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Comparative Assessment of Surface and Groundwater Quality in Owerri Municipal, Imo State, Nigeria

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Abstract-The present study assessed and compared the quality of the two major sources of water supply namely, Groundwater (Borehole) and the Surface water (Otamiri river) in Owerri municipal area of Imo State. Emphasis was placed on the comparison between the physicochemical properties of these two water sources. Water samples of Otamiri River were collected from four (4) locations while those of boreholes were collected from six (6) sampling locations. In-situ measurements were made and water samples collected with 500ml sample bottles according to standard methods for laboratory analysis. Descriptive analysis, Analysis of variance (ANOVA) and Principal Component Analysis (PCA) were used to analyze data. Mean values of the parameters obtained for the Otamiri and Borehole samples respectively were: temperature 28.49 and 28.01^{O}C, pH 7.53 and 7.02, TDS 170.22 and 133.92mg/l, electrical conductivity 145.59 and 88.02 us/cm, turbidity 0.17 and 0.03 NTU, alkalinity 42.11 and 26.37mg/l, total hardness 0.44 and 0.01mg/l, chloride 13.99 and 8.34mg/l, NO_3 3.35 and 2.03mg/l, SO_4 3.49 and 2.20mg/l, DO 4.38 and 4.13mg/l, BOD 10.55 and 7.69mg/l, COD 20.89 and 10.39mg/l, Magnesium 6.64 and 4.52mg/l, Calcium 9.22 and 6.62mg/l, Fe^{2+} 0.19 and 0.07mg/l, Mn 0.05 and 0.01mg/l, Zn^{2+} 0.34 and 0.15mg/l, Cu^{2+} 0.05 and 0.03mg/l. All the parameters analyzed were within WHO (2012) and NESREA (2011) regulatory limits except BOD of Otamiri River. From the findings and conclusion, statistically there was a significant difference from the quality of the two sources of water sample and the borehole water quality was seen as more portable to the surface water quality.

Keywords- *Groundwater, Surfacewater, Borehole, Otamiri, Water Quality, Water Sample, Phsico-Chemical Parmeters*

I. INTRODUCTION

Water is one of the most vital natural resources necessary for the existence of life. According to Osunkiyesi (2012), water is an essential component of life, and also a useful resource for domestic, industrial and agricultural purposes. Though, it is abundant in nature occupying 70% of the earth's surface, approximately 3% is fresh water and less than 1% of the world's fresh water is accessible for human consumption (Suthra *et al.*, 2009). The World Health Organization (WHO, 2010) recommends that the minimum daily per capita water consumption to be 27 liters/person/day. However, many people manage with far less than 27 liters. This could be because approximately 70% of the renewable water resources are unavailable for human use or under developed or unevenly distributed (Minh *et al*., 2011). Water shortage and difficulties in accessing water affect domestic and productive livelihood of communities. The world is facing a water crisis and it is indispensable that there is enough of clean water available to meet today's populations' needs. Access to adequate supplies of good quality drinking water continues to be limited among many rural and peri-urban communities of Africa, despite several years of water improvement programmes (Mireille *et al.,* 2011).

The provision of public water supply has gone a record low. In most urban cities in most countries of the world, including Nigeria, it is the duty of the government to provide potable water (Afolabi *et al*, 2012). Most often, the responsibility is not adequately discharged, causing the inhabitants of the cities to look elsewhere for alternatives to meet their water needs. These alternatives include sourcing for groundwater via boreholes or wells, and also from streams and rivers.

Globally, groundwater is estimated to provide about 50% of current drinking water supplies. It provides a reasonably constant supply for domestic use, livestock and irrigation, which is not likely to dry up under natural conditions thereby buffering the effects of rainfall variability across seasons. Boreholes and wells locally distort the natural flow field and create a path that opens up an additional possibility of heat and mass transfer between rock formations/aquifers, surrounding and atmosphere (Akpoveta, 2011). Water is drawn from boreholes using electric pump and pumped into a storage tank. These tanks in some neighborhoods are left open and people draw water directly from the top of the tanks. The indication of some greenish filaments shows poor maintenance of these storage tanks.

Drought, desertification and other forms of water scarcity are already estimated to affect as many as one third of the world's population, affecting consumption and migration patterns in many parts of the world (Talafre and Knabe, 2009). This has increased reliance on groundwater resources thereby creating challenges among which are the provisions of adequate quantity and quality of water (WWDR, 2011).

Monitoring of environmental quality parameters of a water body is a key activity in managing the environment (water body), restoring the environment if polluted and anticipating the effects of man-made changes on wells (Oluyemi, 2013).

Although drinking water standard may vary from country to country the main objective remains the prevention of any harmful health impact on the consumers. Due to the scarcity of freshwater, tap water may be erroneously regarded by many rural people to be a panacea and concerns regarding its safety as less pressing or even irrelevant. A community should be empowered with alternatives means to treat drinking water in order to meet the challenges of providing safe water for every home. Although there are many water treatment methods known to date, there is a need to evaluate, redefine and simplify these procedures according to the realities of each community.

Therefore, water resources policy should integrate equity, gender, efficiency and environmental consciousness (Weiwei *et al.*, 2009) whereas identifying the factors that affect domestic water quality and consumption is very important in management of available water resources.

II. Materials and Method

The study area is Owerri municipal, an urban city in Imo state, south eastern zone of Nigeria. The study area is bounded in the North East and southeast by Owerri North L.G.A and on the West, North West and South West by Owerri West Local Government Area as shown in figure 1. It lies between latitudes 5^o24^1 and 5^o35^1N and longitudes 6^o56^1 and 7^o08^1E.

