◆ Research paper

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Seasonal Variation in Surface and Groundwater Quality in an Oil-Polluted Environment of the Niger Delta

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Abstract: This study was set to examine seasonal variation in surface and groundwater quality in an oil-polluted environment in the Niger Delta Region, Nigeria. To obtain samples for this investigation, three (3) stations were established along Orashi River and three stations also along Sombreiro River, this however enabled the collection of water samples for surface water analysis. Samples for the groundwater quality analysis were collected from boreholes in communities that are very close to the sample location while for the surface water, samples were collected along the two rivers. Parameters of interest in this study include physic-chemical parameters such as pH, conductivity, turbidity, Total Dissolved Solids (TDS), Total hardness, and Total Suspended Solids were sampled using standard methods for water and wastewater analysis (APHA, 2005). Microbiological parameters such as Total Heterotrophic Bacterial (THB), Total Heterotrophic Fungal (THF), Total Coliform (TC), Hydrogen-utilizing Bacteria, Hydrogen-utilizing Fungi and Faecal Coliform (FC). Analysis was done using inferential and descriptive statistics. The study findings revealed that the quality of surface and groundwater in the Orashi and Sombreiro River basins is generally poorer in the wet season than in the dry season. The physiochemical and microbiological analysis showed water quality to be better in the wet season compared to the quality in the dry season. The value for most parameters is higher in the dry season than in the wet season. This applies

to both surface and groundwater quality; hence the study recommends that legislation prohibiting the pollution of any environmental resources, particularly water resources should be reviewed and defaulters should be made to face severe penalties.

Keywords: Surface, Ground, Water, Variation, Oil polluted, Environment, Niger Delta

Introduction

The Niger Delta region of Nigeria is the home of hydrocarbon industry. Oil production commenced in the region following the discovery of oil in Oloibiri in present-day Bayelsa State. While oil was discovered in 1956, exploitation or better still production was delayed until 1958. In other words, commercial oil exploitation started in 1958 following the discovery of crude oil at Oloibiri by the then-Shell British Petroleum in 1956. This was after several failed attempts to strike oil at different locations in the country. What started as a little venture today has grown as the hydrocarbon industry dominates the economic landscape of the Niger Delta and is thus highly visible in the region.

According to Amnesty International Publications (2009), The Niger Delta region is crisscrossed by thousands of kilometers of pipelines, wells and flow stations. These oil infrastructures are scattered in about 800 communities with an extensive network of over 900 producing oil wells and several petroleum production-related facilities (Osuji & Onojake, 2004). From 1958 when commercial production commenced to date, about 1,182 exploration wells have been drilled while about 400 oil and gas fields of varying sizes have been developed (Obaje, 2009). These oil infrastructures are owned and managed by foreign multinationals who operate a joint venture deal with the Nigerian Government through the state-owned oil company, Nigerian National Development Company (NNPC). The industry today contributes a share of approximately 97 percent to the country's foreign exchange portfolio and accounts for 79.5 percent of government revenues. This industry has substantially improved the nation's economy over the past 50 years.

However, activities associated with hydrocarbon exploration, development, and exploitation operations have negatively impacted all spheres of the Niger Delta environment

(Eluchie, 2017). In other words, oil production which has brought much fortune for Nigeria in terms of foreign exchange and revenue has impacted negatively on the physical environment of the oil-bearing communities. The Niger Delta environment (swamps and lands, creeks, and rivers) is been degraded no thanks to oil production activities going on in the region. Oil pollution is the order of the day even as there is no consensus on the number of oil spills and volume of oil spilling into the delta environment, as the operating companies and government of Nigeria keep conflicting data (Amnesty International, 2009).

The Department of Petroleum Resources estimated 1.89 million barrels of petroleum were spilled into the Niger Delta between 1976 and 1996 out of a total of 2.4 million barrels spilled in 4,835 incidents. A UNDP report states that there have been a total of 6,817 oil spills between 1976 and 2001, which account for a loss of three million barrels of oil, of which more than 70% was not recovered. The Nigerian National Petroleum Corporation places the quantity of petroleum jettisoned into the environment yearly at 2,300 cubic meters with an average of 300 individual spills annually. However, a recent report by the United Nations Environment Programme 2011 put the annual average number of oil spills and volume spilled into the delta environment at 273 and 115,000 barrels, respectively. The Niger Delta region has been contaminated with petroleum hydrocarbons qualifying the region as one of the most petroleum spill-vulnerable locations in the world (United Nations Environment Programme, 2011).

Materials and Method

To obtain samples for this investigation, three (3) stations were established along Orashi River and three stations also along Sombreiro River, this however enabled the collection of water samples for surface water analysis. The stations were geographically referenced. This is as shown in Figure 1.1 below;

Samples for the groundwater quality analysis were collected as well from boreholes in communities that are very close to the sample location for the surface water along the two rivers. Parameters of interest in this study include physic-chemical parameters such as pH, conductivity, turbidity, Total Dissolved Solids (TDS), Total hardness, and Total Suspended

Solids were sampled using standard methods for water and wastewater analysis (APHA, 2005). Microbiological parameters such as Total Heterotrophic Bacterial (THB), Total Heterotrophic Fungal (THF), Total Coliform (TC), Hydrogen-utilizing Bacteria, Hydrogen-utilizing Fungi, and Faecal Coliform (FC).

The dry season surface and groundwater samples were collected on 17th January 2020 while the wet season surface and groundwater samples were collected on 24th June 2020.

