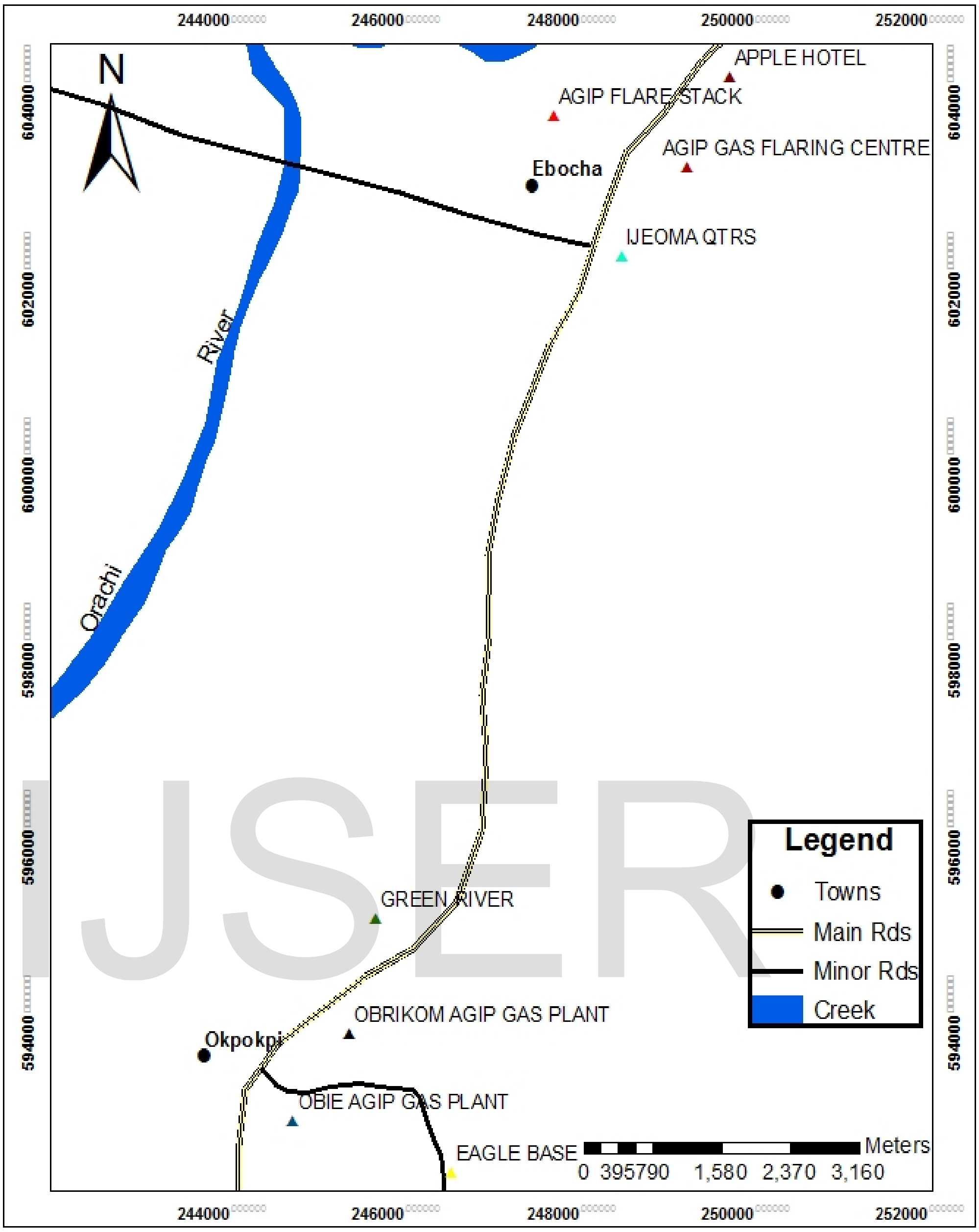
EPA (2003) in its water quality inventory report submitted to the U.S Congress recorded that about 45% of assessed stream miles, 47% of assessed lake acre and 32% of assessed bay and estuarine square miles were classified as polluted. A special report on the Economist in December 11, 2008 reported that an estimated 700 million Indians have no access to proper toilet, with about 1,000 of these Indian children dying of diarrhea sickness (of course through water) everyday while about 90% of China’s cities from some degree of water pollution.

In most developing countries, whether in urban or rural area, a significant number of people lack functional toilets or proper disposal facilities, here the tendency for both biodegradable and non-biodegradable wastes alike being disposed directly or indirectly into surface water bodies; thereby altering the water ecosystem (Enger and Smith, 2010). On a larger scale, water pollution has been recorded more in Niger Delta region than any other part of Nigeria due to the high level of on-going oil related activities within the region (Ukoli, 2005).

