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Original Research Article

Comparative Assessment of Physicochemical and Biological Indicies of Otamiri and Nworie River Using a Piper Diagram Model

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Abstract

The Surface Water Resources of Otamiri-Nworie Watershed within the Owerri Metropolis were studied with the prime aim of developing a Non-Point Source Event-Based Model to Contamination of the water bodies. Clean, safe, and sufficient water is essential for both human existence and the health of ecosystems, communities, and economies (Fubara and Kpormon, 2023). As human populations increase, industrial and agricultural production increases, and climate change pose a threat of significant disruption of the hydrologic cycle, and as such, declining water quality has emerged as a major global problem (Ogbonna and Orinya, 2023). Human-drinking water must be free of organisms and chemical substances, as high amounts might be harmful to one's health (Adeyi *et al.*, 2021). This study aimed at comparatively assessing the physicochemical and biological indices of Otamiri and Nworie Rivers, and the Piper diagram model was employed for the analysis. Fifteen water samples were collected along the course of the two rivers and analyzed for physical, chemical and microbial parameters. Physical, chemical, and biological parameters were analyzed. The analytical results of the samples were compared with notable standards like the World Health Organization [WHO], etc. It was observed that all the parameters analyzed for the rivers fall below the acceptable standards except for pH (6.5-8.5) indicating the acidic nature of these water bodies. Similarly, the colour value of the two rivers ranges between 21.5 to 229 PCU and observed to be decreasing downstream within Nworie and Otamiri rivers. Within the river Nworie axis, both the total dissolved solids (TDS) and the total suspended solids (TSS) were observed to be increasing downstream. Along Otamiri river before confluence, total dissolved solids increased downstream whereas the reverse was the case for the total suspended solids, just after the confluence. There is a noticeable increase in dissolved oxygen (DO) downstream within the Nworie axis. The biological oxygen demand (BOD) values for the rivers were below the WHO standard. Finally, the major sources of contamination within the study area revealed that they are mainly from agricultural practices, dumpsites, and human defecation. The quality can be improved by applying appropriate treatment to the water before its use for various purposes.

Keywords: Event-Based, Non-Point Source, Nworie River, Otamiri River, Pollution, Watershed.

INTRODUCTION

Water is a life resource which is indispensable for life processes (Ekwonu, 2017). Water is life without pollution, but death once polluted (Igwe *et al.*, 2017). It is essential for the wellbeing of mankind and for sustainable development. 97% of the total volume of water available is in the Oceans, 2% stored in the form of ice-sleets and less than 1% is available as fresh water. Its many uses include drinking, domestic uses, industrial cooling, power generation, agriculture (irrigation), transportation and waste disposal (Ekwonu *et al.*, 2019). The importance of water to human survival and development cannot be overstated. The challenge of water pollution has posed a threat to the global world resulting from the increased socio-economic activities of human beings. Water sources have consistently been subjected to the addition of municipal wastes and industrial sewages, which degrades the physicochemical quality of the water and renders it unsafe for consumption by humans, cattle, and other species (Dwivedi and Pandey, 2002).

Increasing activities within and along the Otamiri and Nworie watersheds have made sources of contaminants' introduction into the surface water bodies which hitherto were classified as point sources to recently degenerate to non-point sources with their

attendant complex mechanisms and techniques that are random and sporadic in occurrence with resultant difficulties in monitoring, simulation, treatment as well as control. The exposure of the river banks through diverse activities within the area has necessitated runoff from rainfall to easily carry along with them contaminants from different sources known as NPS pollutants. These pollutants range from natural to man-made pollutants which are usually deposited into water bodies by runoff water. Pollution from both point and non-point sources has had a negative impact on surface water. For irrigation, drinking, and domestic use, these natural water sources are exploited. Most ambient waters have standards that outline minimum acceptable levels of purity.