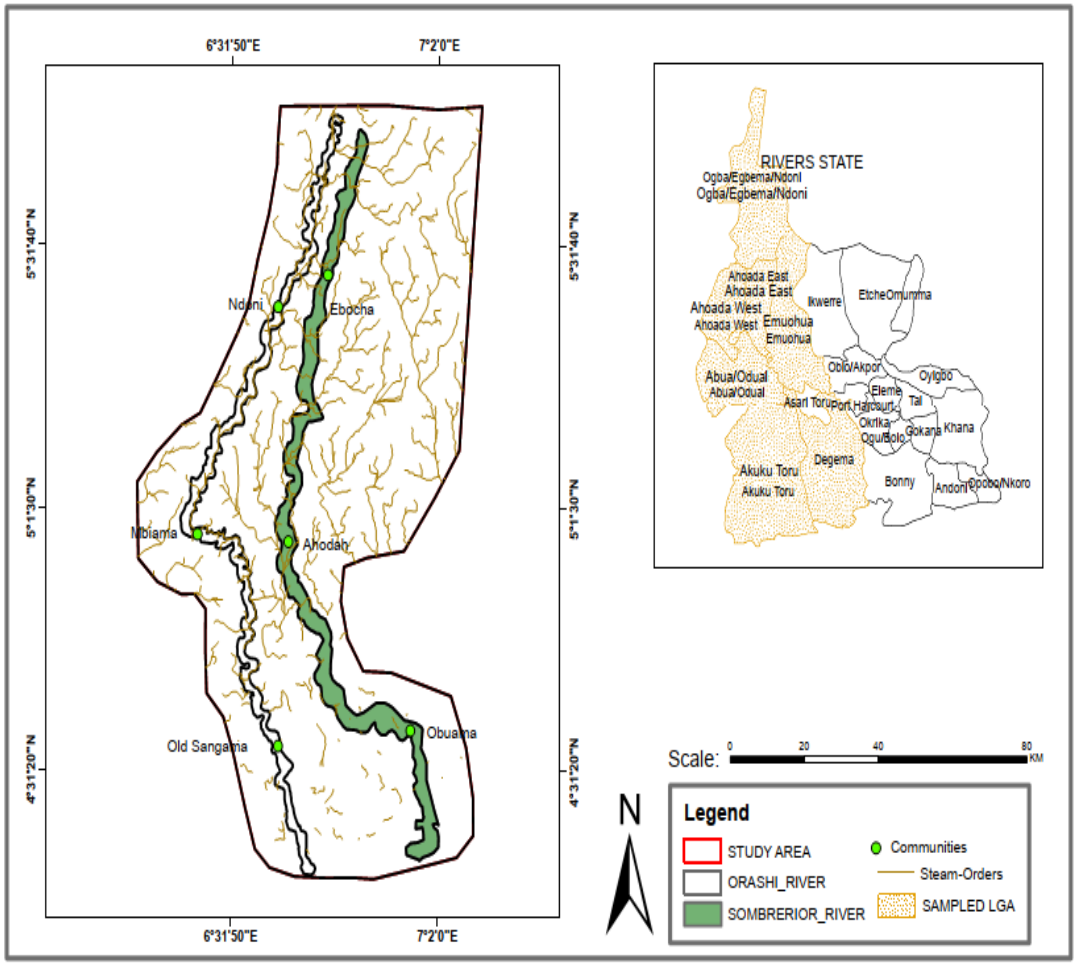

Figure 1.1 Orashi/Sombreiro drainage basins showing Sampling points

Primary data was heavily relied upon in the course of this study. The primary source of data used in this research was acquired through laboratory analysis.

Laboratory Analysis Procedure

Analytical procedures described in Efe (2011) were adopted for this study of water

chemistry. Surface water samples were collected from three (3) stations each along Orashi and Sombreiro Rivers. Turbidity, pH, Total dissolved solids, and Conductivity were carried out in situ using a Teledo MC236 pH meter and digital mercury thermometer while Total hardness and total Suspended Solids were analyzed in the laboratory (APHA, 2005). The water samples collected were poured into sterilized plastic containers labeled, covered, and refrigerated to reduce the degradation of samples before analysis.

The microbiological parameters analyzed include: Total Heterotrophic Baterial (THB), Total Heterotrophic Fungal (THF), Total Coliform (TC), and Faecal Coliform (FC) were analyzed from the collected water samples. Membrane filtration was used to isolate and enumerate all from the sampled stream water according to APHA (1998).

Descriptive and inferential statistics were used in the course of the data analysis. Inferential statistics precisely the Analysis of Variance (ANOVA) was used to test the hypotheses for acceptance or otherwise. Analysis of Variance (ANOVA) was used to measure the variation between surface and groundwater quality from the various river basins. Significance differences will be considered at a 95% error margin.

Results and Discussion

Dry Season Surface Water Quality of Orashi /Sombreiro River Basin

This section of the study presents data on the state of dry season surface water quality in the Orashi /Sombreiro River basins. Table 1 presents the results.