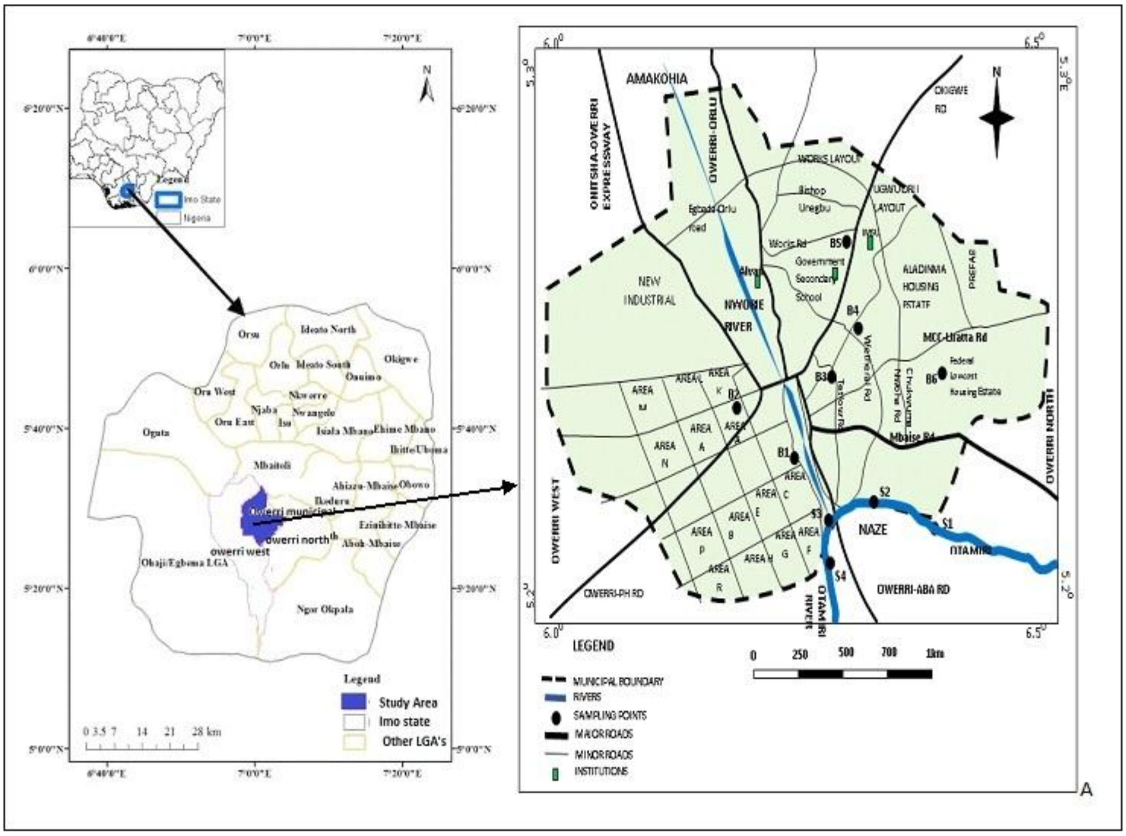


Figure 1. Map of the study area showing sampling points

Owerri Municipal has a total land mass of 24.88km^2 and with an estimated population of 231,789 (2006 census projected to 2014 with 3% growth rate, National Population Council, Owerri). The Otamiri River runs from Egbu where it has its major base or source through to Nekede, Ihiagwa, Eziobodo, Olokwu, Umuisi, Mgbirichi, Umuagwo and finally to Ozuzu in Etche town of Rivers state Nigeria where it finally joins the Imo River to the Atlantic Ocean. The Otamiri River has the Oramiriukwa stream as its major tributary and at Nekede the Otamiri confluences with the Nworie River.

A. Sample collection

This study is an experimental research design. Samples were collected from Otamiri and borehole water and analyzed in the laboratory. The borehole sample collection was evenly distributed across the study zone (B1, B2, B3, B4, B5, and B6).

The surface water Otamiri was sampled at four locations at S1 (upstream), S2 (middle-stream1), S3 (middle-stream2) and S4 (downstream). Data obtained in this analysis were used to achieve the aim and objectives of the study.

B. *Determination of Water Physicochemical Parameters*

Physicochemical parameters of the water samples were determined. The zinc content in the water samples were analyzed using Atomic Absorption Spectrophometer (VGP210 Buck Scientific). The pH and Electrical conductivity (EC) were analyzed using pH meter (model PHC-25), while Total dissolved solids (TDS), Dissolved Oxygen (DO), Total Alkalinity (TA), Chloride, Total Hardness (TH), Sulphate (SO_4) and Nitrate (NO_3) were analyzed according to standard procedures specified by American Public Health Association (APHA 1992).

Sampling took place early in the morning before the effect of the sun on the creek (between 6:30 am and 10 am). The time was carefully chosen to meet the required holding time of 8 hours from time of collection to laboratory specified by Environmental Protection Agency (EPA).

C. *Statistical Analysis*

The water physicochemical parameter data were subjected to statistical analysis using a statistical package for social science (SPSS) 23.0.

III. Results and Discussion

The result of the analysis shows levels of physico-chemical parameters of groundwater and surface water in Owerri Municipality area. The mean values of physico-chemical parameters of Groundwater (Borehole) and Surface water (Otamiri) in Owerri Municipality is as shown in Table 1.

The parameters for groundwater sample varied as follows; Temperature 27.5 to 29.00(28.01±0.099)^{o}C, pH 6.45 to 7.80(7.02±0.114), TDS 127.38 to 145.82(133.92±1.335)mg/l, Turbidity 0.02 to 0.05(0.03±0.02)NTU, Total Alkalinity 22.76 to 32.76(26.37±0.663)mg/l, Chloride 6.76 to 9.84(8.34±0.226)mg/l, NO_3 1.72 to 2.36(2.03±0.047)mg/l, Dissolved Oxygen 3.70 to 4.53(4.13±0.053)mg/l, Biological Oxygen Demand (BOD) 6.66 to 8.87(7.69±0.184)mg/l, Chemical Oxygen Demand (COD) 6.37 to 13.85(10.39±0.517)mg/l, Magnesium 3.47 to 5.84(4.52+0.195)mg/l, Calcium 5.81 to 7.89(6.62±0.154)mg/l, Fe^{2+} 0.05 to 0.09(0.07±0.002)mg/l, Zinc 0.09 to 0.28(0.15±0.012)mg/l and Copper 0.02 to 0.04(0.03±0.001)mg/l.

