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PHYSICOCHEMICAL QUALITY OF BOREHOLE WATER IN ABONNEMA AND ITS PUBLIC HEALTH IMPORTANCE

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ABSTRACT

This study was undertaken to assess potability in relation to physicochemical quality characteristics of borehole water in Abonnema Community of Rivers State. The sampling sites were divided into five zones namely Bob-Manuel, Jack, Briggs, New Site and Obonoma. Water samples from various sites such as urban area, new site and rural areas were obtained. Standard sampling and analysis were done aseptically at different locations according to the compounds and sites of water supply. The result of the analysis showed that the pH values across the zones had a mean range of 6.2 ± 0.2 to 6.8 ± 0.4, while conductivity values for Briggs and Obonoma compounds were 47.8 and 50.6 µs/cm respectively. However, the study revealed that Mg, Fe, SO_4 and CO_2 contents were in greater amounts in the rural area and new site while chloride and copper were relatively low in the same water sites. Total alkalinity ranged between 35.2 ± 9.7 and 112.7 ± 7.1 mg/l in the water samples and is below the permissible limits for drinking water. From the findings of this study, borehole water samples from urban are more potable than those of new site and rural area. The public health implications for people of Abonnema who depend on these sources of water supply daily have been discussed. Treatment of boreholes, boiling and filtering of drinking water as well as improved sanitary conditions and personal hygiene were advocated. Government should as a matter of urgency ensure appreciable decline in the level of water pollution through routine monitoring of groundwater and anthropogenic activities in the zone.

KEYWORDS: Physicochemical, Borehole water, Abonnema community, Public Health, Nigeria.

INTRODUCTION

Human beings like other animals require food, water, space and protection from diseases. The most urgent of all these is the need for water (Lafontaine, 1975). Ehrlichs, (1974), in his work "Ethics of equilibrium" opined that one of the inalienable rights of man is the "right to drink pure (potable) water". Humans need at least 2 liters of drinking water per day and this should be free of physical, chemical and biological impurities (Simmons, 1994; Hanif *et al*., 2005). Our normal drinking water contains several minerals and salts like iron, manganese, nitrate, calcium, magnesium, sulphate, floride, as well as gasses such as carbon dioxide, oxygen and nitrogen; their proportions have to be carefully watched as indeed the possible content of bacteria (Newton, 1997).Water is essential to all forms of life and makes up to 50-95% of all plants and animals, and about 70% of human body (Buchholz, 1998). Water is also a vital resource for agriculture, manufacturing, transportation and many other human activities. Agriculture is believed to be the largest user of the world's freshwater resources, consuming 70% (Grafton and Hussey, 2011).

Contamination of water sources leads to increased pH that affects mucous membranes, causes water to taste bitter and gives water a corrosive nature; increased dissolved oxygen, increases temperature of water and results in increased microbial activity (WHO, 2006). Nitrates can also soak into the ground and end up in drinking-water. All these can result into health problems that contribute to methemoglobinemia or blue baby syndrome disease which causes death in infants (WHO, 2006). In highly developed countries emphasis has shifted from concern over bacterial diseases to concern over water-borne diseases. Viral hepatitis for example has been found to occur more frequently in cities whose water supplies have comparatively high levels of water turbidity (Biswas and Sweetharam, 2008). Ionizing radiation from water polluted by water-soluble radioactive isotopes is capable of being concentrated in various tissues and organs as they pass through food chains and webs (Bartram et al; 1996).

Water supply at Abonnema is of groundwater source (hand-dug well, mono pump and borehole). Dug-out wells and rain fall have been the major sources of domestic water supply in this zone before the advent of mono pump and borehole. These wells have been installed in Abonnema at various depths depending on the

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availability and level of groundwater with or without tight casing, cover or elevation from ground level. In many cases, immediate environmental conditions are unfavourable; for instance, defecating in the nearby bushes, proximity of wells from latrines, the effects of oil exploration and exploitation in the zone coupled with the direct sewage – contamination of natural water bodies due to the cultural habit of defecating inside rivers, practiced in Niger Delta Regions of Nigeria have contributed greatly to water pollution (Wokem and Lawson-Jack, 2014). There has been an occasional outbreak of gastro-enteritis, typhoid and skin itching in Abonnema community (M.O.H, 2006) and in other communities like Kula and Bille in the same L.G.A, the epidemiology of this outbreak has not been sufficiently investigated but was reported to be partly water borne in a microbiological assessment of Abonnema water sources (Wokem and Lawson-Jack, 2014).