Study Area

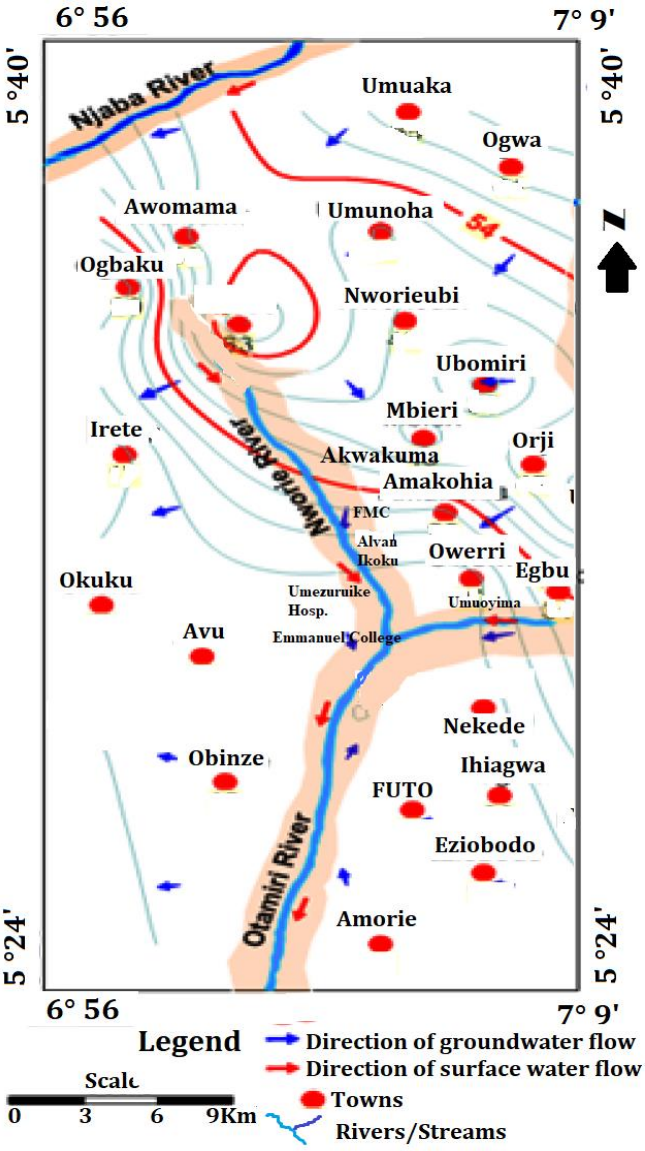


Figure 1.1: Location Map of the Study Area

MATERIALS AND METHODS

Field Mapping

This stage involved moving the research crew to the field to map out the entire axis of the Otamiri and Nworie watersheds and take routing measurements as well as proper documentation of the flow patterns and directions, activities going on at different locations along the full length of the watersheds as well as the land use pattern within the entire watershed. The different land use/land cover patterns around the Otamiri and Nworie watersheds were established.

It is believed that different activities constitute different events operating within and around the river course which in no doubt contributed to the anthropogenic activities going on in the rivers, posing threats to the entire chemistry of the water bodies.

The three-point method of slope determination were adopted during the field mapping stage to estimate the slope of the watershed along the flow path of both Otamiri and Nworie rivers for only the exposed portions of the river bank. Two-point elevation collection were utilized at locations with thick vegetation that had hitherto been classified as fallow lands.

Sample Collection

Immediately after the mapping exercise was completed, sampling materials were mobilized to the field for insitu measurements and collection of water samples. At every sampling point, the following measurements were carried out; depth of the river, coordinates (latitude and Longitude) of the location, elevation of the sampling points above the mean sea level, elevation of peak area within the vicinity of the sampling point for slope analysis; insitu measurement of potential Hydrogen (pH), Temperature, Conductivity, Dissolved Oxygen (DO) and Total Dissolved Solids (TDS) using the right equipment.

The sampling procedure adopted for this study were the surface grab method cum semi-immersion method. The water samples were obtained in 2.5 liters white plastic bottles with tight rubber stoppers and corks. Each sample collected was carefully and routinely corked under the water to avoid atmospheric contact. The white plastic containers were used to collect water samples for the determination of the physical, chemical and microbial parameters in the laboratory. A second bottle was used to collect water samples meant for laboratory determination of Dissolved Oxygen (DO) and consequently Biochemical Oxygen Demand (BOD). The samples collected were safely transported to the laboratory for further studies.

Laboratory Method/ Analysis

The presence of the physio-chemical parameters such as PH, Conductivity, Color, Turbidity, DO, BOD, COD, Appearance, Total solids, Total dissolved solids, Total suspended solids, Total hardness, Calcium hardness, Magnesium hardness, Total Alkalinity, Total chloride, Nitrate, Nitrite, Ammonia, Phosphate, Sulphate, Bicarbonate, Metallic ions (Iron (Fe^2), Sodium (N_a^+), Lead (Pb^{2+}), Chromium (Cr^{2+}), Manganese (Mn^+), Copper (Cu^{2+}), Zinc (Zn^{2+}), Calcium (Ca^{2+}), Potassium (K^+), Magnesium (Mg^{2+})), Heavy Metals, and biological parameters (Total Bacteria Count, Total Coliform) in the water samples that were collected were investigated using standard laboratory procedures.

Water Quality Standards

Water resource (both surface and groundwater) monitoring becomes meaningful only when the results obtained after adequate analysis for water quality are compared with some notable and useful reference points. The results generated were compared against notable standards to draw inference, after which, relevant statistical analysis was carried out on the results.

RESULTS AND DISCUSSION

The analytical results alongside the methods used are presented in Table 1. The comparison of these results with some notable standards like the World Health Organization (WHO), Federal Environmental Protection Agency (FEPA), Canadian Drinking Water Quality Guideline (CDWQG), European Union (EU), Saskatcheivan Drinking Water Objective (SK), Secondary Maximum Contaminant Level (SMCL) is presented in Table 2.

