Journal of Geosciences and Geomatics, 2015, Vol. 3, No. 5, 128-132
Available online at http://pubs.sciepub.com/jgg/3/5/3

DOI:10.12691/jgg-3-5-3

Assessing Chloride Distribution and Concentrations in the Aquifer Systems of the Niger Delta

H.O Nwankwoala[1], S.A Ngah[2,*]

[1]Department of Geology, College of Natural and Applied Sciences, University of Port Harcourt, Nigeria
[2]Institute of Geosciences and Space Technology, Rivers State University of Science and Technology, PMB 5080, Nkpolu-Oroworukwo, Port Harcourt, Nigeria
*Corresponding author: nwankwoala_ho@yahoo.com

Abstract This study aims at assessing the distribution of chloride in the aquifer systems and evaluating its occurrence in the different geomorphologic zones of the Niger Delta. The chloride values range from 3mg/l – 810mg/l. 68% of the samples have chloride concentration less than 48mg/l, 24% with chloride concentration between 48mg/l and 250 mg/l while 8% with chloride concentration greater than 250mg/l. The highest concentration of 801mg/l was obtained from a borehole at Oloma. The chloride content in groundwater appears generally to decrease from north to south i.e. from the hinterland to the coast. The localized chloride enrichment around the Old GRA, Borokiri, Moscow road and Central Police Station in Port Harcourt could be as a result of brackish water invasion from nearby creeks and tidal channels. The study revealed that chloride is a major quality issue especially in groundwater in these areas as well as in the mangrove swamps and the coastal beaches and ridges.

Keywords: *chloride, aquifer, borehole, groundwater, Niger Delta*

Cite This Article: H.O Nwankwoala, and S.A Ngah, "Assessing Chloride Distribution and Concentrations in the Aquifer Systems of the Niger Delta." *Journal of Geosciences and Geomatics*, vol. 3, no. 5 (2015): 128-132. doi: 10.12691/jgg-3-5-3.

1. Introduction

The Niger Delta (Figure 1) is a large and ecologically sensitive region in which various water species (including surface and groundwater, saline and freshwaters) are in dynamic equilibrium [1]. It is the second largest delta in the world with a coastline spanning about 450km terminating at the Imo River entrance. The region spans over 20,000km^2 and it has been described as the largest wetland in Africa and consists mainly of freshwater swamps, mangrove swamps, beaches, bars and estuaries [4].