STUDY AREA

Location

The Ebocha-Obrikom area is located between latitude 5^0 20N - 5^0 27N and longitude 6^0 40E - 6^0 46E (Figure 3.1). It comprises Obrikom, Obor, Obie, Ebocha and Agip New Base towns all in Ogba/ Egbema/Ndoni Area of Rivers State (Figure 3.2). The study Area is bounded to the North by Nkissa River, by the West, the Orashi River, by the East, the Sombrero River and by the South Omoku town.



Sampled pointS

- ▲ 1000M AWAY FROM THE AGIP FLARE STACK
- ▲ 200M OPPOSITE AGIP GAS FLARING CENTRE EBOCHAAND 500M FROM AGIP WASTE PIT
- ▲ APPLE HOTEL 500M FRO WASTE PIT AND 150M AWAY FROM MGBEDE FIELD OIL
- ▲ EAGLE BASE OBOR 2.KM AWAY FROM AGIP GAS PLANT
- ▲ GREEN RIVER PLANT PROPAGATION CENTRE- NAOC 3KM AWAY FROM AGIP PLANT
- ▲ OPPOSITE IJEOMA QTRS 750M AWAY FROM AGIP GAS FLARING CENTRE
- ▲ OBOR RD OBIE AGIP GAS PLANT2KM AWAY FROM AGIP GAS PLANT
- ▲ ABACHA RD OBRIKOM 1.8KM AWAY FROM AGIP GAS PLANT

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Relationship between Physico-chemical Variables

Table 4.1 shows the nature and strength of bivariate relationship between any of the physico-chemical parameter. The result reveals that pH has a significant positive relationship with TDS (r = 0.422, p= 0.01). The same goes for conductivity which has a significant positive relationship with TDS (r = 0.955, p = 0.01). Also, the result recorded that turbidity has a significant positive relationship with TDS, pH and conductivity. TDS (r = 0.821, p = 0.01), pH (r = 0.735, p = 0.05) and conductivity (r = 0.641, p = 0.05). Similarly, the result shows that salinity has a positive relationship with TDS and conductivity. TDS (r = 0.876, p = 0.01) and conductivity (r = 0.861, p = 0.01). The result of bivariate relationship also reveals that Total Alkalinity has a significant positive relationship with TDS, turbidity and Well Dept. TDS (r = 0.679, p = 0.05) Turbidity (r = 0.693, p = 0.05) Well Dept (r =1.000, p = 0.01). Total hardness shows a significant positive relationship with pH and show a negative relationship with TDS and Conductivity. TDS (r = -1.000, p = 0.01) pH (r = 0.957, p = 0.05) Conductivity (-0.977, p = 0.05). Additionally, the result reveals that Iron has a significant positive relationship with TDS, pH and turbidity. TDS (r = 0.708, p = 0.05) pH (r = 0.843, p = 0.01) Turbidity (r = 0.960, p = 0.01). Manganese also shows a significant positive relationship with TDS, pH, Turbidity and Iron. TDS (r = 0.649, p = 0.05) pH (r = 0.852, p = 0.01) Turbidity (r = 0.820, p = 0.01) Iron (r = 0.876, p = 0.01). Lastly, Zinc shows significant positive relationship with only SO_4 (r = 0.787, p = 0.01). The result of the relationship between other physico-chemical parameters were not statistically significant (p = 0.05).

Table 4.1: Correlation matrix showing the relationship between the physico-chemical parameters

Parameters	DO	ORP	TDS	Ph	Conductivity	Turbidity	Salinity	Temperature	Altitude	Well Dept	SO_4	Total Alkalinity	Total Hardness	BOD	Iron	Manganese	Zinc
DO	1																
ORP	-0.083	1															
TDS	0.395	0.170	1														
pH	-0.116	-0.361	0.422 **	1													
Conductivity	0.495	0.315	0.955**	0.176	1												
Turbidity	0.271	0.017	0.821**	0.735*	0.641*	1											
Salinity	0.378	-0.146	0.876**	0.449	0.861**	0.610	1										
Temperature	-0.026	-0.331	0.149	0.156	0.184	0.026	0.351	1									
Altitude	0.729	-0.036	-0.416	-0.240	-0.427	-0.218	-0.456	-0.575	1								
Well Depth	0.500	-0.410	-0.277	0.510	-0.476	0.484	-0.277	-0.904	0.885	1							
SO_4	0.465	0.269	0.415	-0.515	0.555	0.110	0.362	0.023	0.117	0.079	1						
Total Alkalinity	0.510	-0.220	0.679*	0.418	0.631	0.693*	0.632	0.277	-0.669	1.000**	0.335	1					
Total Hardness	-0.421	-0.881	-1.000**	0.957*	-0.977*	-0.717	-0.907	0.133	0.214	0.277	-0.867	0.500	1				
BOD	-0.409	0.066	0.330	0.378	0.175	0.364	0.416	-0.467	0.365	0.545	-0.165	-0.297	-0.634	1			
Iron	0.201	-0.072	0.708*	0.843**	0.499	0.960**	0.483	0.025	-0.151	0.792	-0.133	0.532	-0.404	0.415			
Manganese	0.174	-0.017	0.649*	0.852**	0.477	0.820**	0.441	0.141	-0.512	-0.874	-0.333	0.612	0.199	0.236	0.876**	1	
Zinc	0.291	0.090	0.389	-0.189	0.405	0.283	0.423	-0.335	0.277	0.701	0.787**	0.427	-0.515	0.129	0.049	-0.178	1

****** - Correlation is significant at the 0.01 level (2-tailed), ***** - Correlation is significant at the 0.05 level (2- tailed), a – Cannot be computed because at least one of the variable is constant.

