Assessment Of Groundwater Potability Using Water Quality Index Approach In Tombia Town, Yenagoa, Nigeria

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***Abstract*—An assessment of potability of groundwater in Tombia town in Bayelsa State was carried out using Water Quality Index (WQI) approach. Physico-chemical analysis was done on 25 (twenty five) water samples from shallow boreholes randomly collected around the community. Results of 11 parameters analyzed (pH, conductivity, total dissolved solids, nitrates, chloride, sulphate, bicarbonate, total alkalinity, total hardness, magnesium and iron) were used to compute WQI for groundwater in the area using the WHO standard for potable water as a reference. Results from computation showed water from 10 random boreholes which represented 40% of the total samples collected was fit for consumption (WQI < 100), on the other hand, 15 boreholes which represented 60% of the total samples collected was unfit for consumption (≥ 100). Results from computation of WQI also showed non-potability of water was largely due to slight acidity, salinity and iron content which characterized most of the water samples from Tombia area.**

Keywords—Groundwater, Quality assessment, Water Quality Index (WQI), Tombia.

INTRODUCTION

The importance of water to living organisms cannot be over-emphasized. Surface water's susceptibility to contamination has made groundwater a better alternative source of fresh potable water in the Niger Delta, as such; assessment of groundwater quality is of great importance especially for drinking and other domestic purposes. Due to growth in population and industrialization, the demand for groundwater has rapidly increased [1]; this increase has resulted in a degradation of the quality of groundwater in some areas [2]. Quality of groundwater depends mainly on the quality of recharge water, atmospheric precipitation and subsurface geochemical processes. Water contamination and subsequent pollution is not only a threat to health, it also has a negative impact on the economic development and social prosperity of the local populace utilizing it [3]. It becomes imperative to monitor groundwater quality to forestall negative implications associated with the use of contaminated water.

Several groundwater quality studies have been carried out in Yenagoa metropolis and environs [4]; [5]; [6]; [7], however, there is no documented research reports of groundwater studies in Tombia town. An effective index for the summarization of water quality data later known as Water Quality Index (WQI) was first proposed by [8]. WQI is based on a numerical rating of different water quality parameters, it tends to simplify large amount of water quality data into consistent class of excellent to poor by values which range from 0 to ≥100 respectively. WQI < 100 is classed as fit for consumption, whereas WQI ≥ 100 is unfit for consumption [9]; [10]; [11]. This information becomes easily understood by end users and policy makers. In the present study, an attempt has been made to ascertain the potability of groundwater from shallow boreholes across Tombia town using WQI as the tool of assessment.

DESCRIPTION OF STUDY AREA

The study area is Tombia town, it is located within latitude 4 55' 29" and Longitude 6 15' 51" of Yenagoa Local Government Area (Fig. 1), the capital city of Bayelsa State in the oil rich Niger Delta. It is accessible by a good network of minor and major roads; it is drained by tributaries of the River Nun and has an average rainfall and temperature of 2,899 mm and 26.7 ^{0} C respectively. The major socio-economic activities of the people in the area are fishing and farming. Tombia town plays host to the massive Gbarian Liquefied Natural Gas plant from where gas is flared continually through the year.

METHODOLOGY

25 water samples from shallow boreholes with a mean depth of 30 m were randomly collected using sterilized 50 cl polyethylene bottles across the community in August after the peak of the wet season. Sample collection, preservation and transportation were done with strict adherence to [12] samples were analyzed for 11 parameters (pH, conductivity, total dissolved solids, nitrates, chloride, sulphate, bicarbonate, total alkalinity, total hardness, magnesium and iron) which were used for computing the WQI in the area. Sample locations were determined using a Global Positioning System (GPS) and recorded accordingly. pH meter was used to determine pH, conductivity meter to determine

conductivity and also total dissolved solids. Chemical analysis for chloride and bicarbonate was done by volumetric titration method. Nitrate, sulphate, calcium, magnesium and iron were estimated by spectrophotometric method, while, sodium and potassium were analyzed by flame photometry method.