Table 1 Dry Season Surface Water Quality of Orashi /Sombreiro River Basin

Parameters	SOMBREIRO			ORASHI		
	Sample Locations			Sample Locations		
	SP1 Obuama	SP2 Ahoada	SP3 Ebocha	SP1 Mbiama	SP2 Old Sanna	SP3 Ndoni
pH	4.28	4.44	4.87	3.48	4.92	5.15
Conductivity	1410.58	1152.69	1250.37	1310.47	1720.81	874.16
Total Dissolved Solids	846.34	691.61	750.22	786.28	1032.38	524.49
Turbidity	0.114	0.134	0.036	0.156	0.014	0.116
Total Hardness	315.78	170.21	498.13	275.63	355.94	260.85
Total Suspended Solids	153.17	110.25	195.29	218.81	270.33	143.57
Lead	2.532	3.174	2.1575	4.8526	2.9822	3.0053
Chromium	5.82	2.520	3.2286	5.2519	6.8206	6.5391
Nickel	4.84	3.536	3.7585	6.9332	4.1024	7.5469
Total Heterotrophic Bacteria ($cfuml^{-1}$)	1400	3300	3000	6000	9000	1000
Total Fungi ($cfu\ ml^{-1}$)	Nil	800	200	900	500	500
Total Coliform Count (100ml)	17	2	9	7	9	14
Feacal Coliform Count (100ml)	2	4l	Nil	2	2	4

***SP = Sample point**

Table 1 above shows the dry season surface water quality of the Sombreiro/Orashi river basin, the water source was collected from the Sombreiro and Orashi Rivers respectively. It is observed that the pH level of the surface water ranged from 4.28 to 4.87, with sample point 3 which is located at Ebocha having the highest pH value of 4.87. The Orashi River section result showed that the pH value ranged from 3.48 to 5.15; with sample point 3 which is in the Ndoni section having the highest value of 5.15.

Conductivity as observed from the table also showed that the Sombreiro Rivers section ranged from 1152.69µs/cm to 1410.58µs/cm, with sample point 1 which is Obuama having the highest conductivity value of 1410.58µs/cm. The Orashi Rivers section as observed from the table showed that conductivity ranged from 874.16µs/cm to 1720.81µs/cm, with sample point 2 of the Orashi section located at Old Sangana accounting for the highest conductivity value of 1720.81µs/cm.

Total dissolved solids as observed from the table showed that the Sombreiro River

section ranged from 691.61mg/L to 846.34mg/L, with sample point 1 at Obama having the highest amount of total dissolved solids accounting for 846.34mg/L. The Orashi river section as observed from the table showed that total dissolved solids ranged from 524.49mg/L to 1032.38mg/L, with sample point 2 of the Orashi section located at Old Sangana having the highest amount of total dissolved solids accounting for 1032.38mg/L.

Turbidity level as observed showed that the Sombreiro River section of the study area ranged from 0.036(NTU) to 0.134(NTU), with sample point 2 which is located in Ahoada having the highest amount of turbidity accounting for 0.134(NTU). The Orashi River section as observed from the table showed that turbidity ranged from 0.014(NTU) to 0.156(NTU), with sample point 1 of the Orashi section located at Mbiama having the highest amount of turbidity accounting for 0.156(NTU).

Total Hardness as observed showed that in the Sombreiro River section of the study area, total hardness level ranged from 170.21mg/L to 498.13mg/L, with sample point 3 which is at Ebocha having the highest value of total hardness accounting for 498.13mg/L. In the Orashi River section of the study area, it is observed that the total hardness value ranged from 260.85mg/L to 355.94mg/L, with sample point 2 located in Old Sangana having the highest amount of 355.94mg/L.

Total suspended solids (TSS) as observed showed that in the Sombreiro River section of the study area, total suspended solids level ranged from 110.25mg/L to 195.29mg/L, with sample point 3 which is located in Ebocha having the highest value of total suspended solids accounting for 195.29mg/L. In the Orashi River section of the study area, it is observed that total suspended solids value ranged from 143.57mg/L to 270.33mg/L, with sample point 2 located in Old Sangana having the highest amount of 270.33mg/L.

Lead as observed in Table 4.1 showed that in the Sombreiro River section of the study area, lead level ranged from 2.157mg/L to 3.174mg/L, with sample point 2 which is located in Ahoada having the highest value of 3.174mg/L. In the Orashi River section of the study area, it is observed that lead values ranged from 2.9822mg/L to 4.8526mg/L, with sample point 1

located in Mbiama having the highest amount of 4.8526mg/L.

Chromium as observed showed that in the Sombreiro River section of the study area, chromium levels ranged from 2.520mg/L to 5.820mg/L, with sample point 1 which is located in Obama having the highest value of 5.820mg/L. In the Orashi River section of the study area, it is observed that chromium value ranged from 5.2519mg/L to 6.8206mg/L, with sample point 2 located in Old Sangana having the highest amount of 6.8206mg/L.

Nickel as observed showed that in the Sombreiro River section of the study area, nickel levels ranged from 3.536mg/L – 4.840mg/L, with sample point 1 which is located in Obuama having the highest value of 4.840mg/L. In the Orashi River section of the study area, it is observed that nickel value ranged from 4.1024mg/L – 7.5469mg/L, with sample point 3 located in Ndoni having the highest amount of 7.5469mg/L.

Total Heterotrophic Bacteria as observed showed that in the Sombreiro River section of the study area, total heterotrophic bacteria level ranged from 1400(cfu g^{-1}) to 3300(cfu g^{-1}), with sample point 2 which is located in Ahoada having the highest value of 3300(cfu g^{-1}). In the Orashi River section of the study area, it is observed that total heterotrophic bacteria values ranged from 1000(cfu g^{-1}) to 9000(cfu g^{-1}) with sample point 2 located in Old Sangana having the highest amount of 9000(cfu g^{-1}).

Total Fungi as observed showed that in the Sombreiro River section of the study area, total fungi levels ranged from 200(cfu g^{-1}) to 800(cfu g^{-1}), with sample point 2 which is located in Ahoada having the highest value of 800(cfu g^{-1}). In the Orashi River section of the study area, it is observed that total fungi value ranged from 500(cfu g^{-1}) to 900(cfu g^{-1}) with sample 1 point located in Mbiama having the highest amount of 900(cfu g^{-1}).