Table 4.2 shows the result of the assessment of the quality of ground water and surface water in the study area. Result shows that for ground water, out of the 22 physico-chemical parameters analysed only dissolved oxygen, temperature, biological oxygen demand and total petroleum hydrocarbon (TPH) were within WHO standards. Result obtained for other physico-chemical parameters were outside the recommended WHO standards. For Surface water only temperature, total petroleum hydrocarbon and lead were within WHO standards. Other parameters were outside the standard values as recommended by WHO. Similarly, for groundwater and surface water, only temperature and lead is within the NAFDAC recommended standards. Other parameters were outside the standards.

Table 4.2: Quality of surface and ground water in the study area relative to WHO and NAFDAC standard

			Groundwater			Surface water		
Parameters	WHO	NAFDAC	Mean±SD	Remark WHO	Remark NAFDAC	Mean±SD	Remark WHO	Remark NAFDAC
DO	>7.0	7.50	14.5±0.48	WS	OS	6.32±0.38	OS	OS
ORP	-	-	123.5±132.07	-	-	-	-	-
TDS	1500mg/L	500mg/L	30.9±22.88	OS	OS	12.35±4.91	OS	OS
pH	7.0-8.9	6.50-8.5	5.4±3.57	OS	OS	6.08±0.50	OS	OS
Conductivity	1200us/cm	1000us/cm	51.6±27.54	OS	OS	21.87±5.94	OS	OS
Turbidity	5.0NTU	5.0NTU	21.5±35.04	OS	OS	1.49±0.40	OS	OS
Salinity	-	-	18.8±11.26	-	-	-	-	-
Temperature	27-28	27-28	27.7±1.05	WS	WS	27.71±0.74	WS	WS
Altitude	-	-	19.5±6.44	-	-	-	-	-
Well Depth	-	-	16.7±4.16	-	-	-	-	-
Sulphate	500mg/L	100mg/L	1.7±0.52	OS	OS	1.20±0.28	OS	OS
Total Alkalinity	100mg/L	100mg/L	4.3±1.80	OS	OS	2.00±0.00	OS	OS
Total Hardness	500mg/L	100mg/L	6.7±3.69	OS	OS	-	-	-
BOD	<3.0	-	2.4±1.25	WS	-	3.80±0.42	OS	-
TPH	<10	-	0.001±0.00	WS	-	0.001±0.00	WS	-
Iron	3mg/L	0.3mg/L	5.3±12.18	OS	OS	0.001±0.00	OS	OS
Copper	2.0mg/L	1.0mg/L	0.01±0.001	OS	OS	0.00±0.001	OS	OS
Chromium	0.05mg/L	0.05mg/L	0.001±0.00	OS	OS	0.001±0.00	OS	OS
Manganese	0.4mg/L	2.0mg/L	0.05±0.08	OS	OS	0.02±0.01	OS	OS
Nickel	0.02mg/L	0.07mg/L	0.001±0.00	OS	OS	0.001±0.00	OS	OS
Lead	0.01mg/L	0.01mg/L	0.001±0.00	OS	OS	0.01±0.00	WS	WS
Zinc	3.0mg/L	5.0mg/L	0.3±0.49	OS	OS	0.05±0.00	OS	OS

OS= Outside Standard, WS= Within Standard, SD= Standard Deviation

Table 4.3 shows that there is a significant negative relationship between dissolved oxygen and distance from gas flaring (r = -0.697*, p = 0.05). Result obtained between distance from gas flaring and other physico-chemical parameters were not statistically significant (p = 0.05). This implies that as the distance from gas flaring site increases, Dissolve oxygen decrease significantly (p = 0.05). This result is depicted graphically as shown in Figure 4.1.

Table 4.3: Relationship between gas flaring sites and physico-chemical parameters

Parameters	r-value	p-value	Remark
DO	-0.697*	0.025	S
ORP	-0.224	0.594	Ns
TDS	-0.285	0.424	Ns
pH	0.134	0.711	Ns
Conductivity	-0.359	0.308	Ns
Turbidity	-0.157	0.664	Ns
Salinity	0.160	0.705	Ns
Temperature	-0.211	0.558	Ns
Altitude	0.498	0.315	Ns
Well Depth	0.577	0.609	Ns
SO_4	-0.429	0.216	Ns
Total Alkalinity	-0.374	0.321	Ns
Total Hardness	0.824	0.176	Ns
BOD	0.442	0.200	Ns
TPH	-	-	-
Iron	-0.103	0.776	Ns
Copper	-	-	-
Chromium	-	-	-
Manganese	-0.148	0.684	Ns
Nickel	-	-	-
Lead	-	-	-
Zinc	-0.158	0.662	Ns

ns = not significant at 5 % (p = 0.05), s = significant at 5 % (p = 0.05)