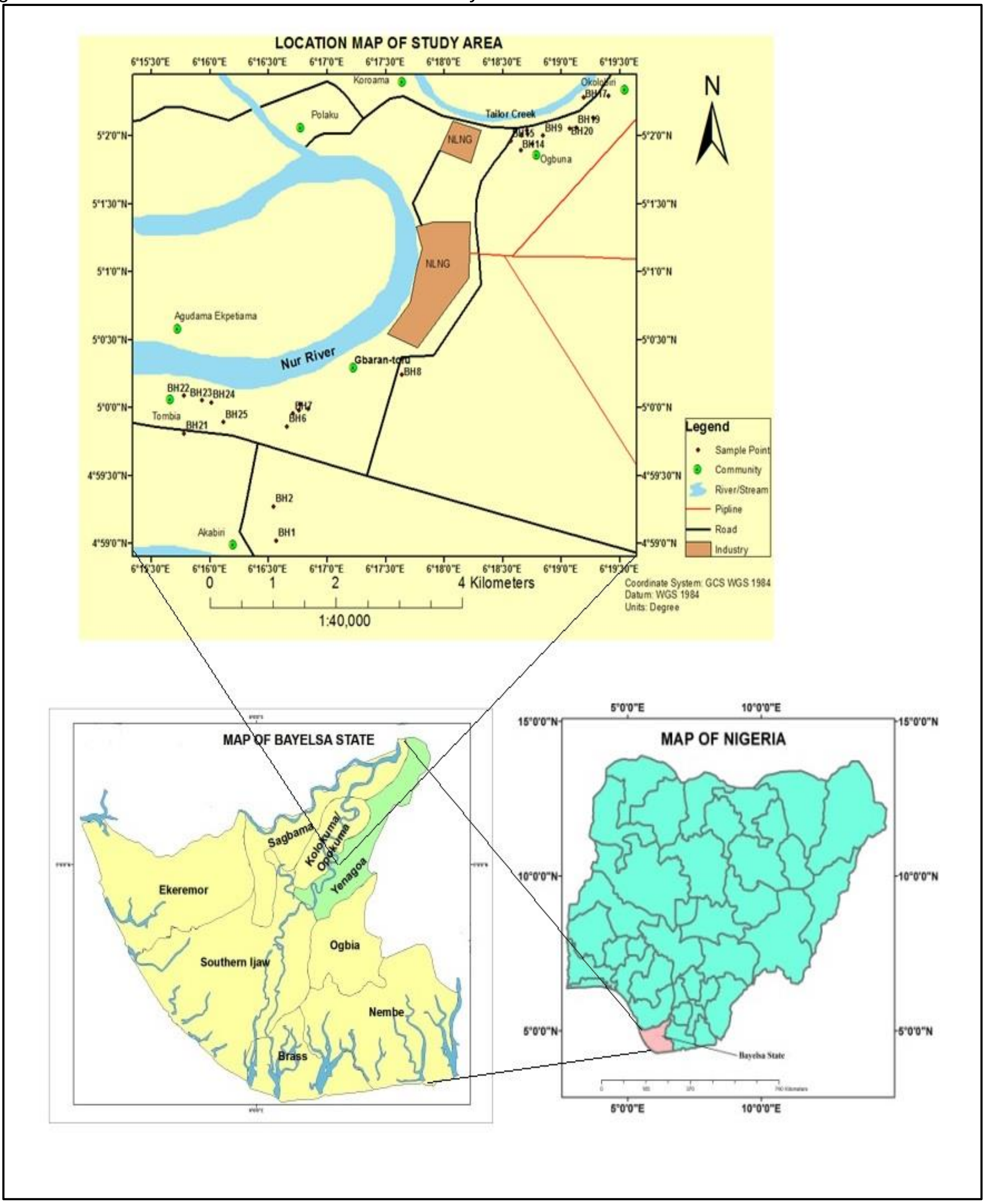

Fig. 1 Study location and sample collection points

In this research, for the computation of WQI eleven (11) parameters were used with reference to [13] standard for potable water. Parameters selected for the computation of WQI was dependent on the intended use of water for consumption and domestic purposes. The weighted arithmetic index method for the computing of WQI was employed [14]; [15]; [16]. The concept of weighted average was used to compute overall WQI because of its simplicity involved in data handling, minimal data processing and flexibility for use under different environmental conditions. Weighted average also provides adequate depression in the WQI values due to low sensitivity function value for variables, i.e., relative importance of a parameter determines its influence on the final outcome. Classification of water quality based on WQI method according to [17] gives WQI of 0 to 25 as excellent, 26 to 50 as good, 51 to 75 as poor, 76 to 100 as very poor and greater than 100 to be unsuitable for drinking.