For the Surface water sample, Temperature, pH, TDS, Turbidity, Alkalinity, Total Hardness, Chloride, NO_3, DO, COD, BOD varied as follows 28 to 29.00(28.49±0.120)^{o}C, 6.64 to 8.57(7.53±0.190), 129.47 to 189.44(170.22±6.492)mg/l, 0.16 to 0.19(0.17±0.004)NTU, 31.62 to 48.56(42.11±1.651)mg/l, 0.01 to 1.01(0.44±0.102)mg/l, 10.78 to 16.78(13.99±0.562)mg/l, 2.45 to 4.45(3.35±0.217)mg/l, 4.09 to 4.76(4.38±0.068)mg/l, 15.24 to 23.42(20.89±0.760)mg/l, 8.72 to 11.92(10.55±0.280)mg/l respectively. Other parameters include Magnesium 5.48 to 7.90(6.64±0.236)mg/l, Calcium 7.62 to 10.24(9.22±0.214)mg/l, Fe^{2+} 0.13 to 0.25(0.19±0.011)mg/l, Manganese 0.039 to 0.08(0.05±0.004)mg/l, Zinc 0.29 to 0.40(0.34±0.011)mg/l and Copper 0.03 to 0.06(0.05±0.002)mg/l.

TABLE I. PHYSICO-CHEMICAL PARAMETERS OF BOREHOLE AND OTAMIRI WATER SAMPLE WITH THE NESREA AND WHO PERMISSIBLE LIMIT.

Parameters	Borehole	Otamiri	NESREA (2011)	WHO (2012)
Temperature (^{o}C)	28.011±0.09	28.49±0.12	-	-
pH	7.02±0.11	7.53±0.19	6.5-8.5	6.5-8.5
TDS (mg/l)	133.92±1.33	170.22±6.49	500	250
EC (µs/cm)	88.02±0.61	145.59±3.13	1000	1000
Turbidity (NTU)	0.03±0.00	0.17±0.00	-	1
Alkalinity (mg/l)	26.37±0.66	42.11±1.65	-	60
Total Hardness (mg/l)	0.01±0.00	0.44±0.10	-	250
Chloride (mg/l)	8.34±0.23	13.99±0.56	250	250
NO_3 (mg/l)	2.03±0.05	3.35±0.22	50	50
SO_4 (mg/l)	2.20±0.08	3.49±0.17	100	250
DO (mg/l)	4.13±0.05	4.38±0.07	5	10
BOD (mg/l)	7.69±0.18	10.55±0.28	-	10
COD (mg/l)	10.39±0.52	20.89±0.76	75	40
Magnesium (mg/l)	4.52±0.19	6.64±0.24	-	50
Calcium (mg/l)	6.62±0.15	9.22±0.21	-	50
Fe^{2+} (mg/l)	0.07±0.00	0.19±0.01	0.3	0.3
Manganese (mg/l)	0.01±0.00	0.05±0.00	0.2	0.1
Zinc (mg/l)	0.15±0.01	0.34±0.01	3	5
Cu^{2+} (mg/l)	0.03±0.00	0.05±0.00	1	2

Source: Field work 2016

A. *Principal Component Analysis (PCA)*

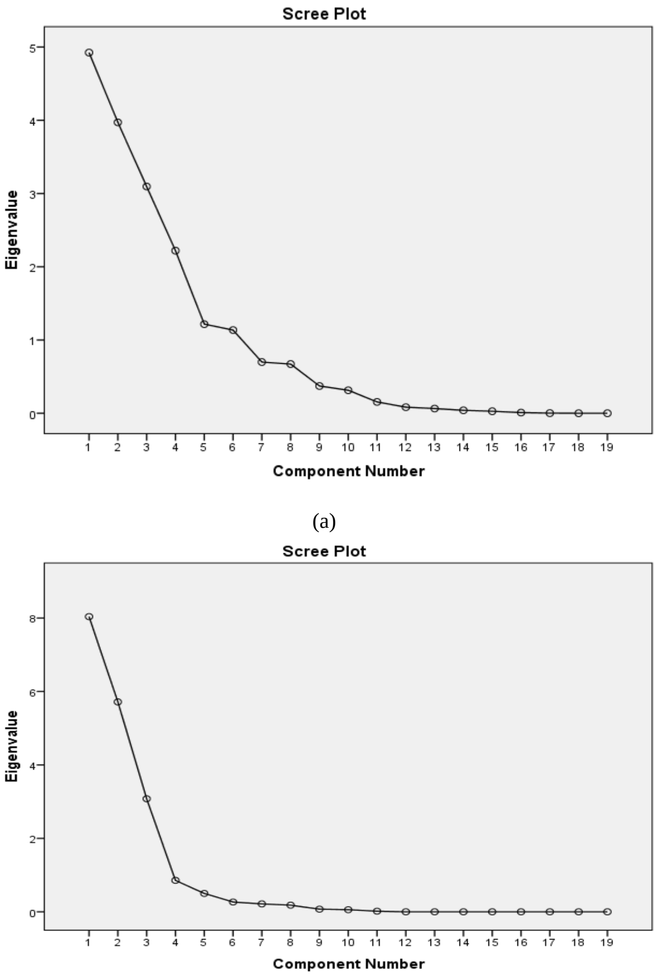
The Principal Component Analysis procedure revealed both Initial and Extraction Communalities that were all high indicating that the extracted components represented the variables appropriately.

