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Physico-Chemical and Bacterialogical Analysis of the Surface Water Used for Domestic Purposes in Okpai and Beneku, Delta State, Nigeria

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PHYSICO-CHEMICAL AND BACTERIALOGICAL ANALYSIS OF THE SURFACE WATER USED FOR DOMESTIC PURPOSES IN OKPAI AND BENEKU, DELTA STATE, NIGERIA

Strictly as per the compliance and regulations of:

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Abstract - The main focus of this study is to analyze the effects of gas flaring and oil spillage on surface water used for domestic purpose in Okpai and Beneku area, Delta State Nigeria. Surface water samples were collected in the dry (December, January and February) and wet (June, July and August) seasons from Okpai (experimental site) and Beneku (control site). The water samples were analyzed for chemical, physical and biological parameters using standard procedures. The results for all the parameters analyzed showed higher variation between samples obtained from the experimental site and those of the control site which indicate possible pollution in the experimental site for instance, the pH values were 5.33 and 5.586 in the dry and wet seasons respectively for Okpa. For Beneku, the pH values were 6.82 and 6.91 in the dry and wet seasons respectively. Magnesium (2.437mg/l in the dry and 2.063mg/l in the wet recorded in samples obtained from Okpai were higher than those obtained Beneku. The presence of coliform (<2 colonies in the dry and approximately <1.67 colonies in the wet were recorded in Okpai samples. These could have serious health implications on the inhabitants of the area. However, most of the other parameters analyzed correspond with the approved maximum permissible limits for drinking water set by NAFDAC, USEPA and WHO. On the basis of the principles of sustainable development, it is recommended that the Gas Flaring Emissions Reduction Policy should be effectively implemented in order to reduce the direct and adverse effects of these pollutants on the consumers in the area.

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I. Introduction

Water is the most unique molecular compound ever known in life. It exists in the solid, liquid and gaseous states. Water in its liquid state is what makes life possible on earth because all living organisms are composed of cells that contain at least sixty percent water (Enger and Smith, 2010). All metabolic activities in the bodies of living organisms take place in a water medium. The usefulness of water depends on whether such waters are timely, quantitatively and qualitatively available. According to Bhatia (2009), of over 70% of the earth's surface covered by water, about 97.57% is salt water from oceans while the remaining less than 3% are contained in soils, rivers, lakes, ground water as well as ice and glaciers. Since salt water cannot be readily consumed by humans or freely used for various industrial and domestic purposes, humans and other living organisms depend and compete for the limited fresh water sources available to them. Ball (1999) put it that 'water can shape history and can make or break a king'. Civilizations have flourished and collapsed as a result of changing water supplies (Waziri, 2006). The availability of quantitative and qualitative fresh water for humans have over the years influenced settlement patterns of people in certain geographical regions in preference for others. For water to be adequately utilized, it has to be reasonably free from contaminants. Otherwise, such waters could pose serious health and environmental risks to living organisms that depend on them. Portable water is a fresh water body that is unpolluted, suitable for drinking, odourless and tasteless. Such water boils at 100^0C, freezes at 0°C, is neutral to litmus and has an atmospheric pressure of 760mmHg (Kolo, 2007). Water is a universal solvent for virtually all solutes hence creates a medium upon which every other chemical reaction takes place; be it living or non-living. It cools and heats more slowly than most substances known to science. It's thus used as either a cooling or heating agent. Water could be cultivated in various forms. It could be tapped from underground aquifers via wells or boreholes; could be harvested as rain (precipitation) from the atmosphere and as is the practice in most communities be fetched from surface water sources like rivers, streams, lakes, ponds, oases, seas or even oceans. Surface water has the basic advantage of being comparatively cheaper and very easy to cultivate. Ball (1999) defined surface water as one that fails to penetrate into the soil, subsoil or flows along surface of the ground and eventually enters the lakes, rivers or oceans. The main focus of this study is to assess the

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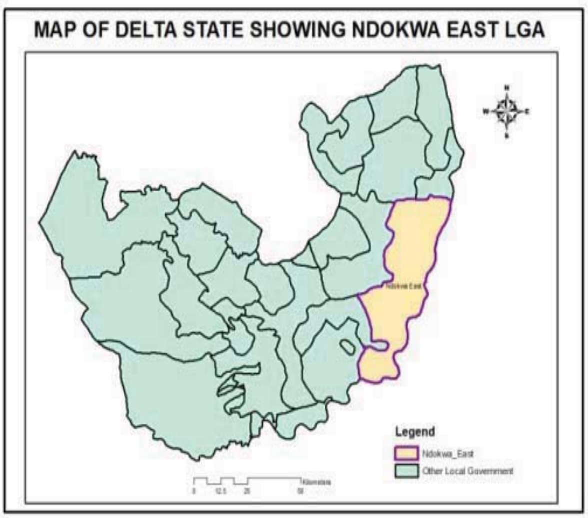
effects of gas flaring and oil spillage on surface water for domestic use in the area.