The results of the analyzed water samples when compared with the World Health Organization (WHO) Standard for safe drinking water indicated that the pH of both Nworie and Otamiri rivers fall below the recommended thresholds of 6.5-8.5 indicating the acidic nature of these water bodies. The consumption of acidic water is not recommended as it could lead to a dangerous condition of acidosis giving rise to arrhythmia often shown in the form of unbalanced heartbeats as well as inequality in the body's electrolyte level which could lead to coma. Low pH in water bodies can cause corrosion and rusting of wares and pipes. Average pH decreases downstream along the Nworie river course and increases downstream along the Otamiri river course as well as pronounced increase further downstream after the confluence between Nworie and Otamiri rivers.

Similarly, the colour value of the two rivers ranges between 21.5 to 229 PCU and observed to be decreasing downstream within Nworie and Otamiri rivers. Though further down after the confluence, the color value increased downstream which could be attributed to the dissolution of sediments and transportation of same as both suspension particles and bed loads along the river course.

Within the river Nworie axis, both the total dissolved solids (TDS) and the total suspended solids (TSS) were observed to be increasing downstream. This simply shows that the short flowing Otamiri river is often laddened with materials as it scouts along its bank being constantly in contact with objects usually dumped with its banks. Along Otamiri river before confluence, Total dissolved solids increased downstream whereas the reverse was the case for the total suspended solids, just after the confluence, TDS was generally decreasing whereas TSS was observed to be increasing downstream. This could be interpreted to mean that the volume of water moving downstream after the confluence between Nworie and Otamiri rivers was large enough to carry majority of its load as suspension deposit as most of these loads were not soluble and could not easily dissolve in the water as to increase the number of dissolved solids in the water body. Excess TDS in water introduces tastes to the water whereas excess TSS causes the water to be turbid in nature. The values of TDS and TSS obtained for the two rivers were below WHO recommended limit of 1000mg/l (Table 2).

There is a noticeable increase in dissolved oxygen (DO) downstream within the Nworie axis. This implies that there is high tendency of improved healthy biotic life including fishes and invertebrates downstream of Nworie river.

The biological oxygen demand (BOD) values for the rivers were below the WHO standard. The implications of low dissolved oxygen (DO) in water is similar to that of high BOD as aquatic organisms are stressed beyond their existential conditions occasioned by suffocation which could lead to death of aquatic organism.

Table 1: Results of the Analysis carried out on the Water Samples

PARAMETERS	FMEnv Standard	N: 5.5231^0 E: 7. 0131^0 ELEVATION: 62m(203ft) TIME: 8:47 AM Depth: 1.5ft NW 01		N: 5.4967^0 E: 7.0218^0 ELEVATION: 57m TIME: 9.22AM Depth: 2.6ft NW 02		N: 5.4878^0 E: 7.0249^0 ELEVATION: 58m TIME: 10:04AM Depth: 1.45ft NW 03		N: 5.4739^0 E: 7.0301^0 ELEVATION:63m TIME: 10:20AM Depth: 1.9ft NW 04		METHOD
		Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	
Temperature, ^{0} C	30.00	28.20	27.50	28.30	27.60	28.80	28.10	28.70	28.10	Electrode thermometer
pH	6.50-8.50	5.80	5.80	5.20	5.20	5.00	5.00	4.90	4.90	Potentiometric
Colour, PCU	5.00	230.0	228.00	67.00	66.00	83.00	85.00	33.00	35.00	Photometric
Total Dissolved Solid, mg/l	500.00	44.20	44.20	59.15	59.15	61.10	61.10	71.50	71.50	Gravimetric
Total Suspended Solid, mg/l	<10.00	19.80	23.80	30.85	34.85	8.90	10.90	20.50	30.50	EDTA Titrimetric
Dissolved oxygen, mg/Lo_2	>7.50	7.60	7.60	7.40	7.40	10.10	10.10	10.90	10.90	Electro-membrane
Biological Oxygen Demand, mg/l BOD5	NS	3.10	3.20	4.00	3.90	3.80	3.70	4.10	4.20	Incubation & Electro-membrane
Chemical Oxygen Demand, mg/l O_2	NS	288.00	288.00	80.00	96.00	112.00	112.00	128.00	112.00	Titrimetric
Conductivity, µS/cm	1000.00	68.00	68.00	91.00	91.00	94.00	94.00	110.00	110.00	Potentiometric
Turbidity, NTU	5.00	55.80	55.10	59.60	59.30	14.80	14.90	14.00	13.90	Nephelometric
Total Solid, mg/l	500.00-1000.00	64.00	68.00	90.00	94.00	70..00	70.00	92.00	102.00	Gravimetric
Calcium hardness, mg/l $CaCO_3$	150.00	46.62	49.21	51.80	51.80	67.34	64.75	56.98	59.57	EDTA Titrimetric
Total Hardness, mg/l Ca&$MgCO_3$	150.00	85.47	85.74	98.42	95.83	119.14	119.14	88.06	93.24	EDTA Titrimetric
Magnesium Hardness, mg/l $MgCO_3$	150.00	38.85	36.26	46.62	44.03	51.39	54.39	31.08	33.67	EDTA Titrimetric
Total chloride, mg/l Cl^-	250.00	14.00	14.00	18.00	18.00	15.00	16.00	19.00	19.00	Argentometric
Nitrate, mg/l $N0^-_3$	50.00	12.17	12.20	11.89	11.91	10.29	10.30	13.13	13.13	UV Spectrophotometer
Nitrite, mg/l $N0^-_2$	0.50	1.41	1.43	1.51	1.50	1.06	1.09	1.15	1.18	Diazotization