Quality rating or Sub-index (Qn) was determined by

$$Qn = 100 *\left\{\frac{Vn - Vi}{Sn - Vn}\right\} \quad (1)$$

Where: Qnquality rating for the nth water quality parameter

Vnestimated value of the nth parameter at a given sampling point

Snstandard permissible value of the nth parameter as given by WHO

Viideal value of the nth parameter in portable water (0 for all parameters except pH=7)

The unit weight is inversely proportional to the standard value Sn, determined by

$$Wn = \frac{K}{Sn} \quad (2)$$

Where: Wnunit weight for the nth parameter

Snstandard value for the nth parameter

Kconstant of proportionality (value is 1)

Aggregating the quality rating with the unit weight linearly gives the overall water quality index is

$$WQI = \frac{\Sigma QnWn}{\Sigma Wn} \quad (3)$$

RESULTS AND DISCUSSION

The results of the physico-chemical analysis carried out on water samples as presented in **Table 1** showed pH values ranged from 5.57 to 6.83 compared with the WHO (2006) standard of 6.5 to 8.5. The mean value of 6.17 implied acidic water in the area [4]; [5]; [6]. The reason for the acidic water was not far-fetched as this could easily be attributed to extensive gas flaring in the area, also, mild acidity in groundwater can also be due to organic acids from decomposition of vegetation in the Niger Delta swamps [18]. Electrical conductivity directly depends on the amount of TDS. Conductivity values ranged from 120 μS/cm to 641 μS/cm and TDS values ranged from 60 mg/l to 321 mg/l. The values observed implied increased salts in groundwater, although both were well within the permissible [13] limits.

Iron had values which ranged from 0.11 mg/l to 0.24 mg/l, with a mean value of 0.2 mg/l which was quite high but still within the standard permissible limit of 0.3 mg/l according to [13]. Growth of iron bacteria from ferruginous materials in water distribution systems can cause water quality to deteriorate [19]. The primary source of iron contamination in groundwater system of the Niger Delta can be traced to leached iron from ferrigenous laterites in the Benin Formation [20]. One fast, cost effective and environmentally friendly way to remove dissolved iron from borehole water is treatment with alkaline hydrogen peroxide [21].

All other parameters were within allowable [13] limits for potable water. No_3^- had concentrations ranging from 0.12 mg/l to 0.38mg/l with a mean of 0.24 mg/l. Cl^- ranged in concentration from 11 mg/l to 62 mg/l with a mean of 20.3 mg/l across boreholes. So_4^{2-} had a mean concentration of 3.5 mg/l with values ranging from 1.54 mg/l to 5.2 mg/l. Total Alkalinity ranged from 10 mg/l to 28 mg/l with a mean of 18.5 mg/l. Total hardness across boreholes ranged from 10 mg/l to 52 mg/l with a mean concentration of 32 mg/l. Ca and Mg had mean concentrations of 13 mg/l and 3.8 mg/l, with values ranging from 8.8 mg/l to 32.8 mg/l and 1.86 mg/l to 10.72 mg/l respectively.

A detailed computation of WQI for sample location 1 using equations 1, 2 and 3 from physico-chemical data was presented in **Table 2**. Summary of results of WQI for locations 1 to 25 were presented in **Table 3** with values that ranged from 53 in location 25 to 368 in location 22. The final outcome of the computation was clearly influenced by pH, EC and Fe. These parameters are known to have a major influence on the quality of groundwater in the Niger Delta [5].

A graphical presentation of the summary of WQI in Tombia on a pie-chart (Fig 2) showed 40% of sample locations to be fit for consumption, whereas, 60% of sample locations were unfit for consumption. The result implied that 40% (10 sample locations) had WQI values < 100; on the other hand 60% (15 sample locations) had WQI values ≥ 100. Locations with unfit water were randomly scattered across the area, as such, water quality was not directly influenced by geological processes like groundwater flow.