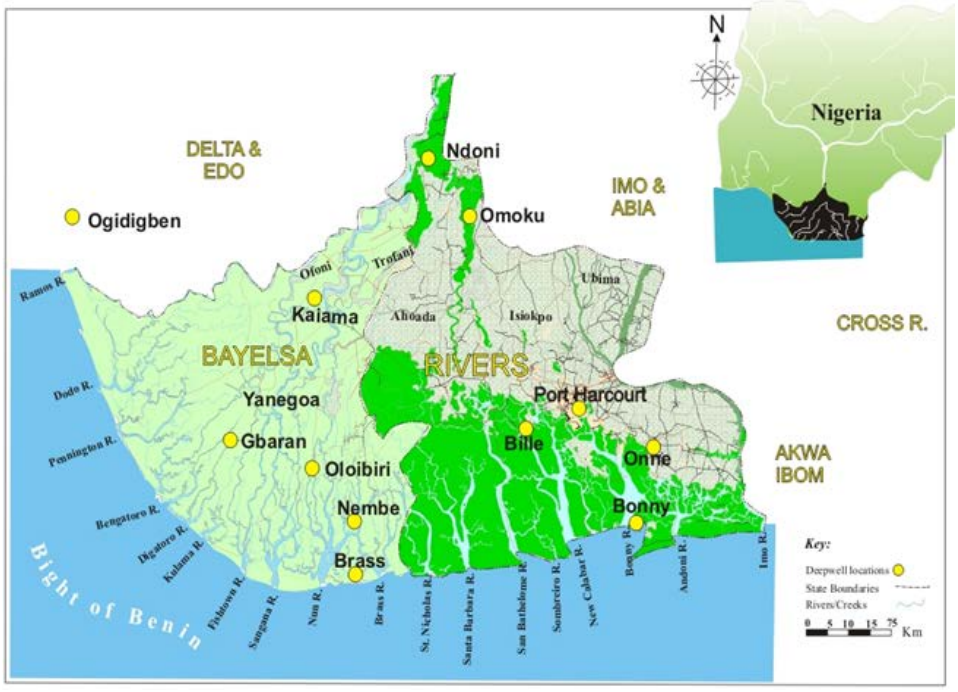

Figure 1. Location Map of the Study Area

Because of the very nature of the region, groundwater constitutes the predominant, if not the only source of water supply in the area and unless a determined effort is made to understand the nature of the groundwater in the region, serious problems would be encountered in the area of water needs of the region, in future. Although, detailed stratigraphic analysis of the various geologic/geomorphic and aquifer systems [6,7,18] have yielded a better understanding of the groundwater potentials of the Niger Delta region, they have not addressed the important and crucial question of over-abstraction and its associated consequences, particularly the possibility of large scale saltwater intrusion and general issue of sustainable supply of potable water in the region.

Chlorine is the most abundant of the halogens. Its compounds with common metallic elements, alkali metals and alkali earth metals are readily soluble in water. Therefore, chloride is present in all natural waters but its concentration is lower than that of sulphates and bicarbonates. The most common type of water in which chlorine is the dominant anion is one in which sodium is the predominant cation. Chloride produces salty taste in water which varies with quantity of sodium ions (Na^+). Predominance of Na^+ imparts highly noticeable salty taste even in small quantities of chlorine unlike when Ca^{2+} and Mg^{2+} predominate. Determination of chloride content is very important especially in coastal aquifers because the first sign of saline water intrusion is a progressive upward trend in chloride concentration in the water obtained from the affected boreholes.

2. Geomorphologic/Geologic Setting

The geomorphology of the Niger Delta has been described by many researchers [19,23]. The topography of the area is essentially flat, sloping very gently seawards. The area is low lying (usually does not exceed 20m above sea-level) and is drained and criss-crossed by network of distributaries. The Niger Delta constitutes an extensive plain exposed to periodical inundation by flooding when the rivers and creeks overflow their banks [18]. A prominent feature of the rivers and creeks is the occurrence of natural levees on both banks, behind which occur vast areas of backswamps and lagoons/lakes where surface flow is negligible [12,13,15].

Although various types of morphological units and depositional environments have been recognized in the area (coastal flats, ancient/modern sea, river and lagoonal beaches, sand bars, flood plains, seasonally flooded depressions, swamps, ancient creeks and river channels), the area can be sub-divided into five major geomorphological units namely:

a. Active/abandoned coastal beaches
b. Saltwater, mangrove swamps
c. Freshwater swamps, back-swamps, deltaic plain alluvium and meander belt
d. Dry deltaic plain with abundant freshwater swamps (Sombreiro-Warri deltaic plain) and
e. Dry flat land and plain.

Several authors have discussed the geology of the Niger Delta [2,3,5,7,10,11,19,21,23,25]. The influence of geology on the groundwater resources of the Niger Delta constitutes the most important factor besides that of climate in the region [9]. Geology has been observed to be responsible for the complex groundwater distribution, extractability and quality in the Niger Delta [20,22]. Unfortunately, the present knowledge of the true geological condition prevailing within the groundwater domain, especially with quality status in the various aquifer zones of the Niger Delta is limited.

The geologic sequence of the Niger Delta consists of three main Tertiary subsurface lithostratigraphic units [21] which are overlain by various types of Quaternary deposits. From bottom to top, the Tertiary units are the Akata, the Agbada and the Benin Formations (Table 1).