Phosphate, mg/l PO^{-3}_4	5.00	0.48	0.50	1.16	1.17	0.56	0.57	0.90	0.90	Ascorbic acid
Phenolphthalein Alkalinity, mg/l$CaCO_3$	NS	ND	ND	ND	ND	ND	ND	ND	ND	Titrimetric
Total Alkalinity, mg/l $CaCO_3$	200.00	12.00	12.00	20.00	19.00	17.00	18.00	21.00	20.00	Titrimetric
Bicarbonate, mg/l HCO_3	NS	11.99	11.99	19.99	18.99	16.99	17.99	20.99	19.99	Gravimetric
Carbonate, mg/l CO_3	NS	ND	ND	ND	ND	ND	ND	ND	ND	Gravimetric
Sulphate, mg/l SO^{-2}_4	100.00	18.10	18.10	21.75	22.22	14.76	14.92	12.22	12.54	Turbidimetric
Calcium, mg/l Ca	200.00	15.14	15.98	16.82	16.82	21.87	21.03	18.50	19.34	EDTA Titrimetric
Magnesium, mg/l Mg	30.00	9.45	8.82	11.34	10.71	12.50	13.23	7.56	8.19	EDTA Titrimetric
Aluminium, mg/l Al	0.20	43.64	44.55	11.82	11.82	26.36	26.36	2.73	1.82	AAS
Ammonia, mg/l NH_3	0.30	0.52	0.52	0.75	0.75	0.82	0.82	0.83	0.83	Phenate Spectrophotometric
Iron, mg/l Fe	0.30	1.27	1.31	1.63	1.67	1.12	1.13	1.25	1.27	UV Spectrometric
Sodium, mg/l Na	200.00	3.28	3.24	3.15	3.10	3.39	3.39	3.87	3.84	AAS
Manganese, mg/l Mn	0.05	0.15	0.16	0.18	0.19	0.08	0.08	0.05	0.06	AAS
Potassium, mg/l K	10.00	13.67	13.33	12.83	13.00	15.67	16.17	12.67	12.67	Tetraphenylborate
Total Bacteria count, cfu/ml	0-30	$7.0x10^6$	$6.0x10^6$	$2.7x10^7$	$2.8x10^7$	$1.1x10^7$	$1.1x10^7$	$1.5x10^7$	$1.3x10^7$	Spread plate method
Total Coliform count, cfu/ml	0-10	$9.0x10^6$	$9.0x10^6$	$1.4x10^7$	$1.4x10^7$	$4.0x10^6$	$3.0x10^6$	$3.9x10^7$	$3.9x10^7$	Spread plate method
E. coli Count, cfu/ml	0	NG		NG		NG		$1.3x10^7$	$1.3x10^6$	Spread plate method
Total *Klebsiella* count, cfu/ml	0	$3.0x10^6$	$1.0x10^6$	$1.0x10^7$	$1.2x10^7$	$2.0x10^6$	$4.0x10^6$	$8.0x10^7$	$9.0x10^6$	Spread plate method
Total *Shigella*, cfu/ml	0	NG		NG		NG		NG		Spread plate method
Total *Salmonella*, cfu/ml	0	NG		NG		NG		NG		Spread plate method

PARAMETERS	**FMEnv Standard**	**N: 5.4685^0 E: 7.4685^0 ELEVATION:64m (209ft) TIME: 11:43 AM Depth: 1.9ft OT 01**		**N: 5.4702^0 E: 7.0393^0 ELEVATION: 61m (200Ft) TIME: 12.34PM Depth: 2.4ft OT 02**		**N: 5.4653^0 E: 7.0347^0 ELEVATION: 72m (236Ft) TIME: 1 :19PM Depth: 2.4ft CP 01**		**N: 5.4437^0 E: 7.0230^0 ELEVATION: 45m (147Ft) TIME: 1:27PM Depth: 7ft ON 01**		**METHOD**
		Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	
Temperature, ^{0}C	30.00	28.70	27.90	28.70	28.10	29.70	29.80	29.30	28.90	Electrode thermometer
pH	6.50-8.50	4.40	4.50	4.70	4.70	4.90	4.90	5.30	5.50	Potentiometric
Colour, PCU	5.00	54.00	53.00	45.00	47.00	28.00	31.00	22.00	21.00	Photometric
Total Dissolved Solid, mg/l	500.00	26.65	26.65	33.80	33.80	52.00	52.00	41.60	41.60	Gravimetric