The importance of this study is to assess the physicochemical qualities in relation to potability of groundwater (borehole) in Abonnema community as well as to compare the results with the recommended guidelines of W.H.O. for drinking water. It attempts to proffer measures to improve the quality of drinking water, create awareness on the Public Health implications of the results, and make the findings serve as a springboard for subsequent research in the study area.

MATERIALS AND METHODS

The study was conducted at Abonnema in Akuku-Toru Local Government Area of River State, situated between latitude 4^0 43′ and 4^0 45′ North of Equator and between longitude 7º 7′ and 7º 12′ East of the Greenwich Meridian. It is in the Niger Delta Region of Nigeria hence grossly exposed to oil exploration and exploitation activities. Abonnema community was divided into five zones for collection of groundwater samples from boreholes.

The water samples were aseptically collected using 500 ml sterilized amber bottles at early morning when activities at the source sites were at their peak. Standard sampling and analytical methods were employed to investigate each water sample to assess the physicochemical characteristics of the water samples. In all, forty five samples were collected for a period of one year.

The pH was read without delay using electronic pH meter (Orion Research Model Cell). For physicochemical analysis, most of the parameters were determined using spectrophotometer (Model HACH/DR 2010) with its reagent pillows. Where the pillows were not available, titrimetric method was carried out (Bartram and Balance, 1996).

STASTICAL ANALYSIS

Data were entered and analyzed with Statistical Package for Social Sciences (SPSS) software version 12 for windows (SPSS Inc., Chicago, IL). Statistical tools included mean, standard deviation, Pearson correlation coefficient and frequency distribution.

P values less than 0.05 were considered statistically significant.

RESULTS

Table 1, shows the distribution of borehole water in compounds within the study area. Abonnema had 27 sampling stations with a percentage frequency of 60% since it was grouped as an urban city, the New Site had 9 sampling stations with a percentage frequency of 20% and it is a recent developing area, while Obonoma in this study represents the rural setting with 9 sampling stations and 20% as percentage frequency.

The mean levels of various physical properties of the study sites are presented in Table 2. The mean pH values were 6.2 ± 0.2 and 6.8 ± 0.4 for Bob-Manuel and Obonoma respectively, while the mean Total Dissolved Solids (TDS) were observed to be as high as 55.6 ± 27.3 and 11.0 ± 0.3 mg/l for Obonoma and Jack respectively. The mean levels of Total Suspended Solids (TSS) in Obonoma was 23.9 ± 23.7 mg/l and 1.0 ± 0 mg/l in the other compounds while conductivity (47.5 ± 1.8 μs/cm) and turbidity (2.01 ± 1.5 NTU) values were highest in Obonoma. However, these values are within the World Health Organization (W.H.O, 2006) permissible limits.

Mean values of physical parameters of water samples from the sites (Table 3) showed that the new site with 25.7 ± 20.9 mg/l for TDS, 1.08 ± 0.09 NTU for turbidity is significantly (P< 0.05) higher than other sites of water sampled for these parameters. The pH means values ranged between 6.5 ± 0.4 and 6.7 ± 0.3 for rural area and urban respectively. The mean values of other parameters were not significant.

Tables 4 showed the mean values of chemical parameters of borehole water according to compounds. Total alkalinity mean values ranged from 35.2 ± 9.7 to 112.7 ± 7.1 mg/l in the compounds, while chloride content ranged between 23.7 ± 12.7 to 59.5 ± 14.7 mg/l in New Site and Briggs compounds respectively.

Total mean hardness and magnesium content in the new site and rural area borehole water samples were observed to be high (table 5). The values for total hardness showed that the urban had 56.0 ± 33.6 mg/l, new site recorded 57.9 ± 29.9 mg/l while 64.6 ± 28.9 mg/l was recorded for rural area. Magnesium content for rural area was 8.6 ± 6.1 mg/l, whereas sulphate was 77.8 ± 23.1 mg/l for new site in the study area. Iron content in the new site water was 0.75 ± 0.3 while 0.6 ± 1.4 mg/l was recorded in rural. Mean alkalinity values ranged between 65.2 ± 30.2 to 74.1 ± 28.3 mg/l in the sites of water supply. P values were significant in some of the samples analyzed.