Table 1. Geological units of the Niger Delta (after Short and Stauble, 1967)

Age	Geological Unit	Lithology
Quaternary	Alluvium (general) fresh water back swamp meander belt. Mangrove and salt water. Back Swamps Active/Abandoned Beach ridges Sombreiro Warri Delataic plain.	Gravel, sand, clay, silt, sand, clay, some silt, gravel. Medium-fine sands, Clay and some silt.
Miocene	Benin Formation (coastal plain sand)	Coarse to medium grain sand with subordinate silt and clay lenses. Fluviatile marine
Eocene	Agbada Formation	Mixture of sand, clay and silt, fluviatile marine.

3. Methods of Study

In this study, available data and literature were gathered and categorized on the basis of the different geomorphologic zones in the Niger Delta area of Nigeria. In categorizing these, only Chloride data with depth range were utilized. The data were also compared with the World Health Organization [26] standards to assess their concentrations in the various geomorphic zones in the study area. Data were sourced from the Niger Delta Basin Development Authority (NDBDA), Rivers State Ministry of Water Resources (RMWR), Rivers State Water Board (RSWB) and Rural Water Supply and Sanitation Agency (RUWSSA) and from some borehole companies operating in the area. Table 2 shows the summary of chloride concentrations and locations in the different geomorphic zones of the Niger Delta.

4. Results and Discussion

Chloride values were reported in all the samples analysed. Their values range from 3mg/l – 810mg/l. WHO [27] specified 250mg/l as the upper limit of harmless tolerance. 68% of the samples have chloride concentration less than 48mg/l, 24% produced water with chloride concentration between 48mg/l and 250 mg/l while 8% produced water with chloride concentration greater than 250mg/l. The highest concentration of 801mg/l was obtained from a borehole at Oloma. Table 2 shows the

Chloride data while Figure 2 the relationship of Chloride with depth while Figure 3 shows a chloride distribution map of the study area. From the map, the chloride content in groundwater appears generally to decrease from north to south i.e. from the hinterland to the coast. The localized chloride enrichment around the Old GRA, Port Harcourt, Borokiri, Moscow road and Central Police Station in Port Harcourt could be as a result of brackish water invasion from nearby creeks and tidal channels. Chloride again is a major quality issue especially in groundwater in these areas as well as in the mangrove swamps and the coastal beaches and ridges [16,17]. Figure 3 shows the relationship of Chloride with depth in the area.