Table 1 Results of Physico-chemical analysis on Groundwater samples from Tombia town

SAMPLE CODE	pH	COND	TDS	NO_3	Cl	SO_4	TA	TH	Ca	Mg	Fe
BH1	6.13	284	142	0.218	14	2.48	17	17	10.35	2.87	0.21
BH2	6.48	355	178	0.231	20	3.5	18	34	14.36	3.54	0.164
BH3	6	420	210	0.31	20	4	22	52	13.3	4.2	0.136
BH4	5.98	583	292	0.318	34	4.8	20	48	22.18	5.68	0.142
BH5	5.96	363	182	0.22	20	3.85	18	30	14.7	2.53	0.136
BH6	5.73	282	141	0.215	24	2.46	12	30	13.82	4.54	0.14
BH7	5.92	364	182	0.23	30	3.64	17	24	17.48	4.86	0.132
BH8	6.15	310	155	0.197	12	3	18	26	8.76	3.38	0.23
BH9	6.43	260	130	0.186	15	1.78	17	22	9.47	2.84	0.221
BH10	6.49	379	189	0.271	13	4.3	18	43	10.2	3	0.208
BH11	6.35	304	152	0.176	14	2.34	23	27	9.78	2.56	0.186
BH12	6.52	279	140	0.185	11	2.97	15	30	8.5	2.28	0.20
BH13	6.08	285	143	0.121	12	2.58	17	21	8.64	2.3	0.172
BH14	6.15	330	165	0.23	11	3.36	17	46	7.72	4.38	0.204
BH15	6.06	641	321	0.376	27	5.24	26	45	20.47	10.72	0.21
BH16	6.15	382	191	0.287	62	4.84	23	43	32.76	3.52	0.188
BH17	5.99	457	274	0.328	16	4.75	28	44	13.6	2.84	0.174
BH18	6.6	348	174	0.281	12	3.84	24	41	9.55	1.78	0.128
BH19	6.83	298	199	0.217	12	3.76	21	35	9.28	2.1	0.146
BH20	6.62	306	153	0.227	13	4	22	35	10.32	3	0.146
BH21	6.24	436	218	0.29	14	3.46	18	45	9.88	4.34	0. 2
BH22	6.08	307	154	0.214	21	3.2	12	22	13.25	5.63	0.24
BH23	6.1	376	188	0.245	32	4	16	19	18.72	5.82	0.136
BH24	5.67	357	178	0.235	33	3.85	13	10	19.3	1.86	0.122
BH25	5.57	120	60	0.079	15	1.54	10	12	8.8	1.94	0.112
Mean	6.171	353.04	175.3	0.236	20.28	3.5	18.48	32.04	13.408	3.774	0.200
SD	0.309	103.14	63.13	0.064	11.42	0.95	4.417	11.93	5.8019	1.91161	0.105
WHO	6.5-8.5	1000	1000	50	250	400	500	150	75	50	0.3

****Concentrations of all the parameters are expressed in milligrams per liter (mg/l) except pH without a unit and EC in μS/cm**

Table 2 Computation of Water Quality Index for Groundwater from Borehole 1

S/No	Parameters	Estimated values (Vn)	Standard Values (Sn)	Unit weight (Wn)	Quality rating (Qn)	QnWn
1	pH	6.13	7.5	0.133	-63.503	-8.467
2	Conductivity	284	300	0.003	1775	5.917
3	Total dissolved solids	14.2	500	0.002	2.923	0.006
4	Nitrates	0.218	45	0.022	0.487	0.011
5	Chlorides	14	250	0.004	5.932	0.024
6	Sulphate	2.48	150	0.006	1.681	0.011
7	Total alkalinity	17	120	0.008	16.505	0.138
8	Total hardness	17	300	0.003	6.007	0.020
9	Calcium	10.35	75	0.013	16.009	0.213
10	Magnesium	2.87	30	0.033	10.579	0.353
11	Iron	0.21	0.3	3.333	233.333	777.778
				Σ=3.563		Σ =776.002
						WQI=217.781

Concentrations are expressed in milligrams per liter (mg/L) except pH with no unit and EC in μS/cm.