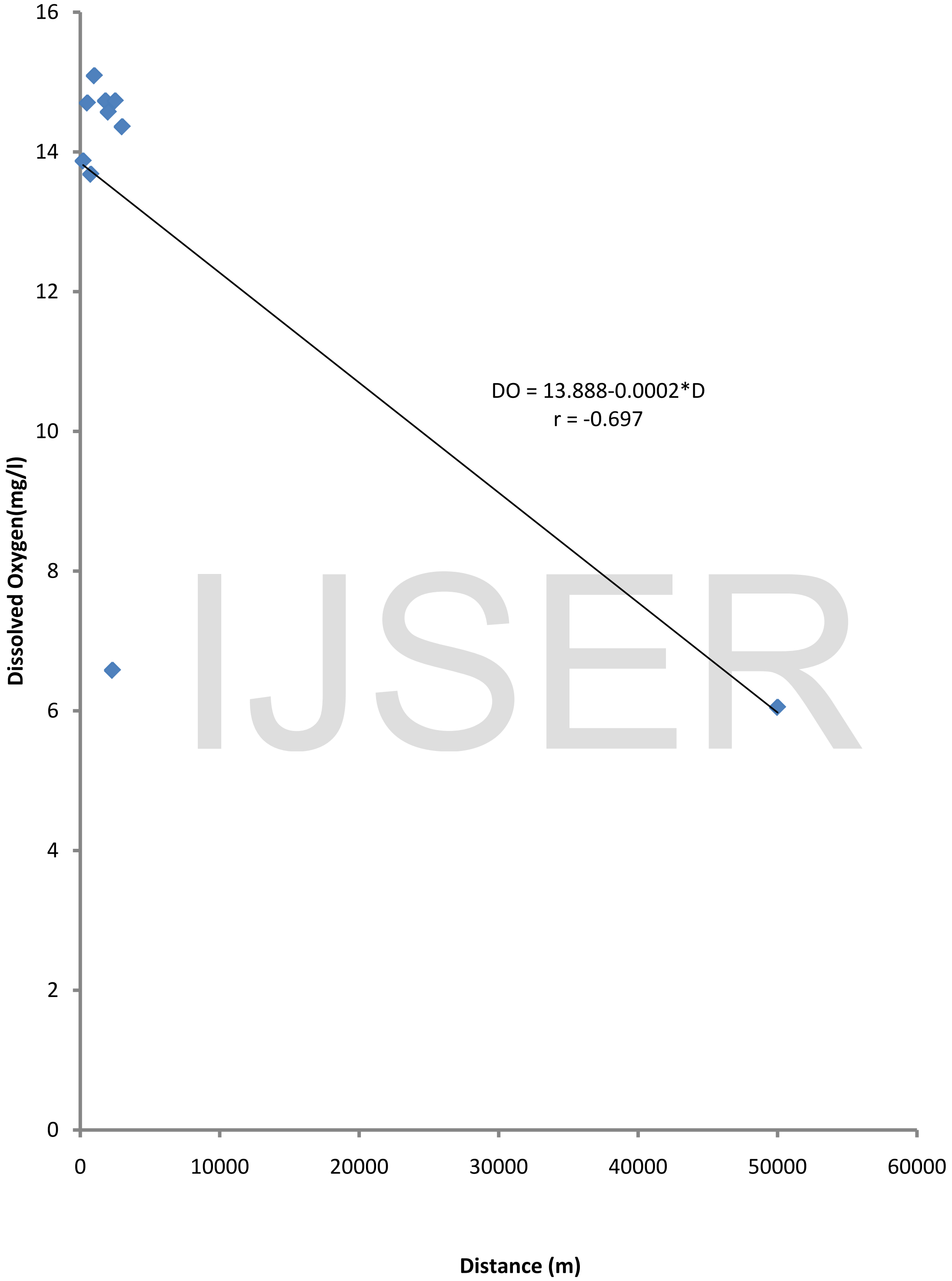


Figure 4.1: Relationship between dissolve oxygen (DO) and distance from the gas flaring

4.2 Discussion

Relationship between the physico-chemical parameters

This study found significant relationship among some of the physico-chemical parameters. Specifically, the result revealed total dissolve solid to be significantly related with conductivity, turbidity, pH, salinity, total alkalinity, total hardness, iron and manganese. All these physico-chemicals parameters were found to have significant positive relationship with TDs except total hardness which had perfect negative relationship. This result implies that as pH, conductivity, turbidity, salinity, total alkalinity, iron and manganese of the water increases, the total dissolve solid increases significantly. However, for total hardness, the reverse was the case such that as the total hardness of the water increases, total dissolved solid and conductivity decreases significantly. Furthermore, the pH of the water was found to be significantly related with turbidity, total hardness, iron and manganese. This is an indication that the pH of the water tends to increase as the level of turbidity, total hardness, iron and manganese increases. Also, physico-chemical parameters like turbidity, salinity, total hardness also revealed significant relationship with conductivity. Turbidity and salinity showed significant positive relationship with conductivity while the result for total hardness was significantly negative. Perfect significant relationship was obtained between sulphate (SO_4) and total alkalinity revealed significant relationship with each other. Iron showed significant positive relationship with manganese ($p<0.05$).