The first six (6) Principal Components (PCs) formed the extraction solution with a cumulative percentage variability of about 87.178% in the original (19) variables for the groundwater sample. This reduces the complexity of the data set by using these components with only about 12.822% loss of information.

Principal component 1(PC1) accounted for about 25.915% variability, PC2 accounted for about 20.903% variability, PC3 had about 16.293% variability, PC4 accounted for about 11.686% variability, PC5 had 6.403% variability while PC6 had 5.978% variability.

The first three (3) components of the surface water sample formed the extraction solution with a cumulative percentage variability of about 88.600% in the original (19) variables

The Scree plot represents the Eigen value of each component in the initial solution as illustrated in Fig. 2a and 2b. The extracted components are on the steep slope which are the six (6) components and three (3) components while on shallow slope contributed little (12.822%) and (11.4%) to the solution for the Groundwater and Surface water respectively.



(a)

(b)

Figure 2. a) Scree plot of Eigen value by components of the water quality parameters for Groundwater. b) Scree plot of Eigen value by components of the water quality parameters for Surface water.

The One-way analysis of variance test for the groundwater quality revealed that the levels of NO_3, SO_4, DO, COD, Calcium, Fe^{2+}, Mn, Cu, Temperature, TDS, EC, Turbidity, Mg and Zinc were significantly different at $p<0.05$ across the sampling locations. The result for the surface water showed that all the parameters were significantly different at $p<0.05$ across the sampling locations.

The analysis was also subjected to a post hoc Duncan Multiple test to determine the observed differences in the parameters. Concentrations of pH, TA, TH and Chloride were not significantly different at $p<0.05$ across the Groundwater sampling locations as shown in table 2. For the Surface water, all the parameters were significantly different across the locations at $p<0.05$ as shown in table 3.

TABLE II. MEAN SEPARATION IN WATER QUALITY PARAMETERS OF GROUND WATER IN OWERRI MUNICIPAL USING THE DUNCAN MULTIPLE RANGE RANDOM TEST

Parameters	B1	B2	B3	B4	B5	B6
Temp.	27.5670^{a}	$28.2000b^{c}$	$28.2000b^{c}$	27.7330^{ab}	28.5670^{c}	27.8000^{ab}
pH	7.3461^{a}	6.7167^{a}	7.2267^{a}	7.3367^{a}	6.5867^{a}	6.8833^{a}
TDS	133.3900^{a}	130.7367^{a}	133.0367^{a}	142.9400^{b}	134.9333^{a}	128.5100^{a}
EC	86.6367^{a}	90.9367^{c}	84.0867^{a}	$89.5367b^{c}$	$88.2900b^{c}$	$88.6200b^{c}$
Turbidity	0.0303^{a}	0.0283^{ab}	0.0250^{a}	0.0457^{c}	0.0313^{ab}	0.0373^{bc}
Alkalinity	28.8433^{b}	23.8133^{a}	26.6233^{ab}	26.0933^{ab}	24.4800^{ab}	28.3800^{ab}
Total Hardness	0.0097^{a}	0.0143^{a}	0.0000^{a}	0.0123^{a}	0.0053^{a}	0.0000^{a}
Chloride	8.4000^{ab}	9.6900^{b}	8.2833^{ab}	7.4900^{a}	8.0733^{a}	8.1167^{a}
Nitrate	2.1500^{c}	2.1533^{c}	2.2833^{c}	1.7800^{a}	1.8467^{ab}	1.9733^{b}
Sulphate	$2.5267b^{c}$	1.8900^{a}	1.8400^{a}	1.9633^{a}	2.6633^{c}	2.3233^{b}
DO	4.2433^{b}	4.3033^{b}	3.8967^{a}	3.7900^{a}	4.2700^{b}	4.2567^{b}
BOD	7.2333^{ab}	8.1533^{bc}	7.5433^{abc}	7.6667^{abc}	8.6500^{c}	6.8933^{a}
COD	13.2333^{d}	$9.7933b^{c}$	10.5033^{c}	6.9333^{a}	9.3600^{b}	12.5367^{d}
Mg^{2+}	3.9800^{ab}	4.4700^{ab}	5.6733^{c}	3.5667^{a}	4.7633^{bc}	4.6457^{abc}
Ca^{2+}	6.6033^{b}	6.5500^{b}	7.1733^{c}	6.0000^{a}	5.8667^{a}	7.4967^{c}
Fe^{2+}	0.0770^{e}	0.0623^{b}	0.0547^{a}	0.0670^{c}	0.0703^{d}	0.0840^{f}
Mn	0.0037^{b}	0.0050^{b}	0.0133^{d}	0.0083^{c}	0.0073^{c}	0.000^{a}
Zn^{2+}	0.1467^{a}	0.2267^{b}	0.1400^{a}	0.1633^{ab}	0.1367^{a}	0.0907^{a}
Cu^{2+}	0.0270^{b}	0.0233^{a}	0.0250^{ab}	0.0343^{c}	0.0363^{c}	0.0257^{ab}

Values with same superscript along same row are not significantly different at $p<0.05$

TABLE III. MEAN SEPARATION IN WATER QUALITY PARAMETERS OF SURFACE WATER IN OWERRI MUNICIPAL USING THE DUNCAN MULTIPLE RANDOM TEST