Table 3 Summary of WQI for Groundwater samples at Tombia town

Sample location	WQI	Remark	Sample location	WQI	Remark
1	218	unfit	14	196	unfit
2	111	unfit	15	217	unfit
3	75	poor	16	155	unfit
4	82	Very poor	17	127	unfit
5	75	poor	18	68	poor
6	81	Very poor	19	102	unfit
7	79	Very poor	20	83	Very poor
8	302	unfit	21	184	unfit
9	261	unfit	22	368	unfit
10	209	unfit	23	75	poor
11	144	unfit	24	61	poor
12	187	unfit	25	53	poor
13	125	unfit			

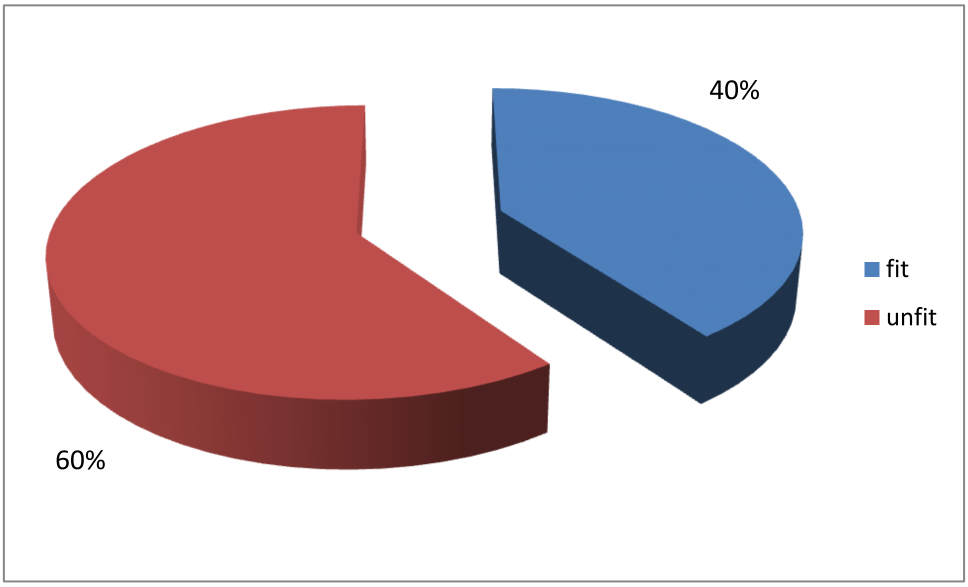

Fig 2 Percentage of water fit and unfit for consumption by WQI analysis for sampled wells in Tombia town

CONCLUSION

Interpretation and presentation of water quality data to end users and policy makers is very important to water quality researchers. This paper underpins the suitability of WQI analysis on complex water quality data. Investigations on groundwater quality in Tombia town showed that fifteen (15) of the twenty (25) sample locations randomly had water unfit for consumption. Parameters used for computing the WQI showed pH, EC and Fe to be the major contributors to the high index values (≥ 100) obtained in these 15 locations. Acidity of groundwater associated with the observed pH values can be managed by transferring flared gas from the NLNG plant to other uses, also alkaline materials can be added to water in these locations as a measure of treatment to make groundwater in these areas fit or suitable for consumption. The most common method of iron treatment in water is aeration which allows soluble Fe^{2+} to be oxidized to insoluble Fe^{3+} and subsequent filtration of precipitates, treatment with alkaline hydrogen peroxide is also a good alternative.

REFERENCES

[1]G. O. Adeyemi, A. O. Adesile and O. B. Obayomi, “Chemical Characteristics of some well waters in Ikire, South-western Nigeria”. Water Resources. Vol. 14, 2003, pp. 12 – 18.

[2]K. Murli, R. D. Swathik and R. Elangovan, “Assessment of Groundwater quality in Coimbatore, South Taluk, Coimbatore District, India. A Water Quality Index approach”. Vol. 10(4), 2011, pp. 521 – 524.

[3]M. Milovanovic, "Water Quality Assessment and Determination of Pollution Sources along the Axios/Vardar River, South-Eastern Europe". Desalination. Vol. 213, 2007, pp. 159 – 173.

[4]K. S. Okiongbo and R. Douglas, "Hydrogeological Analysis and evaluation of Groundwater Quality in Yenagoa City and Environs, Southern Nigeria. Ife Journal of Science". Vol. 15(2), 2013, pp. 209 – 222.

[5]G. J. Udom, H. O. Nwankwoala and H. A. Jephthah, "Seasonal variations in Groundwater Chemistry in parts of Yenagoa, Bayelsa State, Nigeria. International Journal of Innovative Environmental Studies Research". Vol. 1(2), 2013, pp. 40 – 54.