Total coliform count as observed showed that in the Sombreiro River section of the study area, total coliform count level ranged from 2cfu/100ml to 17cfu/100ml, with sample point 2 which is located in Obama having the highest value of 17cfu/100ml. In the Orashi River section of the study area, it is observed that total coliform count value ranged from

7cfu/100ml to 14cfu/100ml, with sample point 3 located in Ndoni having the highest amount of 14cfu/100ml.

Fecal coliform count as observed showed that in the Sombreiro River section of the study area, fecal coliform level ranged from 2cfu/100ml to 4cfu/100ml, with sample point 1 which is located in Obama having the highest value of fecal coliform accounting for 4cfu/100ml. In the Orashi River section of the study area, it is observed that fecal coliform values ranged from 2cfu/100ml to 4cfu/100ml, with sample point 3 located in Ndoni having the highest amount of 4cfu/100ml.

Wet Season Surface Water Quality of Orashi /Sombreiro River Basin

This section of the study presents data on the state of wet (rainy) season surface water quality in the Orashi /Sombreiro River basins. This is captured in Table 2 below.

Table 2 Wet Season Surface Water Quality Status of Orashi /Sombreiro River Basin

Parameters	SOMBREIRO			ORASHI		
	Sample Locations			Sample Locations		
	SP1 Obuama	SP2 Ahoada	SP3 Ebocha	SP1 Mbiama	SP2 Old Sangana	SP3 Ndoni
Ph	6.48	5.74	5.59	4.79	5.42	5.92
Conductivity	853.27	922.53	750.40	1020.775	1130.66	660.74
Total Dissolved Solids	512.00	553.51	450.24	612.45	678.39	396.44
Turbidity	0.013	0.021	0.012	0.029	0.008	0.014
Total Hardness	250.36	120.57	370.85	210.11	270.39	200.43
Lead	78.43	54.39	110.82	120.73	140.15	88.47
Lead	1.2587	1.5286	1.0074	2.5838	1.1274	2.4643
Chromium	4.1348	1.1595	2.0029	3.0049	4.1427	5.2055
Nickel	2.1081	4.3282	2.0363	5.2692	2.2496	5.3005
Total Heterotrophic Bacteria	48000	50000	660000	640000	720000	49000
Total Fungi	3000	2800	3200	3400	3500	2800
Total Coliform Count	24	19	16	14	17	19
Feacal Coliform Count	9	9	2	2	2	9

***SP = Sample point**

Table 2 above shows the wet season surface water quality of the Sombreiro/Orashi river

basin, the water source was collected from the Sombreiro and Orashi Rivers respectively. It is observed that the pH level of the surface water ranged from 5.59 to 6.48; with Sample point 1 which is located in Obama having the highest pH value of 6.48. The Orashi river section result showed that the pH value ranged from 4.79 to 5.92 with sample point 3 which is the Ndoni having the highest pH value of 5.92.

Conductivity as observed from the table also showed that the Sombreiro River section ranged from 750.40μs/cm to 922.53μs/cm, with sample point 2 which is Ahoada having the highest conductivity value of 922.53μs/cm. The Orashi river section as observed from the table showed that conductivity ranged between 660.74μs/cm – 1130.66μs/cm, with sample point 2 of the Orashi section located at Old Sangana accounting for the highest conductivity value of 1130.66μs/cm.

Total dissolved solids as observed from the table showed that the Sombreiro River section ranged from 450.24mg/L to 553.51mg/L, with sample point 2 which is Ahoada having the highest amount of Total dissolved solids accounting for 553.51mg/L. The Orashi River section as observed from the table showed that total dissolved solids ranged between 396.44mg/L to 678.39mg/L, with sample point 2 of the Orashi section located at Old Sangana having the highest amount of total dissolved solids accounting for 678.39mg/L.

Turbidity level as observed showed that in the Sombreiro River section of the study area, turbidity level ranged from 0.012(NTU) to 0.021(NTU), with sample point 2 which is located in Ahoada having the highest amount of turbidity accounting for 0.021(NTU). The Orashi River section as observed from the table showed that turbidity ranged from 0.008(NTU) to 0.029(NTU), with sample point 1 of the Orashi section located at Mbiama having the highest amount of total dissolved solids accounting for 0.029(NTU).

Total Hardness as observed showed that in the Sombreiro River section of the study area, total hardness level ranged from 120.57mg/L to 370.8mg/L, with sample point 3 which is located in Ebocha having the highest value of total hardness accounting for 370.8mg/L. in the Orashi River section of the study area, it is observed that total hardness value ranged between

200.43mg/L to 270.39mg/L, with sample point 2 located in Old Sangana having the highest amount of total hardness value of 270.37mg/L.

Total Suspended Solids as observed showed that in the Sombreiro River section of the study area, total suspended solids level ranged from 54.39mg/L to 110.82mg/L, with sample point 3 which is located in Ebocha having the highest value of total suspended solids accounting for 110.82mg/L. In the Orashi River section of the study area, it is observed that total suspended solids value ranged from 88.47mg/L to 140.15mg/L, with sample point 2 located in Old Sangana having the highest amount of suspended solids value accounting for 140.15mg/l.

Lead as observed showed that in the Sombreiro River section of the study area, lead level ranged from 1.0074mg/L to 1.5286mg/L, with sample point 2 which is located in Ahoada having the highest value of lead accounting for 1.5286mg/L. In the Orashi River section of the study area, it is observed that lead values ranged from 1.1274mg/L to 2.5838mg/L, with sample point 1 located in Mbiama having the highest amount of 2.5838mg/l.