Parameters	S1	S2	S3	S4
Temperature	28.5000^{ab}	28.9000^{b}	28.1000^{a}	28.4867^{ab}
pH	7.2667^{ab}	8.3733^{c}	7.7133^{b}	6.7800^{a}
TDS	133.5500^{a}	186.9667^{c}	177.3933^{b}	182.960^{c}
EC	135.0433^{a}	145.9367^{b}	161.8633^{c}	139.4967^{a}
Turbidity	0.1623^{a}	0.1893^{b}	0.1637^{a}	0.1627^{a}
Alkalinity	38.0833^{a}	46.8833^{c}	42.9967^{b}	45.4600^{c}
Total Hardness	0.2313^{a}	0.2367^{a}	0.3200^{a}	0.9600^{b}
Chloride	11.6767^{a}	12.9133^{a}	15.2833^{b}	16.0967^{b}
Nitrate	2.6100^{a}	4.3767^{c}	2.9033^{a}	3.5000^{b}
Sulphate	3.7133^{c}	2.6700^{a}	3.3833^{b}	4.1967^{d}
DO	4.2367^{a}	4.1133^{a}	4.5667^{b}	4.5833^{b}
BOD	9.1400^{a}	10.6400^{b}	10.7400^{c}	11.6667^{d}
COD	16.8800^{a}	22.3467^{b}	21.3133^{b}	23.0267^{b}
Mg^{2+}	5.7733^{a}	6.3500^{b}	6.5833^{b}	7.8533^{c}
Ca^{2+}	8.9767^{a}	8.9733^{a}	10.0800^{b}	8.8400^{a}
Fe^{2+}	0.1500^{a}	0.2067^{b}	0.1633^{a}	0.2367^{b}
Mn	0.0387^{a}	0.0603^{c}	0.0433^{b}	0.0753^{d}
Zn^{2+}	0.3067^{a}	0.3800^{b}	0.3667^{b}	0.3833^{a}
Cu^{2+}	0.0530^{c}	0.0540^{c}	0.0457^{b}	0.0360^{a}

Values with same superscript along same row are not significantly different at $p<0.05$

B. *Spatial Variations in Water Quality Parameters*

Spatial variations were observed in water quality parameters for the Groundwater in the six (6) sampling point in Owerri municipal.

Sample Location 1(B1), concentrations of Temperature, pH, NO_3 and SO_4 were 27.6±0.067°C, 7.35±0.367, 2.15±0.017mg/l and 2.53±0.12mg/l respectively (Fig 3a). TDS, EC, Total Alkalinity and Chloride varied as follows 133.39±2.53mg/l, 86.64±0.569µs/cm, 2.15±0.017mg/l and 2.53±0.123mg/l respectively (Fig. 3b). Dissolved Oxygen 4.24±0.034mg/l, BOD 7.23±0.065mg/l, COD 13.23±0.470mg/l and Zinc 0.14±0.009mg/l were all illustrated in Fig. 3d.

At Sample Locations 2(SLB2), Temperature, pH, NO_3 and SO_4 had 28.2±0.667°C, 6.72±0.06, 2.15±0.015mg/l and 1.89±0.036mg/l respectively (Fig.3a). TDS, EC, TA and Chloride were 130.74+2.088mg/l, 90.94±0.258µs/cm, 23.81±0.561mg/l and 9.69±0.075mg/l respectively as shown in Fig. 4.3b. Fe^{2+}, Manganese and Copper were 0.062±0.000mg/l, 0.005±0.000mg/l and 0.023±0.000mg/l respectively (Fig. 3e).

Sampling Location 3(SLB3) had TDS, EC, TA and Chloride of 133.04±1.369mg/l, 84.09±0.634µs/cm, 26.62±2.19mg/l and 8.28±0.183mg/l respectively as shown in Fig. 4.3b. Concentrations of DO, BOD, COD and Zinc were 3.89±0.027mg/l, 7.54±0.653mg/l, 10.50±0.108mg/l and 0.14±0.006mg/l respectively (Fig. 3d).

At Sampling Location 4(SLB4), Temperature, pH, NO_3 and SO_4 were 27.73±0.145°C, 7.33±0.268, 1.78±0.035mg/l and 1.96±0.048mg/l respectively (Fig. 3a). Concentrations of TH, Magnesium, Calcium and Turbidity were 0.012±0.006mg/l, 3.56±0.048mg/l, 6.0±0.129mg/l and 0.045±0.001NTU respectively as shown in Fig. 4.3c. DO 3.79±0.046mg/l, BOD 7.6±0.083mg/l, COD 6.93±0.282mg/l and Zinc 0.163±0.014mg/l (Fig. 3d).

Sampling Location 5(SLB5) recorded TDS, EC, TA and Chlorine at 134.93±3.56mg/l, 88.29±1.139µs/cm, 24.48±0.869mg/l and 8.07±0.768mg/l respectively (Fig. 3b). TH, Magnesium, Calcium and Turbidity were 0.0053±0.0053mg/l, 4.76±0.265mg/l, 5.87±0.031mg/l and 0.0313±0.0012NTU respectively (Fig. 3c). Fe^{2+}, Manganese and Copper were 0.073±0.001mg/l, 0.007±0.000mg/l and 0.036±000mg/l respectively (Fig. 3e).

At Sampling Location 6(SLB6), Temperature, pH, NO_3 and SO_4 had 27.8±0.153°C, 6.88±0.316, 1.97±0.091mg/l and 2.32±0.026mg/l respectively (Fig. 3a). TDS, EC, TA and Chloride were 128.51±0.644mg/l, 88.62±0.563µs/cm, 28.38±2.34mg/l and 8.11±0.272mg/l respectively (Fig. 3b). DO, BOD, COD and Zinc were 4.25+0.043mg/l, 6.89+0.142mg/l, 12.53±0.133mg/l and 0.907±001mg/l respectively (Fig. 3d).

The Spatial variation for the Surface water quality across the sample areas were seen as follows:

At Sampling Location 1 (SLS1), the concentrations of Temperature, pH, NO_3 and SO_4 were 28.5±0.288°C, 7.27±0.290, 2.61±0.089mg/l and 3.71±0.148mg/l respectively (Fig. 4a). TH, Magnesium, Calcium and Turbidity were 0.231±0.199mg/l, 5.77±0.235mg/l, 8.97±0.14mg/l and 0.16±0.001NTU respectively (Fig. 4c). Dissolved Oxygen, BOD, COD and Zinc were 4.23±0.04mg/l, 9.14±0.214mg/l, 16.88±0.953mg/l and 0.31±0.012mg/l respectively (Fig. 4d).