TABLE 1: Distribution of borehole water in compounds within the study sites

S/N	Study sites /setting	(% Frequency)	Number of compounds	(NO.)	Bore hole sites frequency %
1.	Abonnema /Urban	(33.3)	Bob-Manuel	(9)	20
			Briggs	(9)	20
			Jack	(9)	20
2.	New site /Developing	(33.3)	New site	(9)	20
3.	Obonoma /Rural	(33.3)	Obonoma	(9)	20
4.	Total	(100)		45	100

Table 2: Mean values of the physical parameters of borehole water according to compounds in the study area

Compounds	Mean values of physical parameters					
	P^H	TDS mg/l	TSS mg/l	Conductivity µs/cm	Turbidity NTU	Colour TCU pl. Co. unit
Bob Manuel	6.2±0.2	11.2±1.48	1.0±0	43.7±2.2	0.05±0.1	1.0±0.0
Briggs	6.8±0.3	12.8±2.6	1.0±0	44.8±3.4	0.15±0.1	1.0±0.0
Jack	6.8±0.3	11.0±0.3	1.0±0	38.9±2.0	0.07±0.02	1.0±0.0
New Site	6.5±0.3	11.2±1.0	1.0±0	39.2±2.2	0.05±0.0	1.0±0.0
Obonoma	6.8±0.4	55.6±27.3	23.9±23.7	47.5±1.8	2.01±1.5	3.2±2.5
F value	7.265	23.226	8.406	21.384	6.493	6.639
P value	0.201	0.001*	0.001*	0.001*	0.001*	0.001*
W.H.O guideline, (2006)	6.5 – 8.5	500	-	2500 at 20°c	5	15

Key: - = Limit not established, * Significant at P<0.001,

TABLE 3: Mean values of the physical parameters of boreholes according to their sites

Sites	Mean values of physical parameters					
	P^H	TDS mg/l	TSS mg/l	Conductivity µs/cm	Turbidity NTU	Colour TCU pl. Co. unit
Urban	6.7±0.3	13.5±6.0	1.1±0.2	42.4±4.2	0.08±0.1	1.0±0.0
New site	6.6±0.3	25.7±20.9	11.6±10.1	42.5±3.58	1.08±0.09	1.5±1.3
Rural area	6.5±0.4	21.9±15.4	4.1±3.3	43.7±4.2	0.24±0.3	1.8±1.6
F value	1.189	1.293	2.522	0.476	3.002	1.242
P value	0.315^{ns}	0.285^{ns}	0.092^{ns}	0.824^{ns}	0.05*	0.299
WHO Guideline (2006)	6.5 – 8.5	500	-	2500 at 20⁰c	5	15

KEY: *= significant at P<0.05, ns = not significant, - = limit not established

Table 4: Mean values of the chemical parameters of borehole water according to the compounds

Parameter	Total Alkalinity Mg/l	Acidity Mg/l	Chloride Mg/l	Total Hardness Mg/l	Calcium Mg/l	Magnesium Mg/l	Sulphate Mg/l	Carbon dioxide Mg/l	Fluoride Mg/l	Copper Mg/l	Iron mgl	Salinity PPT(0/00)
Permissible Limit	**400**	**-**	**250**	**500**	**-**	**2**	**250**	**-**	**1.5**	**2.0**	**0.3**	**-**
Compound	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**	**Mean ±SD**
Bob-Manuel	50.8±19.8	21.8±5.1	56.1±10.1	66.6±11.3	59.8±8.0	6.8±3.8	85.0±5.6	36.1±10.3	0	0.04±0.03	0	0.08±0.02
Briggs	112.7±7.1	54.0±12.4	59.5±14.7	86.0±12.7	81.0±11.4	8.3±7.3	61.3±37.6	39.6±16.0	0	0.05±0.02	0.06±0.05	0.1±0.02
Jack	81.0±5.6	28.1±8.8	47.6±3.7	89.8±5.3	82.9±4.9	5.7±1.8	49.3±34.7	40.7±6.8	0	0.08±0.05	0.06±0.05	0.14±0.02
New site	35.2±9.7	34.9±4.9	23.7±12.7	16.1±1.7	13.6±1.9	2.57±0.5	76.5±18.5	16.6±1.9	0	0.03±0.01	0.09±0.02	0.1±0.00
Obonoma	72.2±17.3	23.3±4.8	27.3.0±11.3	39.1±17.4	37.3±16.6	2.6±1.0	41.7±26.8	34.3±4.3	0	1.05±0.9	2.04±0.02	0.1±0.00
Total	70.4±29.7	32.5±14.0	42.9±18.3	59.5±30.4	54.9±28.4	5.2±4.3	63.6±30.4	33.5±12.5	0	0.25±0.3	2.04±2.0	0.1±0.00
F Value	45.365	25.263	19.524	71.109	79.147	4.093	3.584	9.919	0	1.000	8.457	5.500
P Value	0.001[a]	0.001[a]	0.001[a]	0.001[a]	0.001[a]	0.007	0.014[b]	0.001[a]	0	0.419[c]	0.001[a]	0.001[a]

Key: a = Significant at P<0.001, b = Significant at P<0.01, c = Not significant, - = Limit not established

Table 5: Mean values of the chemical parameters of borehole water according to their sites.