Chromium as observed showed that in the Sombreiro river section of the study area, chromium level ranged from 1.1595mg/L to 4.1348mg/L, with sample point 1 which is located in Obuama having the highest value of chromium of 4.1348mg/L. In the Orashi River section of the study area, it is observed that chromium value ranged between 3.0049mg/L to 5.2055mg/L, with sample point 3 located in Ndoni having the highest amount of 5.2055mg/L.

Nickel as observed showed that in the Sombreiro River section of the study area, nickel level ranged from 2.0363mg/L to 4.3282mg/L, with sample point 1 which is located in Obuama having the highest value of 4.3282mg/L. In the Orashi River section of the study area, it is observed that nickel values ranged from 2.2496mg/L to 5.3005mg/L, with sample point 3 located in Ndoni having the highest amount of 5.3005mg/L.

Total Heterotrophic Bacteria as observed showed that in the Sombreiro River section of the study area, total heterotrophic bacteria level ranged from 48000(cfu g^{-1}) to 660000(cfu g^{-1}), with sample point 3 which is located in Ebocha having the highest value of 660000(cfu g^{-1}

^{1}). In the Orashi River section of the study area, it is observed that total heterotrophic bacteria value ranged from 49000(cfu g^{-1}) to 720000(cfu g^{-1}) with sample point 2 located in Old Sangana having the highest amount of 720000(cfu g^{-1}).

Total Fungi as observed showed that in the Sombreiro River section of the study area, total fungi levels ranged from 2800(cfu g^{-1}) to 3200(cfu g^{-1}), with sample point 3 which is located in Ebocha having the highest value of 3200(cfu g^{-1}). In the Orashi river section of the study area, it is observed that total fungi value ranged from 2800(cfu g^{-1}) to 3500(cfu g^{-1}) with sample 2 point located in Old Sangana having the highest amount of 3500(cfu g^{-1}).

Total Coliform count as observed showed that in the Sombreiro River section of the study area, total coliform count level ranged from 16cfu/100ml – 24cfu/100ml, with sample point 1 which is located in Obama having the highest value of 24cfu/100ml. In the Orashi River section of the study area, it is observed that the total coliform count value ranged from 14cfu/100ml to 19cfu/100ml, with the sample point located in Ndoni having the highest amount of 19cfu/100ml.

Fecal coliform count as observed showed that in the Sombreiro River section of the study area, fecal coliform levels ranged from 2cfu/100ml to 9cfu/100ml, with sample points 1 and 2 which are located in Obuama and Ahoada having the highest value of 9cfu/100ml. In the Orashi River section of the study area, it is observed that fecal coliform values ranged from 2cfu/100ml to 9cfu/100ml, with sample point 3 located in Ndoni having the highest amount of 9cfu/100ml.

Dry Season Ground Water Quality of Orashi /Sombreiro River Basin

This section of the study presents data on the state of dry season groundwater quality in the Orashi /Sombreiro River basins. This is presented in Table 3 below.

Table 3 Dry Season Ground Water Quality of Orashi /Sombreiro River Basin

Parameters	SOMBREIRO			ORASHI		
	Sample Locations			Sample Locations		
	SP1 Obuama	SP2 Ahoada	SP3 Ebocha	SP1 Mbiama	SP2 Old Sangana	SP3 Ndoni
Ph	5.53	5.97	6.23	5.13	6.11	6.39
Conductivity	370.92	572.31	440.51	980.54	722.64	230.54
Total Dissolved Solids	222.55	343.38	264.30	588.32	433.58	138.32
Turbidity	0.116	0.011	0.032	0.121	0.018	0.210
Total Hardness	240.39	235.71	230.47	220.41	240.56	150.08
Total Suspended Solids	21.49	134.92	38.03	121.74	44.20	31.93
Lead	1.8532	3.6933	1.6924	3.4131	1.5341	2.0171
Chromium	3.1632	2.5201	2.0047	4.6113	1.3473	1.8452
Nickel	2.1722	5.0242	4.4215	4.4836	6.0122	3.1158
Total Heterotrophic Bacteria	900	600	900	200	400	500
Total Fungi	Nil	300	Nil	Nil	Nil	Nil
Total Coliform Count	4	6	2	2	2	4
Feacal Coliform Count	Nil	Nil	Nil	Nil	Nil	Nil

***SP = Sample point**

Table 3 shows the dry season groundwater quality of the Sombreiro/Orashi River basin, the water source was collected from the Sombreiro and Orashi Rivers respectively. It is observed that the pH level of the surface water ranged from 5.53 to 6.23; with Sample point 3 which is located in Ebocha having the highest pH value of 6.23. The Orashi River section result showed that the pH value ranged from 5.13 to 6.39; with sample point 3 which is the Ndoni section of the River having the highest pH value of 6.39.

Conductivity as observed from the table also showed that the Sombreiro River section ranged from 370.92μs/cm to 572.31μs/cm, with sample point 2 which is Ahoada having the highest conductivity value of 572.31μs/cm. The Orashi River section as observed from the table showed that conductivity ranged from 230.54μs/cm to 980.54μs/cm, with sample point 1 of the Orashi section located at Mbiama accounting for the highest conductivity value of 980.54μs/cm.

Total dissolved solids as observed from the table showed that the Sombreiro River

section ranged from 222.55mg/L to 343.38mg/L, with sample point 2 which is Ahoada having the highest amount of Total dissolved solids accounting for 343.38mg/L. The value in the Orashi River section as observed from the table showed that total dissolved solids ranged between 138.32mg/L to 588.32mg/L, with sample point 1 of the Orashi section located at Mbiama having the highest amount of total dissolved solids accounting for 588.32mg/L.