Sampling Location 2(SLS2) recorded Temperature, pH, NO_3 and SO_4 as 28.90±0.057°C, 8.37±0.107mg/l, 4.37±0.038mg/l and 2.67±0.086mg/l respectively (Fig. 4a). Parameters of TDS, EC, TA and Chloride were 186.96±1.382mg/l, 145.93±0.142µs/cm, 46.88±0.852 and 9.69±0.750mg/l respectively (Fig. 4b). Fe^{2+} concentration recorded 0.206±0.012mg/l, Manganese 0.06±0.001mg/l and Copper 0.054±0.001mg/l (Fig. 4.4e).

At Sampling Location 3(SLS3), Total Dissolved Solid, Electrical Conductivity, Total Alkalinity and Chloride had concentrations of 177.39±1.105mg/l, 161.86±0.644µs/cm, 42.99±0.343mg/l and 15.28±0.020mg/l respectively (Fig. 4b). TH, Magnesium, Calcium and Turbidity recorded 0.32±0.017mg/l, 6.58±0.100mg/l, 10.08±0.122mg/l and 0.16±0.000NTU respectively (Fig. 4e). Dissolved Oxygen, BOD, COD and Zinc concentrations were 4.56±0.122mg/l, 10.74±0.059mg/l, 21.31±0.456mg/l and 0.04±0.000mg/l respectively (Fig. 4d).

Concentration at Sampling Location 4(SLS4) were Temperature, pH, NO_3 and SO_4 as 28.46±0.260°C, 6.78±0.075, 3.5±0.332mg/l and 4.19±0.027mg/l respectively (Fig. 4a). Total Hardness, Magnesium, Calcium and Turbidity recorded 0.16±0.001mg/l, 7.85±0.024mg/l, 8.84±0.053mg/l and 0.16±0.001NTU respectively (Fig. 4c). Manganese, Copper and Fe^{2+} concentrations were 0.075±0.000mg/l, 0.04±0.00mg/l and 0.23±0.006mg/l respectively (Fig. 4e).

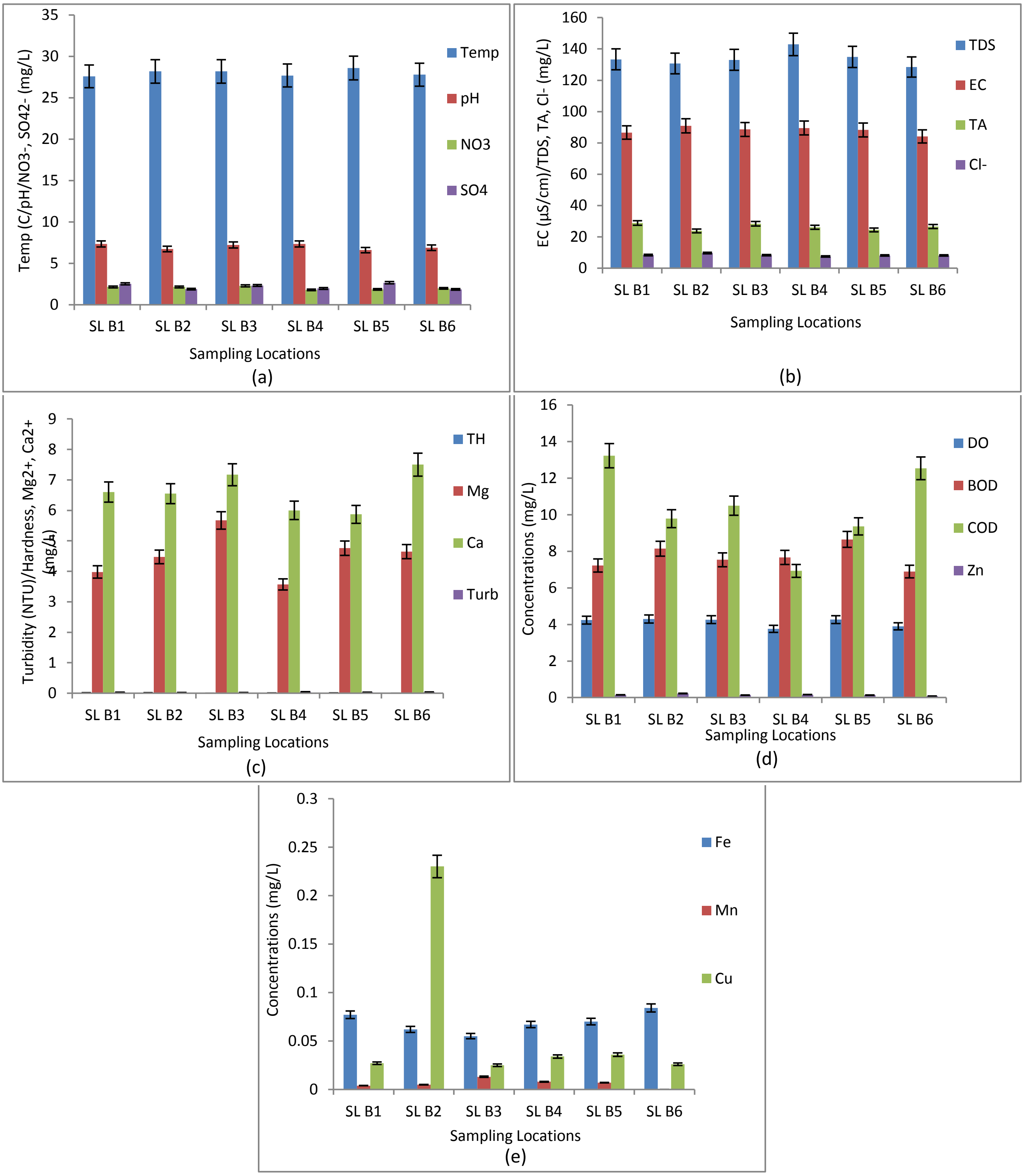


Figure 3. a) Spatial Variations in Mean Water Temperature, pH, Nitrate and Sulphate ion concentrations in groundwater of Owerri Municipal. b) Spatial variations in mean total dissolved solids, electrical conductivity, total alkalinity and chloride ion concentrations in groundwater of Owerri Municipal. c) Spatial variations in mean total hardness, turbidity, magnesium and calcium ion concentrations in groundwater of Owerri Municipal. d) Spatial variations in mean dissolved oxygen, biological and chemical oxygen demands, and zinc ion concentrations in groundwater of Owerri Municipal. e) Spatial variations in mean Fe, Mn and Cu ion concentrations in groundwater of Owerri Municipal