[6]E. Oborie and H. O. Nwankwoala, "Analysis of Major Ion Constituents in Groundwater of Amassoma and Environs, Bayelsa State, Nigeria". Journal of Applied Chemistry. Vol. 2(5), 2014, pp. 1 – 13.

[7]T. C. N. Angaye, E. I. Ohimain and C. E. Mieyepa, "The Potability of Groundwater in Bayelsa State, Central Niger Delta: A Review". Journal of Environmental Treatment Techniques. Vol. 3(2), 2015, pp. 127 – 135.

[8]R. K. Horten, "An Index Number for Rating Water Quality. Journal of Water Pollution Control Federation". Vol. 37(3), 1965, pp. 300 – 305.

[9]O. J. Oko, M. O. Aremu, R. Odoh, G. Yebpella and G. A. Shenge, "Assessment of Water Quality Index of borehole water and groundwater in Wukari Town, Taraba State, Nigeria". Journal of Environment and Earth Science. Vol. 4(5), 2014, pp. 1 – 9.

[10]J. A. Olatunji, O. A. Odediran, P. I. Obaro and P. I. Olasehinde, "Assessment of Groundwater Quality of Ilorin Metropolis using Water Quality Index Approach. Nigerian Journal of Technological Development". Vol. 12(1), 2015, pp. 18 – 21.

[11]O. Oni and O. Fasakin, O, "The Use of Water Quality Index Method to determine to Potability of Surface water and Groundwater in the vicinity of a municipal waste dumpsite in Nigeria. American Journal of Engineering Research". Vol. 5(10), 2016, pp. 96 – 101.

[12]American Public Health Association (APHA), "Standard Methods for the Examination of Water and Waste water". 20th Edition. 2002.

[13]World Health Organization, "Guidelines for Drinking Water Quality - First Addendum. 3rd Edition Recommendations, World Health Organization, Geneva". Vol. 1, 2006, pp. 185 – 186.

[14]K. Yogendra and E. T. Puttaiah, "Determination of Water Quality Index and Suitability of an Urban water body in Shimoga Town, Karnataka. Proceedings of Taal 2007: 12th World Lake Conference, 28th October to 2nd November, Jaipur, India". 2008, pp. 342 – 346.

[15]I. S. Akoteyon, O. A. Omotayo, O. Sodadoye and H. O. Olaoye, "Determination of Water Quality Index and Suitability of Urban river for municipal water supply in Lagos, Nigeria". European Journal of Scientific Research. Vol. 54(2), 2011, pp. 263 – 271.

[16]O. Ushure, T. Origho, A. O. Ohwohere and E. J. Ewhuwhe, "A comparative assessment of Water Quality Index and Suitability of River Ase for Domestic water supply in Urban and Rural communities in South-western Nigeria. Journal of Humanities and Social Science". Vol. 4(1), 2014, pp. 234 – 245.

[17]C. Chatterjee and M. Raziuddin, "Determination of Water Quality Index (WQI) of a degraded river in Asanol Industrial Area, Raniganj, Burdwan, West Bengal". Nature, Environment and Pollution Technology. Vol. 1(2), 2002, pp. 181 – 189.

[18]W. A. Davidson, "Hydrogeology of groundwater resources of the Perth Region, Western Australia". Geological Survey of Western Australia, Government of Western Australia, Perth. Bulletin 142, 1995, pp. 257 – 259.

[19]S. A. Ngah and R. O. Allen, "High Bivalent Iron contaminants in groundwater of the Niger Delta: Their Genesis and Distribution. Journal of Environmental Pollution and Health". Vol. 5(1), 2005, pp. 35 – 47.

[20]J. O. Etu-Efeotor, "Preliminary hydrogeochemical investigation of subsurface waters in parts of the Niger Delta". Journal of Mining and Geology. Vol. 18(1), 1981, pp. 103 – 105.

[21]C. L. Orjiekwe, K. Oguniran and S. A. Solola, "Novel method for iron removal from underground dug well waters in communities around Okada Town, Ovia North-East L. G. A., Edo State. International Journal of Physical Sciences". Vol. 8(28), 2013, pp. 1464 – 1469.