Turbidity level as observed showed that in the Sombreiro River section of the study area, turbidity level ranged between 0.011(NTU) to 0.116(NTU), with sample point 1 which is located in Obama having the highest amount of turbidity accounting for 0.116(NTU). The value at the Orashi River basin ranged from 0.018(NTU) to 0.121(NTU), with sample point 1 of the Orashi section located at Mbiama having the highest amount.

Total Hardness as observed showed that in the Sombreiro River section of the study area, the total hardness level ranged from 230.47mg/L – 240.39mg/L, with sample point 3 which is located in Ebocha having the highest value of total hardness accounting for 240.39mg/L. In the Orashi River section of the study area, it is observed that total hardness value ranged from 150.08mg/L to 240.56mg/L, with sample point 2 located in Old Sangana having the highest amount of total hardness value accounting for 240.56mg/L.

Total Suspended Solids as observed showed that in the Sombreiro River section of the study area, total suspended solids level ranged from 21.49mg/L to 134.92mg/L, with sample point 2 which is located in Ahoada having the highest value of total suspended solids accounting for 131.92mg/L. In the Orashi River section of the study area, it is observed that total suspended solids value ranged from 31.93mg/L to 121.74mg/L, with sample point 1 located at Mbiama having the highest amount of suspended solids value accounting for 121.74mg/L.

Lead as observed showed that in the Sombreiro River section of the study area, lead level ranged from 1.6924mg/L to 3.6933mg/L, with sample point 2 which is located in Ahoada having the highest value of lead accounting for 3.6933mg/L. In the Orashi River section of the study area, it is observed that lead value ranged from 1.5341mg/L to 3.4131mg/L, with

sample point 1 located in Mbiama having the highest amount of lead value accounting for 3.4131mg/L.

Chromium as observed showed that in the Sombreiro River section of the study area, chromium levels ranged from 2.0047mg/L to 3.1632mg/L, with sample point 1 which is located in Obama having the highest value of 3.1632mg/L. In the Orashi River section of the study area, it is observed that chromium value ranged from 1.3473mg/l to 4.6113mg/L, with sample point 1 located at Mbiama having the highest amount of chromium value accounting for 4.6113mg/L.

Nickel as observed showed that in the Sombreiro River section of the study area, nickel level ranged from 2.1722mg/L to 5.0242mg/L, with sample point 2 located at Ahoada having the highest value of nickel of 5.0242mg/L. In the Orashi River section of the study area, it is observed that nickel values ranged from 3.1158mg/L to 6.0122mg/L, with sample point 2 located at Old Sangana having the highest amount of 6.0122mg/L.

Total Heterotrophic Bacteria as observed showed that in the Sombreiro River section of the study area, total heterotrophic bacteria level ranged between 600(cfu g^{-1}) to 900(cfu g^{-1}), with sample point 1 (Obuama) and sample point 3 (Ebocha) having the highest value of 900(cfu g^{-1}). In the Orashi River section of the study area, it is observed that total heterotrophic bacteria value ranged from 200(cfu g^{-1}) to 500(cfu g^{-1}), with sample point 3 located in Ndoni having the highest amount of total heterotrophic bacteria value of 500(cfu g^{-1}).

Total Coliform count as observed showed that in the Sombreiro River section of the study area, total coliform count level ranged from 2.0mg/L to 6.0mg/L, with sample point 2 which is located at Mbiama having the highest value of total coliform count accounting for 4.3282mg/L. In the Orashi River section of the study area, it is observed that total coliform count value ranged from 2.0mg/L to 4.0mg/L, with sample point 3 located in Ndoni having the highest amount of total coliform count value accounting for 4.0 mg//L.

This section of the study presents data on the state of dry season surface water quality in the Orashi /Sombreiro River basins. This is captured in Table 4 below.

Table 4 Wet Season Ground Water Quality of Orashi /Sombreiro River Basin

Parameters	SOMBREIRO			ORASHI		
	Sample Locations			Sample Locations		
	SP1 Obuama	SP2 Ahoada	SP3 Ebocha	SP1 Mbiama	SP2 Old Sangana	SP3 Ndoni
Ph	6.11	6.52	6.47	5.84	6.48	6.56
Conductivity	420.34	484.21	533.85	5.77.09	902.11	422.13
Total Dissolved Solids	252.20	290.52	320.31	346.25	541.26	253.27
Turbidity	0.011	0.09	0.009	0.018	0.004	0.006
Total Hardness	210.69	180.43	190.67	140.28	190.22	110.54
Total Suspended Solids	17.51	97.51	15.62	72.18	27.48	21.60
Lead	0.6135	1.1528	0.2485	1.3485	0.2485	0.3679
Chromium	2.0201	2.0254	1.1511	3.1833	1.1511	1.3453
Nickel	1.0012	1.1203	2.1542	3.1157	2.1542	1.2865
Total Heterotrophic Bacteria	5600	6000	3900	4000	4200	5000
Total Fungi	3100	3200	2600	2600	2700	3000
Total Coliform Count	17	14	14	12	14	14
Feacal Coliform Count	4	4	2	2	2	2

***SP = Sample point**

Table 4 shows the wet season groundwater quality of the Sombreiro/Orashi river basin, the water source was collected from the selected communities located within the Sombreiro and Orashi River Basin respectively. It is observed that the pH level of the groundwater ranged from 6.11 to 6.52 with sample point 2 which is located in Ahoada having the highest pH value of 6.52. The Orashi River Basin section result showed that the pH value ranged from 5.84 to 6.56, with sample point 3 located in Ndoni having the highest pH value of 6.56.