Table 2. Chloride data from the study area

S/No.	Borehole Location	Geomorphic Zone	Depth (m)	Chloride (mg/L)
1.	Ahoada	CPS	65.53	21.0
2.	Ogbo	"	186	25.0
3.	Edeocha	"	185	10.0
4.	Udiereke-Ubie	"	76.20	3.5
5.	Abua	"	60.96	26.0
6.	Joinkrama	"	176.22	5.6
7.	Ndoni	"	382	54
8.	Ebubu	"	91.44	10.2
9.	Mbiama	FWS	175	6.4
10.	Obibi	"	76.22	6.0
11.	Zarama	SWS	89	6.4
12.	Bassambiri	"	250	3.0
13.	Atubo	"	193	104.0
14.	Nembe	"	193	13
15.	Ogbia	FWS	101	109.8
16.	Brass	CBR	192	710
17.	Emerego	"	78	50.1
18.	Kolo	"	101.59	111.4
19.	Amakalakala	FWS	160.96	119.0
20.	Sangana	"	60.96	25.0
21.	Oruma	FWS	101.59	6.8
22.	Onne	CPS	264	7.0
23.	Bien Gwara	"	60.96	4.5
24.	Bodo	"	80.56	105
25.	Baen	"	60.96	24.1
26.	Kongho	"	60.96	21
27.	Lubara	"	60.96	22
28.	Baun	"	60.96	14
29.	Opuoko	"	60.96	16
30.	Kono	"	60.96	18
31.	Kanni	"	60.96	21
32.	Beeri	"	60.96	28
33.	Sii Babbe	"	60.96	35
34.	Soku	SWS	95.0	17.5
35.	Tombia	"	59.44	4
36.	Idama	"	100	58
37.	Abonnema	"	9.24	53.5
38.	Harry's Town	"	95	48
39.	Kula	"	183.0	68.5
40.	Bukuma	"	60.96	8
41.	Kanana	SWS	186	34
42.	Kala Degema	"	40.96	18
43.	Krakrama	"	75	48
44.	Abalama	"	60.96	36
45.	Buguma	"	60.96	10.64
46.	Okrika Mainland	"	320	35.5
47.	Ibuluya-Dikibo	"	180	32.0
48.	Bolo I	"	91.44	99
49.	Bolo II	"	91.44	97
50.	Kalio-Ama	"	82.88	10
51.	Abam-Ama	"	128.02	6.38
52.	Okujagu	"	30.0	62
53.	George-Ama	"	109.73	31.5
54.	Isiokpo	CPS	70.1	38.94
55.	Aluu	"	60.96	10
56.	Umuoji	"	81	32
57.	Ogbakiri	"	78.03	24.2
58.	Ndele	"	72.5	10.6
59.	Omerelu	"	70.1	20
60.	Ubima	"	70.1	18
61.	Elele	CPS	60.96	29.8
62.	Ibaa	"	60.96	40
63.	Obelle	"	81.0	48
64.	Rumuewho	"	54.86	10
65.	Egwi	"	61.28	3.4
66.	Rumuoyo	"	57.3	24
67.	Ulakwo	"	67.06	13
68.	Opiro	"	138	16
69.	Rumuokochi	"	91	12
70.	Umuechem	"	132	11
71.	Kalibiama	CBR	281	10
72.	Bonny	"	304	5
73.	Oloma I	"	91.46	810
74.	Oloma II	"	82.88	250
75.	Illoma Opobo	"	19.8	330
76.	Gbokokiri	"	176.8	300
77.	Ikuru	"	190	351
78.	G.R.A. P.H.	"	170	26
79.	Creek Road	"	170.0	390.5
80.	Potts Johnson	"	180.0	401
81.	NDBDA	CPS	170	16
82.	Borokiri	"	176.8	24.7
83.	Govt. House	"	110	14.6
84.	Moscow Road	"	180	63.9
85.	Central Police Stn	"	176.8	408.25
86.	Choba	"	140	12
87.	Rumuomasi	"	131.0	18
88.	Rumuokoro	"	152.0	10.64
89.	Rumuodamaya	"	168.0	12.06
90.	Elelenwo	"	171.8	35.0
91.	Iriebe	"	163.0	38.0
92.	Aagbere Odoni	FWS	76.2	50
93.	Peretorugbene	"	211.0	30
94.	Ekeremor	"	202	58
95.	Toru Ndoro	"	211	68
96.	Torofani	"	165	0.14
97.	Ofoni	"	186	55
98.	Toro Anjiama	"	215	68
99.	Forupa	"	215	34
100.	Asamabiri	"	81.0	7.0
101.	Amarata	FWS	180	50
102.	Ukubie	"	85.3	14
103.	Tebidaba	"	171.0	12
104.	Aguobiri	"	79	19
105.	Okolobiri	"	75	4.5
106.	Amassoma	"	180	4.3
107.	Agudama-Epie	"	242.67	4.5
108.	Oporoma	"	42.7	108.5
109.	Peremabiri	"	300	132.0
110.	Amatolo	"	161.0	5.7
111.	Yenagoa	"	185.34	48.4
112.	Oyorokoto	"	-	-

Note: CPS = Coastal Plain Sands, FWS = Freshwater Swamp, SWS = Saltwater Swamp, CBR = Coastal Beaches and Ridges, SWP = Sombreiro Warri Deltaic Plain