Quality of Surface and Groundwater in the Study Area

The analysis of dissolved oxygen (DO) is used to measure the amount of gaseous oxygen dissolved in the water, which is crucial for all forms of life as oxygen (O_2) plays an influential role in nearly all chemicals and biological processes within water bodies (Chapman and Kimstach, 1992). The lowest mean value was obtained in surface water which was below the acceptable limit of WHO (2008) and NAFDAC (2008). The low value of DO indicates high biological activity which is a reflection of high organic matter input. Low DO levels causes stress and anaerobic decomposition of organic matter. These result corroborate earlier report by Chukwu (2008) that high or low DO values have been reported to affect aquatic life and alter the toxicity of other pollutant in one form or the other (Morrison *et al*, 2001). DO in liquid provides a source of oxygen needed for the oxidation of organic matter when the concentration is high and lack of it causes the water body to become dead or devoid of aquatic life (Chukwu, 2008). This result found support in Dami, Ayuba and Amukali (2012) which established that ground waters could also be conveniently used to support fish pond activities since DO values were above the recommended value of greater than 7 as stream standard for fishing. Typically, DO levels less than 2mg/l will kill fish (Hertz *et al*, 1975). Chapman and Kimstach (1992) noted that DO concentrations below 5mg/l adversely affect the functioning and survival of biological communities and below 2mg/l may lead to death of most lives. Oxygen is soluble in water and it tends to be less as temperature increase.

The values for Total Dissolved Solids (TDS) were significantly lower in the study areas compared with the maximum limit by NAFDAC and WHO. Less than 500 mg/l is the maximum permissible value for TDS in drinking water in Nigeria (NIS, 2007), whereas WHO (2008) recommended 1500mg/l as maximum permissible limit for drinking water. However, should the waters be considered for use in fish ponds, it could be used without fear since WHO (2008) recommended 1500mg/l for the protection of fisheries and aquatic lives as well as for domestic water supply. Since all values were below the acceptable limit, they are all safe for drinking on the basis of

TDS as supported by Dami, Ayuba and Amukali (2012) that waters within the limits obtained here are highly palatable.

Conductivity values were below the permissible criteria of National and International regulatory bodies. The much enhanced conductivity values recorded in the groundwater compared with surface water reflect significant water-soil interaction resulting in the dissolution of the geological medium (Ogunkoya and Efi, 2003). Although samples from gas flared environments are relatively more conductive. Locally, the effect of salt water infiltration into the aquifer from the tide influenced by river Orashi may also be an important factor in the salinization of groundwater, borehole water and well water in the area (Olobaniyi and Owoyemi, 2006).

This result found support in Ekine and Iheonunekwu (2007) and Ehirim and Nwankwo (2010) who established that electrical conductivity values of the ground and surface water samples collected from the studied location are observed to be low throughout the sampling periods including the variations of their mean concentrations at different distances. According to Okafor and Opuene (2007) the electrical conductivity indicates the level of salinity; hence it greatly affects the taste of water and represents a significant impact on the user’s acceptance.

The pH revealed that the maximum and minimum pH values in both surface and groundwater resources from all the sampling sites fall below the permissible criteria of National and International regulatory bodies. Therefore, making these sources of water available to inhabitant of the area as low quality water. The pH values of the samples collected are found to be relatively low; and the low pH values recorded suggest acidic precipitation within the immediate vicinity of the natural gas processing installation. Optimum pH range for sustainable life is 6.5-8.2 (Murdoch *et al*, 2001). Water that is too acidic or too alkaline can be detrimental to human health and lead to nutritional disequilibrium and this was demonstrated in an oil spilled area which found both pH extremes to be problematic (Rosborg, 2002). Acidic precipitation is known to pose a threat to various economic resources; fisheries, forestry, agriculture and wildlife (Opuene and Agbozu, 2008). Acidified waters may leach toxic metals from watersheds and water distribution systems, and the presence of these metals in drinking water can result in a number of serious human health impacts. The observed acidic pH in this study agrees with the report of Abowei (2010) that waters with little change in pH are generally more conductive to aquatic life. Furthermore, the recorded low pH values in the study also agrees with the observation of Beadle (1981) that rivers flowing through forests contain humid acid which is the result of decomposition and oxidation of organic matter and hence low pH. According to Aguwamba (2000) the acidity of natural water is attributed to the presence of carbon-dioxide or strong mineral acids.