Conductivity as observed from the table also showed that in the Sombreiro River Basin section of the study area, conductivity level ranged between 420.34µs/cm to 533.85µs/cm, with sample point 3 Obama having the highest conductivity value of 533.85µs/cm. The Orashi Rivers section as observed from the table showed that conductivity ranged between 422.13µs/cm to 902.11µs/cm; with sample point 2 of the Orashi section Old Sangana

accounting for the highest conductivity value of 902.11μs/cm.

Turbidity level as observed showed that in the Sombreiro River section of the study area, turbidity level ranged between 0.009(NTU) to 0.011(NTU), with sample point 1 which is located in Obuama having the highest amount of turbidity accounting for 0.011(NTU). The Orashi river section as observed from the table showed that turbidity ranged between 0.004(NTU) to 0.018(NTU), with sample point 1 of the Orashi section located at Mbiama having the highest amount of turbidity accounting for 0.018(NTU).

Total dissolved solids as observed from the table showed that the Sombreiro river section ranged from 252.20mg/L to 320.31mg/L, with sample point 3 which is Ebocha having the highest amount of Total dissolved solids accounting for 320.31mg/L. The Orashi river section as observed from the table showed that total dissolved solids ranged from 254.23mg/L to 541.25mg/L, with sample point 2 of the Orashi section located at Old Sangana having the highest amount of total dissolved solids accounting for 541.25mg/L.

Total Hardness as observed showed that in the Sombreiro River section of the study area, the total hardness level ranged from 120.57mg/L to 370.8mg/L, with sample point 3 which is located in Ebocha having the highest value of total hardness accounting for 370.8mg/L. in the Orashi from river section of the study area, it is observed that total hardness value ranged between 200.43mg/L to 270.39mg/L, with sample point 2 located in Old Sangana having the highest amount of total hardness value accounting for 270.37mg/L.

Total Suspended Solids as observed showed that in the Sombreiro River section of the study area, total suspended solids level ranged from 15.62mg/L to 97.51mg/L, with sample point 2 which is located in Ahoada having the highest value of total suspended solids accounting for 97.51mg/L. In the Orashi river section of the study area, it is observed that total suspended solids value ranged from 21.60mg/L to 72.18mg/L, with sample point 1 located in Mbiama having the highest amount of suspended solids value accounting for 72.18mg/L.

Lead as observed showed that in the Sombreiro River section of the study area, lead level

ranged from 1.0074mg/L to 1.5286mg/L, with sample point 2 which is located in Ahoada having the highest value of lead accounting for 1.5286mg/L. In the Orashi river section of the study area, it is observed that lead value ranged from 1.1274mg/L to 2.5838mg/L, with sample point 1 located in Mbiama having the highest amount of lead value accounting for 2.5838mg/l.

Chromium as observed showed that in the Sombreiro river section of the study area, chromium level ranged from 1.1595mg/L to 4.1348mg/L, with sample point 1 which is located in Obuama having the highest value of chromium accounting for 4.1348mg/L. In the Orashi river section of the study area, it is observed that chromium value ranged from 3.0049mg/l to 5.2055mg/l, with sample point 3 located in Ndoni having the highest amount of chromium value accounting for 5.2055mg/l.

Nickel as observed showed that in the Sombreiro river section of the study area, nickel level ranged from 2.0363mg/l to 4.3282mg/l, with sample point 1 which is located in Obuama having the highest value of nickel accounting for 4.3282mg/L. In the Orashi river section of the study area, it is observed that nickel value ranged from 2.2496mg/L to 5.3005mg/L, with sample point 3 located in Ndoni having the highest amount of nickel value accounting for 5.3005mg/l.

Total Heterotrophic Bacteria as observed showed that in the Sombreiro River section of the study area, total heterotrophic bacteria level ranged from 48000(cfu g^{-1}) to 660000(cfu g^{-1}), with sample point 3 which is located in Ebocha having the highest value of total heterotrophic bacteria accounting for 660000(cfu g^{-1}). In the Orashi river section of the study area, it is observed that total heterotrophic bacteria value ranged between 49000(cfu g^{-1}) – 720000(cfu g^{-1}) with sample point 2 located in Old Sangana having the highest amount of total heterotrophic bacteria value accounting for 720000(cfu g^{-1}).

Total Fungi as observed showed that in the Sombreiro River section of the study area, total fungi levels ranged from 2800(cfu g^{-1}) to 3200(cfu g^{-1}), with sample point 3 which is located in Ebocha having the highest value of total fungi accounting for 3200(cfu g^{-1}). In the

Orashi river section of the study area, it is observed that total fungi value ranged from 2800(cfu g^{-1}) – 3500(cfu g^{-1}) with sample 2 point located in Old Sangana having the highest amount of total fungi value accounting for 3500(cfu g^{-1}).

Total Coliform count as observed showed that in the Sombreiro River section of the study area, total coliform count level ranged from 16cfu/100ml to 24cfu/100ml, with sample point 1 which is located in Obama having the highest value of total coliform count accounting for 24cfu/100ml. In the Orashi river section of the study area, it is observed that total coliform count value ranged from 14cfu/100ml to 19cfu/100ml, with the sample point located in Ndoni having the highest amount of total coliform count value accounting for 19cfu/100ml.