Parameter	**Total Alkalinity mg/l**	**Acidity mg/l**	**Chloride mg/l**	**Total Hardness mg/l**	**Calcium mg/l**	**Magnesium mg/l**	**Sulphate mg/l**	**Carbon dioxide mg/l**	**Fluoride mg/l**	**Copper mg/l**	**Iron mg/l**	**salinity PPT(0/00)**
Permissible Limit	**400**	**-**	**250**	**500**	**-**	**2**	**250**	**-**	**1.5**	**2.0**	**0.3**	**-**
Site	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD
Urban area	71.8±31.7	28.8±8.4	50.7±14.9	56.0±33.6	52.6±32.3	3.95±1.9	49.5±26.8	29.8±9.0	0	0.07±0.03	0.04±0.05	0.1±0.00
New site	65.2±30.2	34.8±12.8	36.6±16.2	57.9±29.9	53.6±28.1	3.53±1.7	77.8±23.1	42.2±15.0	0	0.05±0.05	0.5±0.03	0.1±0.02
Rural area	74.1±28.3	33.7±18.9	41.2±21.3	64.6±28.9	58.5±26.0	8.16±6.1	65.5±34.6	28.3±6.7	0	0.63±0.03	0.6±1.4	0.1±0.03
Total	70.4±29.7	32.5±14.0	42.7±18.3	59.5±30.4	54.9±28.4	5.23 ±4.3	63.6±30.5	33.5±12.5	0	0.25±0.3	0.45±0.8	0.1±0.02
F Value	0.354	0.772	2.459	0.322	0.174	6.587	3.597	7.076	0	0.912	1.459	1.672
P Value	0.704^{ns}	0.468^{ns}	0.098^{ns}	0.726^{ns}	0.841^{ns}	0.003**	0.04^{*}	0.002^{**}	0	0.410*	0.244^{ns}	0.2010^{ns}

Key: ns = Not significant, * = Significant at P<0.05, ** = Significant at P <0.01

DISCUSSION

There is a clear evidence to show that the sites used for boreholes are under great influence based on the quality of the water. The physical parameters studied according to compounds and sites of water showed mean pH range values of 6.2 ± 0.2 to 6.8 ± 0.4. Wokem and Udonsi (2003) noted in an earlier investigation at Oso–Edda in Ebonyi State, Nigeria that its ponds had a wider pH range of 5.2 to 7.6 with a mean of 6.1. The former is within the permissible limits of 6.5 – 8.5 (WHO, 2006) except in Bob-Manuel compound where the pH value was slightly acidic with a mean value of 6.2. However, a pH near 7.0 plays a role in determining both qualitative and quantitative abundance of micro flora (Edward, 1990; Federov *et al*., 1993). It could be inferred then, that the more the hydrogen ions become available; so also the lowering of the pH values affect the pattern of microbial population (Nazina *et al*., 2002) which was true of this site (Wokem and Lawson-Jack, 2014).

Total Dissolved Solids (TDS) varied from compound to compound with a mean range of 11.0 ± 0.3 to 55.6 ± 27.3 mg/l. The TDS value was significantly higher in water samples obtained from Obonoma which is an old dwelling site representing the rural setting; with prolonged anthropogenic activities and clustered settlement pattern promoting groundwater pollution. Beyond certain limit, TDS impacts a peculiar taste to water and reduces its potability, and may cause gastrointestinal irritation (Singh *et. al*., 2009). The same effects have been reported to be applicable to TSS, Turbidity and colour; in agreement with Ogbonna *et al;* (2007) findings in Port Harcourt city. However, the studied parameters were within normal levels (WHO, 2006). The conductivity values recorded for Briggs (47.8 µs/cm) and Obonoma (50.6 µs/cm) were significantly ($p<0.001$) below the permissible limit of 2500 µs/c mat 20^{o}C (WHO, 2006). The reason could be attributed to the dilution of salts from increased water volume from the recharge aquifers. Hence, increased inorganic ions were responsible for high conductivity (Wokem and Udonsi, 2003).