Ground water also revealed some level of turbidity with the highest value of 21.50 NTU which is markedly higher than surface water. However, the turbidity values are above the maximum permissible limit of 5NTU for drinking water (WHO, 2008). Nevertheless, the medium range of turbidity consequent on oil related activities like gas flaring and oil spillage could have serious health implications for the residents within the studied areas (Dami *et al.*, 2012). This may be related to the presence of particles of clay, silt, organic component and other microscopic substances. It may also be an indication of deposite of pollutant loads in Ebocha-Obrikom and its environs. This result corroborates earlier reports by Udoessien (2003) that turbidity help to indicate the degree of harmfulness of the water. This also agrees with the findings of Longe and Enekwechi (2007); Nouri *et al.* (2006) who concluded that it is attributed to the leaching from the oil activities and pipeline vandalisation in the study area.

Temperature values revealed that although temperature was highest (with an average value of 27.7^0C) at ground water, generally, temperatures did not significantly change. This suggests that gas flaring and oil spillage seems not to have influenced ground water temperature. When compared with the maximum permissible range of 27 - 28^0C recommended by WHO and NAFDAC, (2008) for drinking water, the temperature values all fall within the permissible range.

Sulphate has markedly lower concentration in groundwater (1.68 mg/l) and surface water (2.07 mg/l), The data revealed that all the sampling sites fall below the maximum permissible limit of National and International regulatory bodies. Hence, could be utilized in fisheries project and agricultural activities (USEPA, 1991). Levels of sulphate above 600 mg/L act as purgative in humans (Esry *et al*., 1991). SO_x from gas flaring introduce sulphates which lead to acid rainfall by the formation of sulphuric acid (Ogoni, 2010). However, health concern regarding $SO4^{2-}$ in drinking water has been raised because of the reports that diarrhea, catharsis, dehydration and gastro-intestinal irritation may be associated with the ingestion of water containing SO_4^{2-}. Also, it could be assumed that sulphate is very unstable in the atmosphere from where it is converted into forms suitable for its stay in well water. Hence, the low value in surface water.

Alkalinity is a measure of the ability of the water to neutralize acids. The constituent of alkalinity which may contribute to alkalinity are OH, CO_3^2 and HCO_3^-. Total alkalinity was markedly lower than the permissible criteria of national and international regulatory bodies. Alkalinity level measured was lower in both surface and groundwater and was still below the permissible limit. This could be attributed to continuous release of acidic substances into the adjourning environment. These results found support in Fakayode (2005) who established that the levels of alkalinity of some studied locations in Niger Delta are at permissible level of 100 mg/l and therefore do not pose challenges.

Total hardness showed generally lower concentration in groundwater (6.70mg/l). This data revealed that the maximum value in the water sources fall below the National and International standards. According to Udoessien (2003), hardness in water is due to Ca_2^+ and Mg^{2+} (ions). Although, Fe^{2+} and Sn^{2+} salts may either occur as HCO_3, SO_4^{2-}, Cl and Na_3. Surface water has no recorded mean value.

Biological oxygen demand (BOD) is used to read the level of biochemically degraded organic matter or carbon loading in the water (Abowei and George, 2009; Dami *et al.*, 2012). The BOD measured was highest in surface water (3.80 mg/l). This however, is higher than the maximum permissible limit of WHO standard. Generally, the high value of BOD in surface water could be attributed to human activities. Thus, gas flaring must have contributed to this trend. This supports higher biochemical activities in surface water. Additionally, the higher value of BOD obtained in surface water could be likely attributed to the increase in microbial activities occasioned by increase in microbial load. This finding is consistent with Fakayode (2005) and Chukwu (2008) who opined that high BOD like that obtained in surface water results in the depletion of dissolved oxygen, which perhaps is detrimental to aquatic lives. However, large amount of organic matter could result in a near absolute depletion of oxygen. The BOD value obtained in this study also compares favorable with the reported values of Abowei and George (2009). Also, Moore and Moore (1976) and Chinda *et al.* (1991) reported that water bodies with BOD levels of between 1.0 – 2.0

mg/l are considered clean; 3.0 mg/l fairly clean, 5.0 mg/l doubtful and 10.0 mg/l are considered bad and polluted. Addionally, it could be deduced that oil-related activities could influence higher BOD in surface water.