Total Suspended Solid, mg/l	<10.00	43.35	49.35	18.20	24.20	56.00	60.00	42.40	46.40	EDTA Titrimetric
Dissolved oxygen, mg/Lo_2	>7.50	8.90	8.90	6.30	6.30	11.50	11.50	8.60	8.70	Electro-membrane
Biological Oxygen Demand, mg/l BOD5	NS	4.70	4.60	2.80	3.00	3.70	3.60	5.70	5.70	Incubation & Electro-membrane
Chemical Oxygen Demand, mg/l O_2	NS	160.00	160.00	144.00	160.00	480.00	496.00	368.00	352.00	Titrimetric
Conductivity, µS/cm	1000.00	41.00	41.00	52.00	52.00	80.00	80.00	64.00	64.00	Potentiometric
Turbidity, NTU	5.00	75.80	75.10	30.90	30.60	23.50	23.30	14.60	14.80	Nephelometric
Total Solid, mg/l	500.00 - 1000.00	70.00	76.00	52.00	58.00	108.00	112.00	84.00	88.00	Gravimetric
Calcium hardness, mg/l $CaCO_3$	150.00	25.90	23.31	23.31	23.31	28.49	25.90	31.08	28.49	EDTA Titrimetric
Total Hardness, mg/l Ca&$MgCO_3$	150.00	44.03	46.62	41.44	38.85	62.16	56.98	46.62	49.21	EDTA Titrimetric
Magnesium Hardness, mg/l $MgCO_3$	150.00	18.13	23.31	18.13	15.54	33.67	31.08	15.54	20.72	EDTA Titrimetric
Total chloride, mg/l Cl^-	250.00	14.00	14.00	14.00	15.00	19.00	18.00	13.00	14.00	Argentometric
Nitrate, mg/l $N0^-_3$	50.00	38.52	38.56	12.47	12.44	14.61	14.61	9.61	9.58	UV Spectrophotometer
Nitrite, mg/l $N0^-_2$	0.50	1.58	1.56	1.32	1.34	1.10	1.09	1.30	1.32	Diazotization
Phosphate, mg/l $PO\text{-}^3_4$	5.00	0.71	0.72	0.50	0.50	0.59	0.57	0.45	0.45	Ascorbic acid
Phenolpthalein Alkalinity, mg/l$CaCO_3$	NS	ND	ND	ND	ND	ND	ND	ND	ND	Titrimetric
Total Alkalinity, mg/l $CaCO_3$	200.00	18.00	17.00	12.00	12.00	17.00	16.00	10.00	11.00	Titrimetric
Bicarbonate, mg/l HCO_3	NS	17.99	16.99	11.99	11.99	16.99	15.99	9.99	10.99	Gravimetric
Carbonate, mg/l CO_3	NS	ND	ND	ND	ND	ND	ND	ND	ND	Gravimetric
Sulphate, mg/l SO^{-2}_4	100.00	64.28	64.13	13.17	13.02	12.22	12.22	10.48	10.63	Turbidimetric
Calcium, mg/l Ca	200.00	8.41	7.57	7.57	7.57	9.25	8.41	10.09	9.25	EDTA Titrimetric
Magnesium, mg/l Mg	30.00	4.41	5.67	4.41	3.78	8.19	7.56	3.78	5.04	EDTA Titrimetric
Aluminium, mg/l Al	0.20	2.73	3.64	58.18	60.00	61.82	60.91	7.27	9.09	AAS
Ammonia, mg/l NH_3	0.30	0.41	0.41	0.66	0.66	2.03	2.03	0.89	0.89	Phenate Spectrophotometric
Iron, mg/l Fe	0.30	2.44	2.46	1.46	1.59	1.60	1.62	1.38	1.40	UV Spectrometric
Total Bacteria count, cfu/ml	0-30	$7.0x10^6$	$7.0x10^6$	$2.8x10^7$	$2.6x10^7$	$1.1x10^7$	$9.0x10^6$	$4.0x10^7$	$3.8x10^7$	Spread plate method
Total Coliform count, cfu/ml	0-10	$4.0x10^6$	$5.0x10^6$	$1.3x10^7$	$1.3x10^7$	$1.1x10^7$	$4.3x10^7$	$1.8x10^7$	$1.8x10^7$	Spread plate method
E. *coli* Count, cfu/ml	0	NG		NG		$1.5x10^7$	$1.3x10^7$	$4.3x10^7$	$4.5x10^7$	Spread plate method
Total *Klebsiella* count, cfu/ml	0	$3.0x10^6$	$3.0x10^6$	$1.0x10^6$	$1.0x10^6$	$8.0x10^6$	$8.0x10^6$	$5.8x10^7$	$5.9x10^7$	Spread plate method
Total *Shigella*, cfu/ml	0	NG		$3.0x10^6$	$4.0x10^6$	$4.0x10^6$	$4.0x10^6$	$1.5x10^7$	$1.6x10^7$	Spread plate method
Total *Salmonella*, cfu/ml	0	NG		NG		NG		NG		Spread plate method