Among all the chemical parameters tested, magnesium, iron, sulphate and carbon dioxide have shown significant changes in relation to the sites of water samles. Greater amount of magnesium 8.16 ± 6.1 mg/l were found in rural area water while iron 0.75 ± 0.3 mg/l, sulphate 77.8 ± 23.1 mg/l and carbon dioxide 42.2 ± 15.6 mg/l were higher in new site water. The findings of this study agree with those of Ogbonna, *et al.,* (2007) on physicochemical parameters of borehole water from Borokiri area of Port Harcourt. However, they contrast Erah *et al.,* (2002) report for quality of boreholes and open wells in Benin City which were contaminated with abnormal levels of dangerous chemicals. Earlier researchers attributed high concentration of mineral salts to the geological nature of the bed rock in which the aquifers are situated, anthropogenic activities, inadequate seals, split castings, wrong choice of materials for casing which may have led to rusting and corrosion hence chemical pollution of the water supply (Ifeadi, 1982; Adeyemo *et al*., 2002). Iron was found to be significantly high in Obonoma (rural area) too.

Generally, it has been reported that toxic chemicals in drinking water may cause either acute or chronic health effects. Acute effects such as; nausea, lung irritation, skin rash, vomiting, dizziness and in the extreme death have been reported (Erah *et al*., 2002). More so, effect of iron overload on some organs such as skin, is trivial, compare to hemosiderotic harm to other organs, like the liver and kidney, which can be fatal (Anon, 1976). Chloride and Copper contents were below permissible limits for drinking water, in agreement with (WHO, 1998; 2004). Chloride becomes more toxic when they combine with other toxic substances such as cyanides (Anon, 1976). The accumulation in trace quantities can also lead to severe contamination which may be undesirable to the consumers because of its health risk implications. Factually, the quality of drinking – water in every community is a powerful environmental determinant of its Public Health's status.

The principal cations imparting hardness are calcium and magnesium. It is a well-accepted fact that, groundwater is much harder than surface water; maximum hardness was observed (89.8 ±5.3 mg/l) in Jack's compound. The hardness may be advantageous, since it prevents the corrosion in the pipes by forming a thin layer of scale that reduces heavy metal contamination from the pipe to the water but the water with hardness greater than 500 mg/l may lead to heart and kidney problems and is not recommended for drinking purposes (Lina *et al*., 2009). Alkalinity is a measure of the substances in water that have acid neutralizing ability; alkalinity buffers against pH changes and makes water less vulnerable to acid rain. In this study the mean range values are less than the recommended permissible limit. This study has revealed that the levels of major physicochemical parameters are within tolerable limits in the urban area than the new site and rural area. The old Abonnema representing the urban setting, has better housing pattern, planned sewage disposal closet system, lesser population density because many of the inhabitants dwell in the mega cities and can only come home when they deem it necessary. The physicochemical property characteristics of borehole water in the new site and the rural area are capable of contributing to water-borne health hazards currently endemic in the zone.

In conclusion, assurance of drinking-water safety is a foundation for the prevention and management of waterborne diseases. Installation of good household water treatment gargets to boreholes, boiling and filtering of drinking-water as well as improved sanitary conditions and personal hygiene have been advocated for. The Government should as a matter of urgency ensure gross reduction in the level of pollution of waters through routine evaluation and monitoring of groundwater and anthropogenic activities within the zone. The exploitation and exploration of petroleum resources, remediation activities must be made environment friendly by the Government and oil explorers. Lastly, the Government should site municipal water-treatment plants in Abonnema and other neighbouring communities to discourage the use of untreated water in Niger Delta Region.

REFERENCES

Lafontaine, 1975. Introduction Report of European Scientific Colloquium on hardness of Drinking Water and Public Health. Laxemburg. 11 – 22.

Adeyemo, O. K., Ayodeji, I. O and Aiki-Rayi, C. O., 2002. The water quality and sanitary conditions in a major abattoir (Bodija) in Ibadan, Nigeria. African Journal of Biomedical Research: (5): 51 – 55.

Anon., 1976. Quality criteria for waters, U. S Environmental Protection Agency. 31 – 35.

Bartram, I and Balance, R., 1996. Physical and chemical analysis. Water Quality Monitoring – A practice Guide to the Design and implementation of Fresh Water Quality studies and Monitoring Programmes, (2nd edition). Eand F. N. Spon. London.