Iron occurs in high concentration in groundwater compared to surface water and which were generally below the maximum tolerable limit of National and International regulatory bodies. This suggests some dissolution of iron (Fe) within the soil particles. It could be due to gas flaring effects. The levels of iron in the ground waters compare significantly with the reported levels in Niger Delta (Ushie and Amadi, 2008). High concentration of iron (Fe) in the Niger Delta has also been reported by Akporido (2000). The presence of high concentration of iron (Fe) recorded impacted colour and also developed turbidity. This is an indication of pollution at ground water while surface water is safe. The results of this study agrees with earlier report by Emoyan *et al.* (2005) that iron concentration in groundwater is closely related to that of borehole water. The high rate of iron in groundwater can also be due to high rate of evaporation which left less volume of water in the borehole, hence the concentration of iron. Also, it may be attributed to the degree of ferruganization of the aquifer materials, quality of ground water materials (Ahmed *et al.*, 2003). Report of Egila *et al.* (2001) oxygen converts the soluble ferrous ion to insoluble ferric ion. They added that this will further degrade the quality of water in terms of the iron content. In addition, Edet and Ntekim (1996) stressed that the geologic materials around the study sites may contain a lot of peat, lignite and organic mud bed that are pyritic. He stated that iron can be leached out of pyrite and entrained in the groundwater system and if the quantity is high, it will contaminate the groundwater systems. Also, Moriber (1994) some heavy metals are naturally present in some natural water sources. This possibly explained the levels of iron contents in the samples. The few excessive concentration of iron obtained in this work may be injurious to health because iron is a potent dietary antagonist of copper metabolism in ruminant (Humphries *et al.*, 1985, Udo, 2004). Iron however, is an important element required for the synthesis of haemoglobin during haemopoiesis in the bone marrow. Iron also promotes the growth of iron bacteria, often taste unpalatable and strains laundry and plumbing features as a result of the precipitation of $Fe(OH)_3$ from unstable $FeSO_4$ present in water (Udosen, 2015). The results also corroborate the findings of Waziri, (2006) and Kolo, (2007) that although, iron in drinking water is not a major health concern, concentrations above 3mg/l can cause food and water to become discoloured and taste metallic. Iron deficiency in the human blood could lead to anemia while excess of it could generate free radicals into the system which could speed up the aging process.

Results of the analysis revealed low concentration of heavy metals (Cu, Cr, Mg, Ni, Pb and Zn) in majority of the sample recorded in the study area. Trace amounts of metals are common in water, and these are normally not harmful to our health. Cobalt, Copper, Iron, Manganese and Zinc etc are needed at low concentrations as catalysis for enzyme activities. Drinking water containing high levels of either essential metals or toxic metals may be hazardous to our health. The mean concentrations of the heavy metals in the analysed water samples are all found to fall below the permissible criteria of National and International regulatory bodies. This suggests a good heavy metal abatement installation at the crude oil processing plants by the Agip oil company present in the study area. Surface water shows no presence of copper, it was generally free from copper as contaminant. Copper could be a natural resource owing to its low concentrations as shown in this study. Copper is essential substance to human life, but chronic exposure to contaminant drinking water with copper can result in the development of anemia, liver and kidney damage (Dami *et al.*, 2012). This disease was a result of drinking water contaminated from corrosion of water pipes made of copper and industrial wastes.

Chromium had insignificant values as ground water and surface water, had a value that is 0.001 mg/l. Chromium does not pose any serious health or environmental threat. Although it should be closely monitored because the present concentration could be due to gas flaring. Manganese in surface water was markedly lower than the concentration encountered in groundwater. This is expected because Mg^{2+} is usually released in ground water by the dissolution of feldspars and micas that are important components of the Deltaic plain sands quifers (Olobaniyi and Owoyemi, 2006).

Concentrations of Nickel and Lead in the sample were about the least detected. Values determined were very insignificant with respect to the maximum tolerable limits. The result revealed that the content levels of Nickel and lead in some of the samples were below detection but surface water for lead is within the acceptable limit thus could be said to be of health concern. Lead can enter the human body through food, water and air. It is found in water when the water is slightly acidic and its presence disrupts biosynthesis of hemoglobin and anemia, increases blood pressure, damages kidney, brain and causes infertility in men and abortion in women (Marcus, 2001). Long term exposure to lead as in over dependence on water sources could lead to decreased performance in some tests that measure functions of the nervous system, weakness in fingers and wrists, emergence of wrinkles, small increases in blood pressure and anaemia while exposure to high levels of lead could instantaneously lead to severe damages to the brain and kidneys, miscarriage as well as outright death (Folkl, 2011).

The highest value for zinc was observed at ground water. The maximum permissible limit of 5 mg/l for zinc was not exceeded by any of the values. Zinc at these limits does not pose serious health and environmental effects. The concentration of Zinc measured may seem insignificant, cumulative effect might be harmful to health. Dami *et al*. (2012) observed in their studies a strong relationship between contaminated drinking water with heavy metals and chronic diseases such as renal failure, liver cirrhosis and anemia and hair loss has been identified. Renal failure is related to Pb and Cd contamination. Liver cirrhosis is related to Cu and Mo where contamination of drinking water with Ni/Cr and Cu/Cd lead to hair loss and chronic anemia, respectively. In addition, chronic health effects include cancer, birth defects, organ damage, disorders of nervous system and damage to immune system (USG, 2002). Cd, Cu, Co, Cr, Mn, Ni, Pb and Zn are toxigenic and carcinogenic agents consistently found as contaminants in human drinking water supplies in many areas around the world (Groopman *et al.*, 1985). The level of Zinc in the borehole and well water compared significantly with the reported level of the Niger Delta (Ushie and Amadi, 2008).