II. Study Area

The Niger Delta is located within the southern part of Nigeria. It is home to numerous creeks, rivers and possesses the world's largest wetland with significant biological diversity (Twumasi and Merm, 2006). Okpai/Aboh region are within Ndokwa East Local Government Area and are situated within the Sombriero Warri deltaic plain deposit invaded by mangroves. The area is located within latitudes 5°40′N and 5°50′N and longitudes 6°15′E and 6°30′E (Figure 1) (Oseji and Ofomola, 2010).



Source : Delta State Ministry of Lands and Survey, 2009

Geographically, Niger Delta has covered an estimated area of between 19,100 km^2 to 30,000 km^2 based on hydrological, ecological as well as political boundaries (SPDC, 2006 and UNDP, 2006). Okpai/Aboh region is within a low-lying height of not more there 3.0 meters above sea level and generally covered by fresh water, swamps, mangrove swamp, lagoonal marshes, tidal channels, beach ridges and sand bars along its aquatic fronts (Dublin-Green *et al*, 1997). The area has a characteristic tropical monsoon climate at the coast with rainfall peaks in June and September/October with prevailing tropical maritime air mass almost all year round with little seasonal changes in wind directions (Olaniran, 1986). Annual mean total rainfall has been put at between 1,500mm and 3,000 mm with a mean monthly temperature range of 24-25°C during the rainy season in August and 27-29°C during tail end of dry season in March/April. Leroux (2001) reported that maximum temperatures are recorded between January and March (33°C) while minimum temperature are recorded in July and December (21°C), respectively. Temperatures are seriously moderated by cloud cover and damp air. It experiences a tropical climate consisting of rainy season (April to November) and dry season (December to march). The average annual rainfall is about 2,500mm while the wind speed ranges between 2-5m/s in the dry season to up to 10m/s in the rainy season especially during heavy rainfall and thunderstorms. The region is criss-crossed with distributories and creeks. This area has been classified geomorphologically to consist of tidal flat and large flood plains lying between mean, low and high tides. Three different highs exist within the Kwale block, namely; a central high where most of the wells have been drilled an eastern high housing one well and a north western high whose extent has not been clearly defined. The area lies within the freshwater forested region of the Niger Delta.

III. Methodology

Surface water samples were collected from two distinct locations. The first was within the Agip Gas Plant in Okpai area (experimental site) while the second was about 5km away at Beneku (control site), both within Ndokwa-East Local Government area of Delta State, Nigeria. Samples were collected during the dry (December 2010, January 2011 and February 2011) and wet (June, July and August 2011) seasons. Means of the three months were then used to represent specific parameters for either dry or wet seasons, respectively. A total of six samples were collected from each of the distinct points. Three samples of surface water were collected from both Okpai and Beneku in the study areas. The samples were collected around 5.00 – 6.00pm of the day. The surface water samples collected were analyzed. At every point, two sets of samples were collected: one for AAS analysis and the other for anions like phosphate, sulphate and nitrate. No further treatment was needed for the anions, thus the samples were analyzed right away to minimize chemical changes in the sample and prevent losses to the environment (Radojevic and Bashkin, 1976).

Pre-treatment of the water samples elemental analysis was necessary because of the likelihood of such samples containing suspended particles along with metals. Pre-treatment involved addition of an acid to preserve the sample, destroying organic matter and bringing all metals into solution (Radojevic and Bashkin, 1976). A few drops of concentrated HNO_3 were added to the water samples after collection to preserve the samples, destroy organic matter and minimize absorption on the walls of the containers. Preparation of standard stock solutions and working standards were done following the methods by USEPA (2007) for calcium, magnesium, sodium, potassium, iron, copper, zinc, cadmium, lead, chromium and aluminium. McConkey broth single and double strengths were also prepared. Full details on preparation of stock solutions and working standards are contained in Amukali (2012).

100cm³ of water samples were measured and put into a beaker. A 5cm³ aqua regia (HNO_3 : HCl in ratio 3:1) was then added and the beaker containing the mixture was placed on a hot plate and evaporated on a fume chamber. As the beaker was allowed to cool, and the 5cm³ aqua regia were added again but this time the beaker was covered with a watch glass and returned to the hot plate. The heating continued with continuous addition of aqua regia to complete the digestion and after which it was brought down and another 5cm³ aqua regia added, with the beaker warmed slightly so as to dissolve the residue (Radojevic and Bashkin, 1976).