Bartram, I., Helmer, R and Balance, R., 1996. Introduction: water quality – monitoring – A Practical Guide to the design and implementation of freshwater quality studies and monitoring programmes UNEP/W.H.O. 1, 2, 9 – 10.

Biswas, A. K and Seetharam, K. E., 2008. Achieving Water Security for Asia, I, 24, (1), 145-176.Bates, B. C., Kundzewicz, Z. W., and Palutikof, J. P., (Eds.) (2008).Climate change and water. Technical paper of the Intergovernmental Penal on Climate Change (IPCC), Geneva, 210.

Buchholz, R. A., 1998. Principles of Environmental Management. The Greening of Business, 2nd Prentice Hall, London, UK. 15-42.

Edward, C., 1990. Microbiology of extreme environments. Open University Press, Milton Keynees. 245 – 250.

Ehrlichs, P., 1974. “Ethics of Equilibrium” Evolutionary ecology. Haer and Row Publication Incorporated, New York. 14 – 25.

Erah, P. O., Akujieze, C. N. and Oteze, G. E., 2002. The quality of ground water in Benin City. A baseline study on inorganic chemicals and microbial contaminants of health importance, in boreholes and open wells. Tropical Journal of Pharmaceutical Research, 1, 75 – 82.

Federov, A. Y., Volchenko, E. V., Korzhenevich, V. I., Singirtsev, I. N and Krest’yaninov, V. Y., 1993. A polysubstrate strain that degrades wastewater conponents of phenol production. Journal of Applied Biochemistry and Microbiology (29): 532 – 536.

Grafton, Q. R and Hussey K., 2011. Water Resources Planning and Management, Cambridge Univerity Press, New York.

Hanif, M. A., Nadeem, R., Rashid, U. and Zafar, M. N., 2005M. Assessing pollution levels of effluents of industries cities zone of Faiasalabad, Pakistan. Journal of Applied Sciences. 5, (10): 1713 – 1717.

Ifeadi, C. N., 1982. Contamination and control of water supply from boreholes system in Nigeria. Proceeding of the Third National Conference on Water Pollution, Port Harcourt Nigeria. 100 – 109.

Lina, J., Schowlen, L., Mons, J., Goldbohm, M. R. N., Piet, R. A and Branelt, V. D., 2009. Environmental Health Perspective. (118): 414 – 420.

M. O. H., 2006. Report from Akuku-Toru Local Government Area, Disease Notification Officer “DSNO” to the Epidermiology Unit (Public Health Division) Rivers State Ministry of Health, Port Harcourt.

Nazina, T. N., Grigoryan, A. A., Xue, Y., Sokolova, D. S., Novikova, E. V., Yourova, T. P., Poltaraus, A. B., Balyaev, S.S. and Ivanov, M, V., 2002. Phylogenetic diversity of aerobic saprophytic bacteria isolated from the Daging Oil Field. Microbiology. (71): 91 – 97.

Newton, M., 1997. Land Water and Development – Sustainable Management of River Basin Systems (2nd edition). Routledge Publishers, America. 28 – 29.

Ogbonna, D. N., Benibo, N. A and Wachukwu, C. K, 2007. Bacteriological and physico-chemical quality of borehole water from Borikiri area of Port Harcourt, Rivers State, Nigeria. Current Topics in Biochemical Research: (9): 63-68.

Simmons, I. G., 1994. Earth, Air and Water Quality Control (2nd edition) Routelege Publishers. 39 – 48.

Singh, P., Fahemi, N and Singh R. V., 2009. Indian Journal of Environmental Science, 13, (2): 175-177.

World Health Organization., 1998. Guidelines for Drinking Water Health Criteria and other supporting information (2nd edition) vol. 2 Geneva, Switzerland.

World Health Organization., 2004. Guidelines for Drinking Water Quality .3rd edition. Geneva, Switzerland. 109 – 116.

World Health Organization., 2006. Guideline for Drinking-Water Quality Recommendation. 1,

Wokem, Gloria N and Udonsi, Jonathan. K., 2003. Physicochemical properties of pond water in relation to zooplanktonic organisms of the ponds of Oso – Adda in Afikpo, Ebonyi State, Nigeria, Global Journal of Environmental Sciences 2, (2): 82 – 87.

Wokem, G. N. and Lawson-Jack, T., 2014. Microbiological Quality of Domestic Water Sources in Abonnema Community. Journal of Aquatic Science 29, (2B): 391 – 400.