PARAMETERS	FMEnv Standard	N: 5.4340^0 E: 7.0125^0 ELEVATION:43m(141ft) TIME: 2:54PM Depth: 2ft ON 02		N: 5.399156^0 E: 6.994228^0 ELEVATION: 39m TIME: 10:13AM Depth: 2.5ft ON 03		N: 5.3893^0 E: 6.9866^0 ELEVATION: 40m(131Ft) TIME: 4 :00PM Depth: 2.6ft ON 04		N: 5.375902^0 E: 6.98537^0 ELEVATION: 39m TIME: 8:10AM Depth: 4.5ft ON 05		METHOD
		Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	
Temperature, ^{0} C	30.00	29.80	28.70	28.80	28.10	29.50	28.70	28.40	28.50	Electrode thermometer
Ph	6.50-8.50	4.90	4.90	5.20	5.40	5.20	5.30	5.70	5.80	Potentiometric
Colour, PCU	5.00	25.00	26.00	36.00	38.00	58.00	59.00	71.00	71.00	Photometric
Total Dissolved Solid, mg/l	500.00	44.20	44.20	31.20	31.85	31.85	31.85	29.90	29.90	Gravimetric
Total Suspended Solid, mg/l	<10.00	61.80	65.80	68.80	74.80	74.15	76.15	66.10	70.10	EDTA Titrimetric
Dissolved oxygen, mg/lo$_2$	>7.50	10.70	10.70	10.20	10.20	12.50	12.50	11.10	11.10	Electro-membrane
Biological Oxygen Demand, mg/l BOD5	NS	3.90	3.90	5.00	5.00	4.00	3.90	4.20	4.50	Incubation & Electro-membrane
ChemicalOxygen Demand, mg/l O_2	NS	1280.00	1264.00	128.00	144.00	128.00	128.00	48.00	64.00	Titrimetric
Conductivity, µS/cm	1000.00	68.00	68.00	48.00	49.00	50.00	49.00	46.00	46.00	Potentiometric
Turbidity, NTU	5.00	17.40	17.30	27.00	26.60	34.30	35.60	34.10	33.70	Nephelometric
Total Solid, mg/l	500.00-1000.00	106.00	110.00	100.00	106.00	106.00	108.00	96.00	100.00	Gravimetric
Calcium hardness, mg/l $CaCO_3$	150.00	33.67	31.08	59.57	56.98	51.80	51.80	36.26	36.26	EDTA Titrimetric
Total Hardness, mg/l Ca&$MgCO_3$	150.00	64.75	64.75	75.11	75.11	72.52	75.11	62.16	59.57	EDTA Titrimetric
Magnesium Hardness, mg/l $MgCO_3$	150.00	31.08	33.67	15.54	18.13	20.72	23.31	25.90	23.31	EDTA Titrimetric
Total chloride, mg/l Cl^-	250.00	16.00	15.00	14.00	14.00	14.00	15.00	15.00	15.00	Argentometric
Nitrate, mg/l $N0^-_3$	50.00	11.03	11.00	7.46	7.45	10.77	10.79	10.27	10.29	UV Spectrophotometer
Nitrite, mg/l $N0^-_2$	0.50	1.11	1.13	2.03	2.04	2.20	2.21	2.82	2.81	Diazotization
Phosphate, mg/l PO^{-3}_4	5.00	0.43	0.43	0.42	0.40	0.42	0.41	0.48	0.49	Ascorbic acid
Phenolpthalein Alkalinity, mg/l$CaCO_3$	NS	ND	ND	ND	ND	ND	ND	ND	ND	Titrimetric
Total Alkalinity, mg/l $CaCO_3$	200.00	13.00	14.00	9.00	10.00	14.00	13.00	10.00	10.00	Titrimetric