According to Udo (2004) zinc has been implicated in rickets-like diseases. It must also be noted that heavy metals, toxic or non-toxic are non-degradable and are therefore persistence in the ecosystem (Ogoni, 2010). It was observed that most of the inhabitant of the rural communities were open wells are sited depend to a large extent on water from such wells for drinking, food processing or washing of utensils. It is therefore, obvious that open wells play a major role in the provision of water for the rural dwellers; especially in communities were other sources of water like streams are located far from settlements. Also, given their dependence on well water, it was likely that people using such water would get infected with water borne diseases, if the well water were contaminated. According to Eja (2002), person infected with water borne diseases acquire infections through oral contact with contaminated water. This is also in consonance with the work of Emoyan *et al.* (2005) who reported that water borne diseases are those obtained by ingesting pathogens through drinking water or water that gets to the mouth from washing utensils and hands or through water used in the preparation of food. He added that such type of water arises from open wells that are polluted.

Relationship between Gas Flaring Site and Physico-chemical Parameters

The result of this study revealed significant negative relationship between dissolved oxygen and distance from gas flaring site (r = -0.697*). This result is an indication that as the distance from gas flaring site increases, dissolve oxygen decreases significantly (i.e. the farther the borehole from gas flaring sites, the lower the level of dissolved oxygen in the water). Thus further confirming the concept of distance decay, which state that the spread of activities decreases with increasing distance from the centre of activities (Botkin and Keller, 1998 and Efe, 2010b). Other physico-chemical parameter showed insignificant relationship with distance from gas flaring sites (p=0.05). This negative significant between dissolve oxygen and other physico-chemical parameters could be due to harmful discharge of untreated effluent into water bodies, as high BOD like that obtained for this study result in the depletion of dissolved oxygen, which perhaps is detrimental to aquatic lives and human health. However, large amounts of organic matter could result in a near absolute depletion of oxygen in the water (Fakayode, 2008; Chukwu, 2008). As well as the self purification capacity of the water body.

Conclusion

The study revealed the following:

i. While groundwater had higher values of turbidity and Iron, the concentrations of biological oxygen demand (BOD) were higher in surface water.

ii. pH of ground water (borehole and well water inclusive) and surface water were acidic.

iii. Only dissolved oxygen showed a significant negative relationship with distance from gas flaring while other physico-chemical parameters were not statistically significant.

The environmental and health implications of the above include:

Ground water from dug wells is generally used for domestic purposes in rural area of EbochaObrikom without prior treatment and there are concerns about health implications. The study revealed that both the surface water and groundwater samples collected over Ebocha-Obrikom oil and gas producing community were relatively acidic, contained acidic radicals and may be attributed to emissions from gas flaring and petroleum refining activities, which is common in the area. Thus, the water quality of Ebocha-Obrikom Communities is believed to be gradually deteriorating particularly in the industrialized area.

Higher concentrations of most of the measured parameters are suggestive of input of effluents into the water from industries within and around the Ebocha-Obrikom oil and gas producing area of rivers state. Therefore by virtue of its present quality status it can be assumed that it is detrimental to aquatic life. High contents of BOD often deplete the amounts of dissolved oxygen which is harmful to aquatic life. The results revealed that the water quality status of Ebocha-Obrikom is adversely impaired with the discharge of industrial effluents. Turbidity which relates to the amount of materials (effluents) present in the water was observed to be high and its aesthetic value seemed lowered as a result of input of wastes from the industries. Likewise, the high content of Iron suggests that ground waters have the potentials to affect ecosystem health and the health of the rural community that use the ground water directly without treatment. Also alarming are the consequences or chronic impacts of the levels of iron recorded in this aquatic ecosystem that may damage tissues as a result of iron accumulation and may result in development of a benign pneumoconiosis. Iron may cause conjunctivitis, chorditis and retinitis when contacted and remained in the tissues. The presence of Iron in drinking water supplies is objectionable for a number of reasons unrelated to health. For example, water containing iron often has taste and stains laundry and plumbing features as a result of the precipitation of Fe $(OH)_3$ from unstable $FeSO_4$ present in water. Iron also promotes the growth of iron bacteria. Furthermore, in the maximum protection of the health of the natives from the potential effects of exposure to Iron through ingestion of the contaminated ground waters and aquatic organisms, the ambient water concentrations of Fe in drinking water are normally 0.3mg/l and the excessive limit is 1.0mg/l. Iron level gets much higher if the Iron gets corroded. This is very common with waste water or effluent from factories which are usually discharged into nearby water bodies using Iron pipes. The results suggest that the use of such waters for drinking and domestic purposes may pose a threat to the health of the users and calls for the intervention of government agencies. However, simple physical treatment of effluents should be carried out. Recently, the Government of Nigeria has set the year 2020 to end all gas flaring activities by oil companies operating in the Niger Delta area. Efforts are also being made by local authorities to ensure better sanitation practices in the communities. These may help reverse the degenerating trend of water resources quality in the area.

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