Fecal coliform count as observed showed that in the Sombreiro River section of the study area, fecal coliform levels ranged from 2cfu/100ml to 9cfu/100ml, with sample points 1 and 2 which are located in Obuama and Ahoada having the highest value of fecal coliform accounting for 9cfu/100ml. In the Orashi river section of the study area, it is observed that fecal coliform value ranged from 2cfu/100ml to 9cfu/100ml, with sample point 3 located in Ndoni having the highest amount of fecal coliform value accounting for 9cfu/100ml.

Hypothesis Test Result

Hypothesis One: There is no statistically significant variation in surface and groundwater quality in the different sample locations of the Orashi /Sombreiro River basins in the wet season.

The ANOVA table above reveals that the calculated F statistic value for the analysis is 0.625476 while the critical value is 2.323126. Therefore, since the calculated F statistic value of 0.625476 is less than the critical value of 2.323126 at $F^{5}{}_{89}$ degree of freedom, this implies that the null hypothesis H_0 of no significant variation is rejected and the alternate H_1 which states that there is a statistical significant variation in surface water quality in the different sample locations of Orashi /Sombreiro River basins in the wet season is accepted.

Table 5 Anova Result for Wet Season Surface Water Quality Variation in Different Sample Locations of Orashi /Sombreiro River Basin

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	15	4162.456	277.4971	259607.9
Column 2	15	7281.564	485.4376	740366.7
Column 3	15	6517.061	434.4707	641513.5
Column 4	15	10420.86	694.7242	2317140
Column 5	15	13609.3	907.2866	5241387
Column 6	15	3643.427	242.8952	113091.2

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4854272	5	970854.5	0.625476	0.680743	2.323126
Within Groups	1.3E+08	84	1552184			
Total	1.35E+08	89				

Table 6 Anova Result for Wet Season Ground Water Quality Variation in Different Sample Locations of Orashi /Sombreiro River Basin

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	15	60531.5	4035.433	1.51E+08
Column 2	15	61481.58	4098.772	1.57E+08
Column 3	15	42986.48	2865.766	75511804
Column 4	15	38191.99	2546.132	55047369
Column 5	15	48387.11	3225.807	94087605
Column 6	15	42833.11	2855.54	67138829

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32007914	5	6401583	0.064055	0.997139	2.323126
Within Groups	8.39E+09	84	99938515			
Total	8.43E+09	89				

The ANOVA table above reveals that the calculated F statistic value for the analysis is 0.064055 while the critical value is 2.323126. Therefore, since the calculated F statistic value of 0.064055 is less than the critical value of 2.323126 at $F^{5}{}_{89}$ degree of freedom, this implies that the null hypothesis H_0 of no significant variation is rejected and the alternate H_1 which states that there is a statistically significant variation in groundwater quality in the different sample locations of Orashi /Sombreiro River basins in the wet season is accepted.

Hypothesis Two: There is no statistically significant variation in surface and groundwater quality in the different sample locations of the Orashi /Sombreiro River basins in the dry season.

Table 7 Anova Result for Dry Season Surface Water Quality Variation in Different Sample Locations of Orashi /Sombreiro River Basin

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	15	4162.456	277.4971	259607.9
Column 2	15	7281.564	485.4376	740366.7
Column 3	15	6517.061	434.4707	641513.5
Column 4	15	10420.86	694.7242	2317140
Column 5	15	13609.3	907.2866	5241387
Column 6	15	3643.427	242.8952	113091.2

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4854272	5	970854.5	0.625476	0.680743	2.323126
Within Groups	1.3E+08	84	1552184			
Total	1.35E+08	89				

The ANOVA table above reveals that the calculated F statistic value for the analysis is 0.625476 while the critical value is 2.323126. Therefore, since the calculated F statistic value of 0.625476 is less than the critical value of 2.323126 at $F^{5}{}_{89}$ degree of freedom, this therefore implies that the null hypothesis H_0 of no significant variation is rejected and the alternate H_1 which states that there is a statistically significant variation in surface water quality in the different sample locations of Orashi /Sombreiro River basins in dry season is accepted.

Table 8: ANOVA Result for Dry Season Ground Water Quality Variation in Different Sample Locations of Orashi /Sombreiro River Basin

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	15	1772.185	118.1456	60432.01
Column 2	15	2409.539	160.6359	44447.83
Column 3	15	1889.691	125.9794	63605.25
Column 4	15	2130.769	142.0513	79170.37
Column 5	15	1858.002	123.8668	49997.14
Column 6	15	1068.448	71.22987	19270.95

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	67353.07	5	13470.61	0.255026	0.936165	2.323126
Within Groups	4436930	84	52820.59			
Total	4504283	89				

The ANOVA table above reveals that the calculated F statistic value for the analysis is 0.255026 while the critical value is 2.323126. Therefore, since the calculated F statistic value of 0.255026 is less than the critical value of 2.323126 at $F^{5}{}_{89}$ degree of freedom, this implies that the null hypothesis H_0 of no significant variation is rejected and the alternate H_1 which states that there is a statistical significant variation in groundwater quality in the different sample locations of Orashi /Sombreiro River basins in the dry season is accepted.

Conclusion and Recommendations

The quality of surface and groundwater in the Orashi and Sombreiro River basins is generally poorer in the wet season than in the dry season. The physiochemical and microbiological analysis showed water quality to be better in the wet season compared to the quality in the dry season. The value for most parameters is higher in the dry season than in the wet season. This applies to both surface and groundwater quality. The study however recommends that Legislation prohibiting the pollution of any environmental resources, particularly water resources should be reviewed and defaulters should be made to face severe penalties. Oil firms should be made to comply with the applied laws and practices. These legislations should be strictly enforced without compromise. This will go a long way to discourage firms particularly those involved in the exploration and extraction of petroleum whose activities often pollute the water.

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