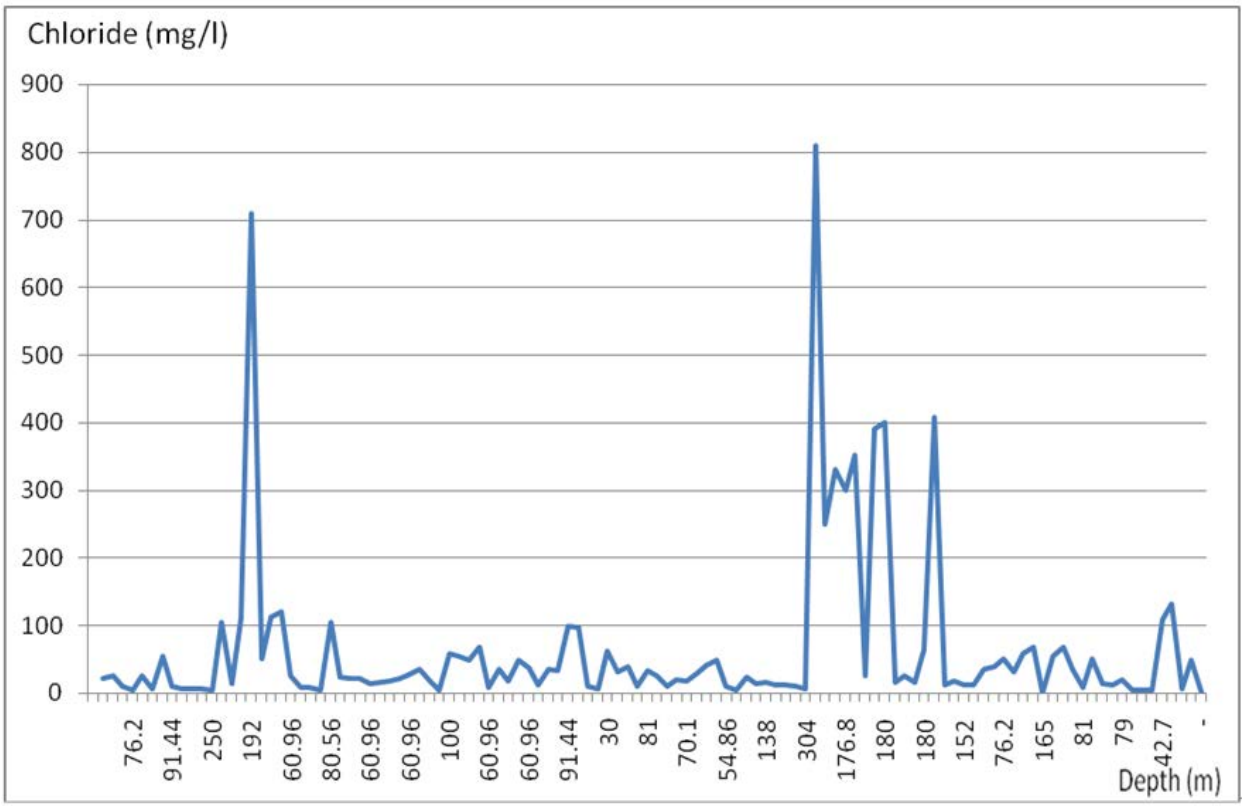

Figure 2. Relationships of Chloride and Depth from the Study Area

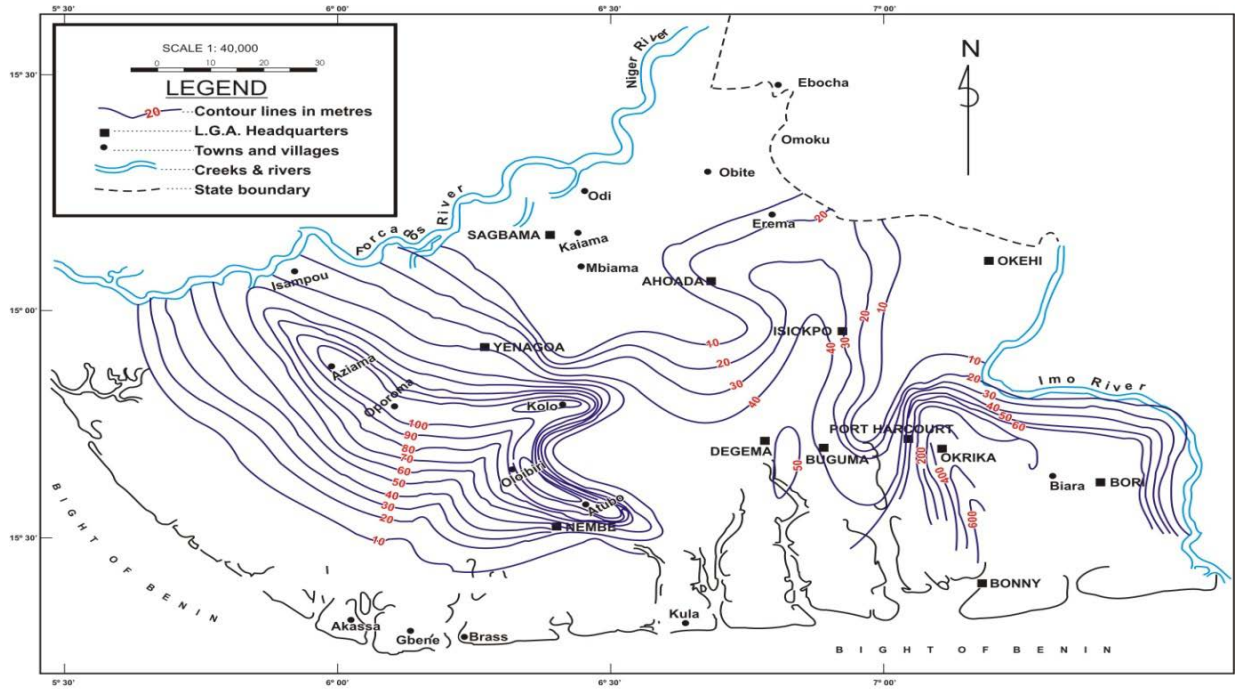

Figure 3. Chloride distribution in groundwater samples in the study area

5. Conclusion

From the above discussions, three parameters form the main water quality issues in the study area. They are: pH, iron and chloride contents. The problem of low pH and acidic water are more pronounced in the eastern parts of the area covering Ahoada, Isiokpo and Port Harcourt, which corresponds to the results of Ngah [14]. Iron is a more common problem in groundwater samples from the freshwater swamps/backswamp/meander belt region as well as the mangrove swamps and coastal ridges. Chloride concentration is high particularly in the coastal areas and parts of Port Harcourt city, bordering saltwater creeks and tidal channels which have influent relationship with the local groundwater table. The chloride originates from the nearby salt/brackish water bodies and from rain water whose composition in the coast resembles diluted sea water.

References

[1] Abam TKS (2001).Regional hydrological research perspectives in the Niger Delta.*Hydrological Sciences-,)'ouriwl-des Sciences Hydrologiques, 46(1): 13-25*.

[2] Agagu OK (1979). "Potential geo-pressured geothermal reservoirs in the Niger Delta subsurface" *Nig. J. Sci*. 13: 201-215.

[3] Avbovbo AA (1978). Geologic Notes: Tertiary lithostratigraphy of the Niger Delta. AAPG Bull. 62 (2): 295-306.

[4] Awosika LF (1995). Impacts of global climate change and sea level rise on coastal resources and energy development in Nigeria. (ed. J.C Umolu) Global Climate Change: Impact on Energy Development DAM TECH Nigeria Limited, Nigeria

[5] Doust H, Omatsola E (1990). "Niger Delta" (ed. J. D.Edwards and P.A Santogrossi), Divergent/Passive Margin Basins. AAPG Memoir 48:201-238.