The brilliant green lactose bile broth medium was prepared by dissolving 40g of the BGLB powder in 1 litre of distilled water. The solution was then thoroughly mixed and put into test tubes fitted with Durham tubes and sterilized by autoclaving at 121ºC for 15 minutes. The parameters analyzed include pH, temperature, taste, colour, conductivity, alkalinity, turbidity, DO, BOD, COD, TDS, TSS, SO_4^{2-}, PO_4^{3-}, NO_3^-, Chlorides and fluorides. The Atomic Absorption Spectrometer (AAS) was used for the determination of all metals studied in this work (calcium, magnesium, sodium, potassium, iron, copper, zinc, cadmium, lead, chromium, and aluminium). Coliform counts were then studied following the method adopted by Kolo (2007) five tubes each of 50ml, 10ml and 1ml of single strength McConkey Broth Medium were inoculated with volumes of the water samples and incubated for 24 hours at 24ºC.

IV. Results and Discussion

The results for the twenty nine (29) parameters analyzed in surface water samples at both Okpai and Beneku are presented in (table 1-5). The pH was found to be highest at Beneku during wet season with an average value of 6.91. A value of 6.82 was observed at same Beneku during dry season, 5.86 at Okpai during wet season while 5.34 at same Okpai during dry season. Using the maximum permissible range of 6.0-8.5 as limit for pH (NIS, 2007) as benchmark, Beneku rain waters were comfortably within safe limits while those of Okpai were within acidic ranges, thus signifying some level of pollution during both seasons. This agrees with the observations made by Nwankwo and Ogagarue (2011) that areas prone to oil spillage have pH levels that are within acidic ranges. In addition, higher acidities at Okpai during dry than wet season is an indication that large volumes of water received during wet season tend to help in neutralizing the acidic contents of Okpai surface waters while highly acidified rains received during dry season tend to further increase the pH levels of surface waters. It could be deduced that large amounts of water received by surface waters tends to be neutralized, thereby reducing the level of acidity within the study area. Direct discharge of oil and its constituents could also be responsible for the higher acidity levels of surface waters of Okpai. Aquatic plants and animals that depend on Okpai surface waters for sustenance stand dangers of ingesting toxic substances that could lead to diseases and death. Okpai surface waters fell below the stream standard for fishing and this is a clear indication that fishes and other aquatic organisms might have migrated to nearby surface water bodies where they could have minimum stress.

Table 1 : Physical Parameters of the Samples

	Parameters			
Samples	Tempt (ºC)	Colour	Taste	Turbidity (WTU)
DRY.OK.SW	27.88	35.33	2	6.25
DRY.BN.SW	28.50	23.00	1	4.54
WET.OK.SW	27.40	32.00	2	4.58
WET.BN.SW	27.10	21.00	1	3.67
Max. Perm. Value	25 – 30ºC	15 TCU	0	5NTU

Table 2 : Chemical/Biological parameters of the samples

Samples	Conductivity	Alkalinity	Dissolved Oxygen	B O D	T D S	T S S	pH
DRY.OK.SW	187.33	11.21	3.10	0.77	62.46	9.62	5.33
DRY.BN.SW	81.04	3.03	3.53	1.12	24.54	10.27	6.82
WET.OK.SW	191.42	11.37	3.54	0.91	48.33	11.44	5.86
WET.BN.SW	86.10	2.26	3.77	1.22	11.42	10.34	6.91
Max. Perm. Value	1,000µ/cm	30 – 500mg/l	>4	0.1 – 1.9mg/l	1,000mg/l	20mg/l	6.0 – 8.5

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Table 3 : Levels of some Anions in the samples

	Anions (Mg/L)				
Samples	SO_4^{2-}	PO_4^{3-}	NO^{3-}	Cl^{-}	F^{-}
DRY.OK.SW	1.29	0.11	0.04	0.63	<0.001
DRY.BN.SW	0.06	0.01	<0.001	0.39	<0.001
WET.OK.SW	1.31	0.020	0.03	0.895	<0.001
WET.BN.SW	0.10	0.02	<0.001	0.24	<0.001
Max. Perm. Value	100mg/l	10 – 50mg/l	50mg/l	250mg/l	0.8 - 1.5mg/l