Bicarbonate, mg/l HCO_3	NS	12.99	13.99	8.99	9.99	13.99	12.99	9.99	9.99	Gravimetric
Carbonate, mg/l CO_3	NS	ND	ND	ND	ND	ND	ND	ND	ND	Gravimetric
Sulphate, mg/l SO^{-2}_4	100.00	9.37	9.52	11.211	11.59	15.08	14.92	16.03	16.19	Turbidimetric
Calcium, mg/l Ca	200.00	10.93	10.09	19.34	1850	16.82	16.82	11.77	11.77	EDTA Titrimetric
Magnesium, mg/l Mg	30.00	7.56	8.19	3.78	4.41	5.04	5.67	6.30	5.67	EDTA Titrimetric
Aluminium, mg/l Al	0.20	2.73	3.64	156.36	155.45	0.91	1.82	13.73	14.55	AAS
Ammonia, mg/l NH_3	0.30	0.81	0.81	0.52	0.52	0.58	0.58	0.68	0.68	Phenate Spectrophotometric
Iron, mg/l Fe	0.30	1.63	1.65	1.37	1.37	1.44	1.44	1.27	1.27	UV Spectrometric
Total Bacteria count, cfu/ml	0-30	$1.3x10^7$	$1.2x10^7$	$7.0x10^6$	$9.0x10^6$	$6.0x10^7$	$6.2x10^7$	$1.3x10^7$	$1.3x10^7$	Spread plate method
Total Coliform count, cfu/ml	0-10	$1.6x10^7$	$1.5x10^7$	$8.8x10^5$	$4.2x10^7$	$3.2x10^7$	$2.9x10^7$	$3.9x10^5$	$2.6x10^7$	Spread plate method
E. *coli* Count, cfu/ml	0	$2.0x10^6$	$1.0x10^6$	NG		$7.1x10^7$	$7.2x10^7$	$5.0x10^6$	$4.0 x10^6$	Spread plate method
Total *Klebsiella* count, cfu/ml	0	$1.2x10^7$	$1.0x10^6$	$1.1x10^7$	$1.0x10^7$	$4.5x10^7$	$4.2x10^7$	$4.0x10^6$	$4.0x10^6$	Spread plate method
Total *Shigella*, cfu/ml	0	$4.0x10^6$	$4.0x10^6$	NG		$4.0x10^6$	$4.0x10^6$	$3.0x10^6$	$3.0x10^6$	Spread plate method
Total *Salmonella*, cfu/ml	0	NG		NG		NG		NG		Spread plate method

PARAMETERS	**FMEnv Standard**	**N: 5.333897^0 E: 6.96652^0 ELEVATION: 43m TIME: 11:28 AM Depth: 2.0ft ON 06**		**N5.515697^0 E7.0163^0 Time: 1:46pm Elevation:55m EGBEADA**		**N5.47194187^0, E7.04166593^0, ELEVATION: 46.62 TIME: 2:40PM OT 03**		**METHOD**
		Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	
Temperature, ^{0}C	30.00	29.20	28.40	30.00	29.20	38.90	27.40	Electrode thermometer
Ph	6.50-8.50	5.30	5.30	6.20	6.20	6.50	6.60	Potentiometric
Colour, PCU	5.00	61.00	63.00	41.00	49.00	58.00	58.00	Photometric
Total Dissolved Solid, mg/l	500.00	27.95	27.95	48.10	48.10	84.45	85.10	Gravimetric
Total Suspended Solid, mg/l	<10.00	106.05	110.05	83.90	77.90	17.55	18.45	EDTA Titrimetric
Dissolved oxygen, mg/Lo_2	>7.50	10.30	10.30	3.60	3.60	4.00	4.10	Electro-membrane
Biological Oxygen Demand, mg/l BOD5	NS	6.90	6.90	2.10	2.10	1.80	1.80	Incubation & Electro-membrane
ChemicalOxygen Demand, mg/l O_2	NS	320.00	368.00	100.80	102.40	640.00	656.00	Titrimetric
Conductivity, µS/cm	1000.00	43.00	43.00	74.00	74.00	53.00	54.00	Potentiometric
Turbidity, NTU	5.00	36.80	34.80	21.90	22.00	35.00	34.90	Nephelometric
Total Solid, mg/l	500.00-1000.00	134.00	138.00	132.00	126.00	52.00	62.00	Gravimetric
Calcium hardness, mg/l $CaCO_3$	150.00	18.13	15.54	25.90	25.90	25.92	23.31	EDTA Titrimetric
Total Hardness, mg/l Ca&$MgCO_3$	150.00	28.49	25.90	59.48	65.43	59.57	56.58	EDTA Titrimetric
Magnesium Hardness, mg/l $MgCO_3$	150.00	10.36	10.36	33.58	40.33	33.67	33.67	EDTA Titrimetric
Total chloride, mg/l Cl^-	250.00	16.00	15.00	21.99	23.99	17.99	19.99	Argentometric