[6] Etu – Efeotor, J.O and Odigi, M.I (1983).Water supply problems in the eastern Niger Delta.*Journal of Mining and Geology*, Vol.20, pp183-193

[7] Etu-Efeotor, J.O &Akpokodje, E.G (1990).Aquifer systems of the Niger Delta.*Journal of Mining and Geology*, Vol. 26 (2): 279-284.

[8] Etu-Efeotor, J.O (1981). Preliminary hydrogeochemical investigation of subsurface waters in parts of the Niger Delta.*Journal of Mining and Geology*, Vol. 18 (1): 103-328.

[9] Frank- Briggs, I.N (2003). Hydrogeology of some island towns in the eastern Niger Delta, Nigeria.UnpublishedPh.D Thesis, University of Port Harcourt, Nigeria. 283p

[10] Koledoye BA., Aydin A, May E (2000)."3-D visualization of fault segmentation and shale smearing in the Niger Delta" *Leading Edge*, 19:692-701.

[11] Merki P (1972). "Structural geology of the Cenozoic Niger Delta". (ed. T.F.J. Dessauvagie& A.J. Whiteman), African Geology, Ibadan Univ. Press, 635-646.

[12] NDES (Niger Delta Environmental Survey) (1995) Phase I Report Vol. 4 NDES Lagos Nigeria.

[13] NEDECO Netherland Engineering Consultant (1961).The Waters of the Niger Delta.NEDECO, the Haque the Netherland.

[14] Ngah, S.A (2009). Deep aquifer systems of eastern Niger Delta: Their hydrogeological properties, groundwater chemistry and vulnerability to degradation. Unpublished PhD Thesis, Rivers State University of Science and Technology, Port Harcourt, Nigeria. 247pp.

[15] Niger Delta Environmental Survey (NDES) (1998). Niger Delta Environmental Survey, Phase 2 Report. Hydrology and Hydrodynamics, Vol. 1 Hydrological characteristics and Resources.

[16] Nwankwoala, H.O and Udom, G.J (2011). Investigation of hydrogeochemical characteristics of groundwater in Port Harcourt City, Nigeria: Implications for use and vulnerability. *Journal of Applied Science and Environmental Management* 15(3):479-488. Available online @www.bioline.org.br/ja.

[17] Nwankwoala, HO (2013). Evaluation of Hydrochemical Characteristics of Groundwater in Port Harcourt, Nigeria. UnpublishedPh.D Thesis, University of Port Harcourt, Nigeria.

[18] Odigi, M.I (1989). Evaluating groundwater supply in the Eastern Niger Delta, Nigeria.*Journal of Mining Geology*, Vol.25:159-164

[19] Reyment, R.A. (1965). Aspects of Geology of Nigeria, University of Ibadan Press, Nigeria.Pp. 133.

[20] Rivers State Water Board (RSWB) (1994). Feasibility Report for the Port Harcourt Metropolitan Water Project. February 1994.

[21] Short, K.C and Stauble, A.J. (1967). Outline Geology of the Niger Delta. Bull Am. Ass Petrol Geol. Vol. 54, No. 5, pg. 761-779.

[22] Tahal Consultant Engineers Ltd (1998). Final Report on Multi-State Water Supply Project, Feasibility Study of Rivers State Capital (Port Harcourt and Environs and Selected Urban Communities)., pp2-9.

[23] Weber, K.J &Daukoro, E.M (1975).Petroleum Geological aspects of the Niger Delta. Proc. 9th World Petroleum Congress, 2: 209-222.

[24] Weber, K.J (1971).Sedimentological aspects of oil fields in the Niger Delta.*Environmental Geology, Minbouw*, Vol.50, No.3, pp559-576.

[25] Whiteman A (1982). "Nigeria: its petroleum geology, resources and potential" 1 and 2, Graham and Trotman Ltd., London, 349.

[26] WHO (2008). International Standards for Drinking Water and Guidelines for water quality. World Health Organization, Geneva.

[27] World Health Organization, WHO (1984). Guidelines for Drinking Water Quality, Vol.2, Recommendations, Geneva 67pp.