Table 4 : Levels of some Elements in the samples

	Elements (Mg/L)										
Samples	Ca	Mg	Na	K	Fe	Cu	Cd	Zn	Pb	Cr	Al
DRY.OK.SW	6.69	2.06	0.27	0.107	0.12	0.02	<0.001	0.05	<0.001	<0.001	<0.001
DRY.BN.SW	3.71	1.98	0.03	0.07	0.01	0.01	<0.001	0.01	<0.001	<0.001	<0.001
WET.OK.SW	4.26	2.44	0.46	0.17	0.08	0.01	<0.001	0.02	<0.001	<0.001	<0.001
WET.BN.SW	3.55	2.24	0.09	0.14	0.01	0.00	<0.001	0.01	<0.001	<0.001	<0.001
Max. Perm. Value	50mg /l	37 - 150mg/l	200m g/l	1 – 2mg/l	0.3m g/l	1.0m g/l	0.003m g/l	3mg/l	0.01mg /l	0.05mg /l	0.2mg/l

Table 5 : Result of the Bacteriological Analysis

Samples	Coliform
DRY.OK.SW	<2.0
DRY.BN.SW	0
WET.OK.SW	<1.667
WET.BN.SW	0
Max. Perm. Value	0

Temperature was found to be highest with an average value of 28.5^{0}C at Beneku during the dry season. Okpai during dry season had an average value of 27.90^{0}C; 27.40^{0}C was observed for Okpai during wet season while the least value of 27.1^{0}C was noticed at Beneku (table 1). The maximum permissible limit of temperature of between 25-30^{0}C for drinking water was not exceeded by all surface water sources assessed in this study. Bhutia (2005) stated that areas prone to discharge of industrial wastes usually have temperature ranges above those of their surrounding environments. Therefore, the operational presence of a ferry that conveys people to and fro Pontu river from where Beneku surface water samples were collected, must have influenced an increase in surface water temperature of Beneku during dry season where there were lesser amounts of water available to neutralize temperatures of rain water and runoff received while wet season has lots of water available to reduce the temperature of received waters. This is indicative of surface water pollution since organisms that initially depend on such surface waters could find the temperature ranges no longer suitable for their continued stay and could migrate to areas with favourable temperature condition. Small increases in temperatures of surface waters puts aquatic organisms living in them to be under environmental stress, kills certain species plants and animals and leaving oxygen-demanding wastes to decay. Oxygen has been reported to be less soluble at higher temperatures (Khan and Khamd, 1994). Higher surface water temperatures limit migration, spawning, egg incubation, growth and metabolism as well as rates of respiration.

Pure water is tasteless (Bhutia, 2005). Okpai and Beneku surface waters (table 1) during wet and dry seasons both had a value of 2 and 1 respectively, which indicates surface water contamination. The maximum permissible limit for taste has no nominal value verbally unobjectionable (NIS, 2007) and this by our adopted scale equals zero. This phenomenon could be attributed to dissolved salts and other contaminants like spilled oil and other wastes substances that could drain into the surface water. Though, tastes as recorded in this study do not have any health effects, but does affect a consumer's choice.

Bhutia (2005) stated that pure water is colourless. Thus, any water with a characteristic colour insinuates contamination. The highest value for colour was observed for Okpai during dry season with a value of 35.33 TCU while a value of 32 TCU was recorded for Okpai during wet season. Beneku during dry and wet seasons had 23 TCU and 21 TCU respectively (table 1). The maximum permissible value for colour of 15 TCU (NIS, 2007) has been exceeded by all values in this area. Colour of surface waters must have been affected more during dry season than wet season and dissolved salts, spilled oil, coloured rain water as well as other contaminants. Colour could also be due to the presence of decaying organic matter, iron compounds, leaching of organic materials into surface waters, waste water of industrial processes, eutrophication and suspended solids.

Okpai during both dry and wet seasons were respectively more than 100% greater than the recommended maximum permissible value for colour. Generally, Okpai showed higher levels of colouration than Beneku on the one hand while dry season was higher than wet season in both study sites. This shows a level of contamination in surface waters of both Okpai and Beneku during the two seasons, most especially at Okpai. There were significant differences between wet and dry seasons and between Okpai and Beneku. Colour affects a consumer's choice for drinking water.

Conductivity was highest at Okpai during wet season with a value 191.42 μs/cm and 187.33μs/cm was recorded for same Okpai during dry season. Conductivity values for Beneku during wet and dry season with values of 86.10μs/cm and 81.04μs/cm, respectively was observed (table 2). The maximum permissible limit of 1,000μs/cm (NIS, 2007) was not met by all values under study for surface water. Significant differences existed between Okpai and Beneku and between both seasons at $p<0.05$ level of significance. Conductivity was higher at Okpai surface waters than Beneku while wet season influenced higher conductivities than dry season. Higher conductivities in surface waters during wet season as against dry season could be due to such waters receiving waters that are already loaded with salts. Higher conductivities in surface waters during wet season as against dry season could be due to such waters receiving waters that are already loaded with salts. The high rate of conductivity in Okpai surface waters could be due to excessive accumulation of salts, impurities in rain water, spilled oil, through run-off from agricultural lands and possible emissions of flared gases getting into surface waters.