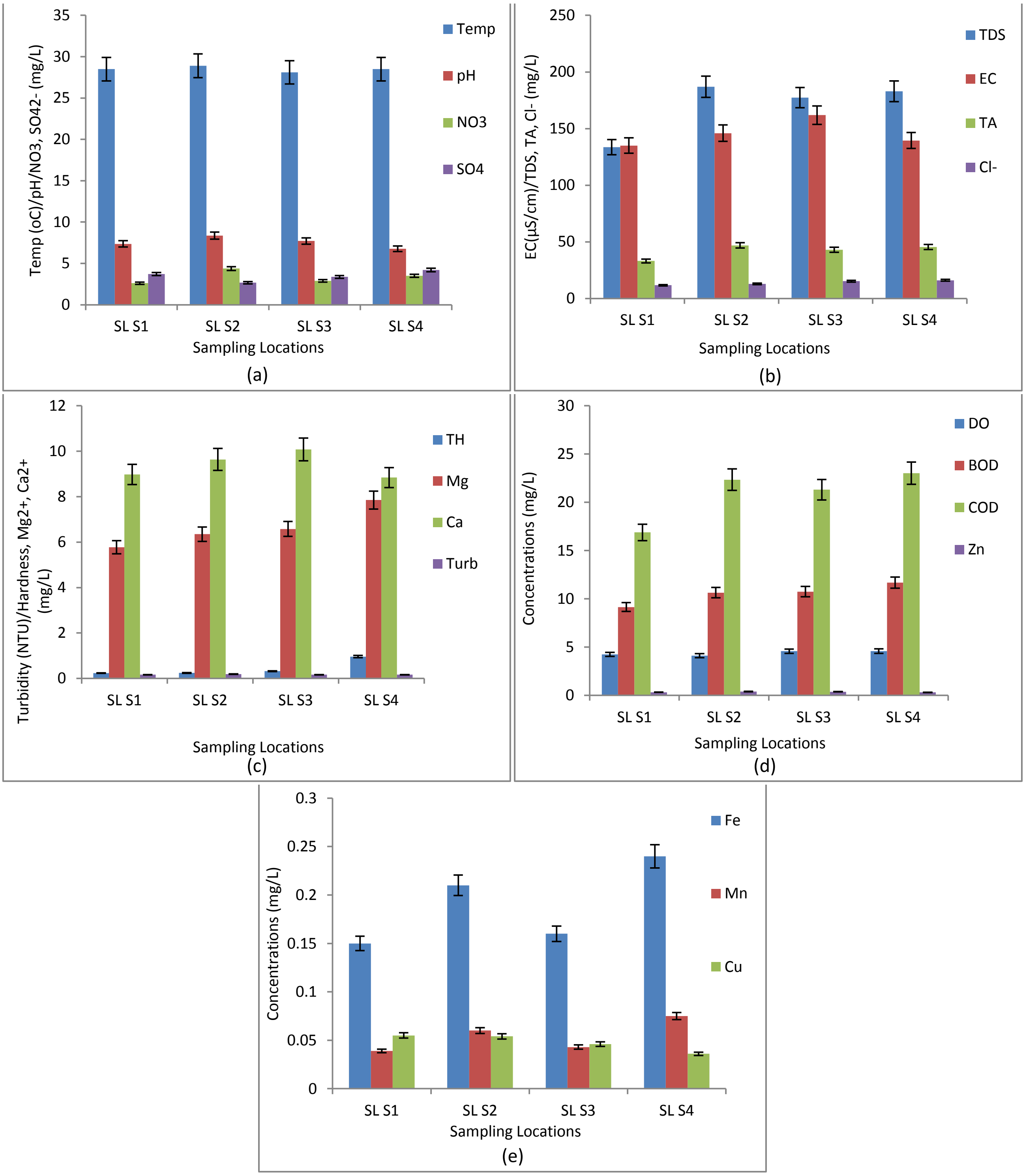


Figure 4. a) Spatial variations in mean water temperature, pH, nitrate and sulphate ion concentrations of Otamiri River in Owerri Municipal. b) Spatial variations in mean total dissolved solids, electrical conductivity, total alkalinity and chloride ion concentrations of Otamiri River in Owerri Municipal. c) Spatial variations in mean total hardness, turbidity, Mg and Ca ion concentrations of Otamiri River in Owerri Municipal. d) Spatial variations in mean dissolved oxygen, biological and chemical oxygen demands, and Zn ion concentrations of Otamiri River in Owerri Municipal. e) Spatial variations in mean Fe, Mn and Cu ion concentrations of Otamiri River in Owerri Municipal

C. Hypothesis testing

The student t-test was used to test the formulated hypothesis employing a software based approach.

Decision rule: The table shows that the output of the result of the student's t-test of significance in pooled values of the physico-chemical parameters measured in Groundwater and Surface water revealed that t=-2.115, df=18 and a significant difference value (sig. value=0.049) at $p<0.05$. This indicates that there is a significant difference in the quality of the borehole water to the surface water in Owerri municipal.