Alkalinity was highest at Okpai during wet season with a value of 11.373 and this was closely followed with a value of 11.21 for Okpai during dry season. Also, 3.03 and 2.26 were then observed for Beneku during dry and wet seasons respectively (table 2). Alkalinity was found to be higher at Okpai than at Beneku. Comparatively, the high rate at Okpai could be attributed to continuous release of chemicalized substances through oil spillage and gas flaring which later drains into surface water bodies. Higher alkalinity levels in surface waters as compared to rain waters could be due to the influences of rocks, soils, certain plant activities and dissolved salts. It could be deduced that Okpai surface waters have higher capacities to neutralize acidified rains than Beneku surface waters.

The approved maximum permissible range of between 30-500mg/l for drinking water (USEPA, 1991) was not met by all study sites during the two seasons. Drinking surface waters which are already below the approved ranges could lead to the acidification of the human body's alkalinity status and these could predispose human being to higher risks of infection.

Total Dissolved Solids of Ground Water (TDS) has the highest value at Okpai during dry season with an average value of 62.46mg/l and this was followed by 48.33mg/l at same Okpai but during wet season. Values for Beneku were then 24.54mg/l and 11.42mg/l during dry and wet seasons (table 2). WHO (1996) recommends 1000mg/l for the protection of fisheries and aquatic lives while NIS (2007) recommended 500mg/l as maximum permissible limit for domestic water supply. All values were below the acceptable limit.

High TDS values at Okpai as compared to Beneku could be attributed to massive contamination by chemicals and allied substances emanating from oil related activities like gas flaring and oil spillage. Surface waters contamination in this wise could be due to continuous contamination of the waters by industrial pollutants as reported by Bhatia (2005). The high TDS with respect to Dissolved Oxygen (DO) with the low DO agrees which depict high TDS (Ademoroti, 1996).

High levels of TDS in drinking water may be objectionable to consumers due to its taste and this could cause excessive scaling in water pipes, boilers and household appliances (Kolo, 2007). Surface water for the two study sites for both seasons could be described as excellent since according to Ademoroti, (1996), a water sample is rated good if TDS is between 300 – 600mg/l, fair if between 600 – 900mg/l, poor if between 900 – 1200mg/l and unacceptable when above 1200mg/l.

The mean values of TSS show that Okpai during wet season had its highest value of 11.443mg/l. During wet season at Beneku, 10.337mg/l was recorded, 10.27mg/l at Beneku during dry season and finally 9.62mg/l at Okpai during dry season (table 2). Okpai and Beneku when compared at $p<0.005$ level of significance showed that in terms of seasons, that wetness had greater impacts over dryness, and there were peculiarities between Okpai and Beneku. The maximum permissible limit for TSS for drinking water of 500mg/l (NIS, 2007) was not exceeded by all study sites during the two seasons.

Coliform colonies (table 5) that were detected in Okpai during two seasons were less than 2.0cfu/ml and 1.67cfu/ml, respectively. The maximum permissible limit of 0cfu/ml for drinking water (NIS, 2007) was exceeded at Okpai but not in Beneku during both seasons. Industrial activities within Okpai must have influenced the presence of coliform bacteria. The stagnant nature of Okpai surface waters must have also contributed to the non dispersal of coliform bacteria in Okpai while Beneku surface waters with very high water current must have easily dispersed coliform bacteria out in a very timely way. Thus, Okpai surface waters could pose a great health and environmental danger owing to evidence of possible bacterial contamination. Pathogenic organisms like E-coli and a host of other pathogenic organisms could be present within the surface waters and this could lead to serious health hazards to the consumers.

In summary, the surface water of the study area is also relatively safe for drinking but not as rain water within the period of study (Amukali, 2012)

V. Conclusion

Surface waters at Okpai showed variation in the levels of the studied parameters with season. Okpai showed slight variation with season since during dry season; only pH, taste, colour, turbidity, magnesium and coliform exceeded the maximum permissible limits for drinking water. But during wet season; only pH, taste, colour, magnesium and coliform were above the limits. On the other hand, Beneku didn't show any marked variation between seasons. It could be deduced that Beneku surface waters were less polluted than Okpai surface waters however none is suitable for drinking except after an appropriate treatment of the water is performed.

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