TABLE IV. PAIRED SAMPLE T-TEST IN POOLED WATER QUALITY PARAMETERS OF GROUNDWATER AND SURFACE WATER

Paired Samples Test								
	Paired Differences					t	df	Sig.(2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
G.W S.W	-7.26945	14.9823	3.43718	-14.4907	-.04820	-2.115	18	.049

D. Discussion

This sub-title covers discussions on the physic-chemical analysis results of the borehole water and surface (Otamiri) water samples.

From the results collected across the ten (10) locations, the physical parameter Turbidity results obtained were in the range of 0.025 to 0.046 NTU for borehole and 0.162 to 0.189 NTU for the surface water samples. Both sampled sources were below the stipulated limit of WHO (2012) standard of 1.00mg/l.

The values of Electrical Conductivity obtained from the borehole water samples ranged from 82.82 to 92.58 µs/cm while that of the surface water ranged from 129.53 to 162.75 µs/cm. Values of electrical conductivity were obtained from a public borehole ranging from 89.18 to 103.00µs/cm in Uruan by (Ukpong and Okon, 2013). These values were below the recommended WHO standard of 1000 µs/cm and were better health wise.

The pH range of water samples from the borehole was 6.5 to 7.80 whereas that of the Otamiri River was 6.64 to 8.57. The borehole sample fell within the WHO limit of 6.5-8.5 while the surface water exceeded a little. This could be as a result of production of more alkaline ions during dredging and excavation.

The range of Dissolved Oxygen (DO) value obtained for borehole water sample was 3.70 to 4.53mg/l, while that of the Otamiri River was 4.09 to 4.76mg/l. Values of 0.01 to 2.00mg/l were obtained in a similar study of borehole water samples from Eastern Obolo Local Government Area of Akwa Ibom State (Itah and Akpan, 2005). This result showed that the DO for the surface water is higher than the borehole water. This shows low presence of microbial action which depletes the oxygen in the river as microbial load in a river reduces as a result of depth, sunlight penetration due to exposure and flow rate. For the borehole the low in DO can be as a result of the depth factor where oxygen reduces with depth. In the underground reservoir, there is little oxygen.

The Total Dissolved Solid for the borehole ranges from 127.38 to 145.82mg/l while that of Otamiri ranges from 129.47 to 189.44mg/l. These were all below the WHO standard of 250mg/l. Similar results were obtained in a study of boreholes by Agbaire and Oyibo, 2009 who showed that TDS concentrations varied from Ugep area (44.47mg/L) and Anantigha area (157.59 mg/L) in Akwa-Ibom state. The higher value in Otamiri is as a result of silt production during dredging and sand excavation from the river. According to Edet and Woden 2009, the high concentrations in TDS and EC can also be attributed to seawater influence, changing seasons and tidal periods.

The Biochemical Oxygen Demand $(BOD)_5$ range of 6.66 to 8.87mg/l was recorded for borehole water samples, while 8.72 to 11.92 mg/l was recorded for the Otamiri river. The BOD for Otamiri slightly exceeded the WHO standard of 10mg/l downstream. This maybe as a result of decaying organic processes in the river which leads to bubble of gases at the river surface and sometimes offers offensive smell as described by Obinna et al, 2014 who also recalled that BOD increase as pollution increases.

COD levels of water samples in this study area are lower than WHO standard suggesting low organic content in the study area.

The average alkalinity values of 42.11mg/l and 26.37mg/l were recorded for the Otamiri and borehole water samples in the study area respectively. These values were below the highest desirable level of 60mg/l recommended by the WHO and were acceptable.

The concentration of Chloride in the borehole water samples ranged from 6.76mg/l to 9.84mg/l while that of the Otamiri ranged from 10.78mg/l to 16.78mg/l. Mishra and Bhatt, 2008 obtained higher values of 17.50 to 22.20mg/l in their studies of borehole water from Anand District of India and were still within the WHO recommended standards of 250mg/l.

Values of Nitrate were below the WHO limit as it recorded an average of 3.35mg/l for Otamiri and 2.03mg/l for borehole water sample but according to USGS 2012, nitrate concentrations of greater than 3mg/l indicate a fairly direct connection of water with source of pollution. Nitrate intrusion is as a result of erosion flow from the river deltas and surface runoff which washes farmland materials into the water.

The concentration of other inorganic cation like Calcium and Magnesium were within the recommended level. The increase in the calcium content in Otamiri (9.22mg/l) more than the borehole (6.62mg/l) is as a result of dredging work which increases the release of Calcium Carbonate (limestone).

For the trace metals, the value of Copper in the borehole water samples ranged from 0.023 to 0.036mg/l while that of the surface water ranged from 0.036 to 0.055mg/l. Both were in accordance with the maximum acceptable limit of 2.00mg/l. The average levels of Zinc in the surface and borehole water samples were 0.34 and 0.15mg/l respectively. These values were within the WHO standard of 3mg/l. The average concentration of Fe^{2+} in the borehole water samples was 0.07mg/l while those of the surface water was 0.19mg/l and were within the acceptable limits. This is an indication of no metal pollution in the river as well. The concentration of Manganese was averaged at 0.01mg/l for borehole and 0.05mg/l for surface water sample and was below the WHO standard of 0.1mg/l.

IV. CONCLUSION

This study tried to assess and compare results obtained from laboratory analysis of water samples from Otamiri (Surface) and boreholes (Groundwater) in Owerri Municipality. Results obtained show that the physicochemical parameters of the selected boreholes and Otamiri river water samples in the study area were within the acceptable limits of WHO (2012) and NESREA (2012) for drinking water except the BOD value which was comparatively high in the river water samples. Although some of the chemical parameters fell below the approved standards, they were judged to be acceptable since they were not above the required maximum permissible limits which could have been more dangerous to health of the consumers.

Generally, from the two major sources of water analyzed, it was discovered that though groundwater is of better quality and more potable than surface water, it is not entirely free from pollutants.

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