Nitrate, mg/l $N0^{-}_{3}$	50.00	8.43	8.46	12.79	12.81	3.77	3.72	UV Spectrophotometer
Nitrite, mg/l $N0^{-}_{2}$	0.50	3.59	3.62	2.12	2.48	1.56	1.60	Diazotization
Phosphate, mg/l $PO-^{3}_{4}$	5.00	0.63	0.64	0.40	0.39	0.59	0.60	Ascorbic acid
Phenolphthalein Alkalinity, mg/l$CaCO_3$	NS	ND	ND	ND	ND	ND	ND	Titrimetric
Total Alkalinity, mg/l $CaCO_3$	200.00	14.00	12.00	22.00	20.00	16.00	14.00	Titrimetric
Bicarbonate, mg/l HCO_3	NS	13.99	11.99	21.99	19.99	15.99	13.99	Gravimetric
Carbonate, mg/l CO_3	NS	ND	ND	ND	ND	ND	ND	Gravimetric
Sulphate, mg/l SO^{-2}_{4}	100.00	9.52	9.37	1.59	1.27	6.51	6.35	Turbidimetric
Calcium, mg/l Ca	200.00	5.89	5.05	8.41	8.41	8.41	7.57	EDTA Titrimetric
Magnesium, mg/l Mg	30.00	2.52	2.52	7.16	8.60	8.19	8.19	EDTA Titrimetric
Aluminium, mg/l Al	0.20	9.09	9.09	2.01	2.11	1.68	1.68	AAS
Ammonia, mg/l NH_3	0.30	0.81	0.81	2.97	2.97	2.53	2.56	Phenate Spectrophotometric
Iron, mg/l Fe	0.30	1.62	1.56	0.91	0.95	1.21	1.19	UV Spectrometric
Total Bacteria count, cfu/ml	0-30	$8.7x10^7$	$8.7x10^7$	$2.6x10^7$	$2.8x10^7$	$4.1x10^7$	$3.9x10^7$	Spread plate method
Total Coliform count, cfu/ml	0-10	$2.9x10^5$	$1.5x10^7$	$2.1x10^5$	$1.9x10^7$	$3.0x10^5$	$2.8x10^7$	Spread plate method
E. coli Count, cfu/ml	0	$5.0x10^6$	$7.0x10^6$	$1.0x10^7$	$9.0x10^6$	$1.1x10^7$	$1.4x10^7$	Spread plate method
Total *Klebsiella* count, cfu/ml	0	$7.0x10^6$	$7.0x10^6$	$3.0x10^6$	$2.0x10^6$	$1.0x10^6$	$1.0x10^6$	Spread plate method
Total *Shigella*, cfu/ml	0	$1.5x10^5$	$4.0x10^6$	$1.5x10^7$	$1.3x10^7$	$2.0x10^7$	$2.0x10^7$	Spread plate method
Total *Salmonella*, cfu/ml	0	NG		NG		NG		Spread plate method

Table 2: Details of Analytical Methodology, WHO (2017), FEPA (2006), CDWQG (2005), EU (2005), SK (2006), Standard for Water Parameters Alongside their Undesirable Effects at Higher Levels

VARIABLE	SYMBOL	POSSIBLE METHOD	UNIT	WHO (2003)	FEPA (2006)	CDWQG (2005)	EU (2005)	SK (2006)	SMCL	UNDESIRABLE EFFECT AT HIGHER LEVELS
PHYSICAL										
COLOUR	CO		TCU or Co Pt. U			15			10	Appearance
TASTE	TA			UNOBJECTIONABLE		INOFFENSIVE				Taste
ODOUR	OR		TON	UNOBJECTIONABLE		INOFFENSIVE			3	Odour
TEMPERATURE	TE	THERMOMETER	^{O}C	25						
TURBIDITY	TU		FTU	5.0	1.0		1.5		0.5	Appearance
CONDUCTIVITY	EC	ELECTROLYTIC		100						
POTENTIAL HYDROGEN	PH	POTENTIOMETRY	P^{H}	6.5-8.5	6.5-8.5		6.5-8.5		6.5-8.5	LOW PH – Corosion HIGH PH – Taste/Soapy Feel
CHEMICAL										
ACIDITY	AC	POTENTIOMETRY								
ALKALINITY	AL	POTENTIOMETRY		30 – 500		500		500		

TOTAL SOLIDS	TS			1000						Taste and Intestinal irritation
TOTAL DISSOLVED SOLIDS	TDS	GRAVIMETRY		1000	500	500		1500	500	Taste
TOTAL SUSPENDED SOLIDS	TSS				>10					Turbidity
TOTAL HARDNESS	TH	EDTA TITRIMETRY	Mg/L of CaC O_3					800	250	High: Scale Deposits Scum Formation Low: Possible corrosion
CALCUIM HARDNESS	CH	TITRIMETRY	Mg/L	200						
MAGINESSUIM HARDNESS	MH	TITRMETRY	Mg/L	12						
SILICA	SiO_2	GRAVIMETRY	Mg/L							
SULPHATE	SO_4^{2-}	NEPHLOTURBIDIMETRY	Mg/L	400	500	500	500		250	Taste and corrosion
NITRATE	NO^-_3	SPECTROPHOTOMETRY	Mg/L	10	10	45	10			Physiological Problems
CHLORIDE	CL^-	ARGENTOMETRY	Mg/L	200		250			250	Taste and corrosion
PHOSPHATE	PO_4^{3-}	PHOTOMETRY	Mg/L		>50					
BICARBONATE	HCO_3^-	TITRIMETRY	Mg/L							
CARBONATE	CO_3^{2-}	TITRIMETRY	Mg/L							
FLUORIDE	F^-	COLOURIMETRIC	Mg/L	0.5		1.5			1.0	Skeletal damage And dental fluorosis
CALCUIM	Ca^{2+}	EDTA TITRIMETRIC	Mg/L	75			100			Scale formation
MAGNESIUM	Mg^{2+}	FLAME PHOTOMETRY	Mg/L	<30		200				Hardness, taste and gastro intestinal irritation
POTASSIUM	K^+	FLAME PHOTOMETRY	Mg/L	200						
BIOLOGICAL										
BIOCHEMICAL OXYGEN DEMAND	BOD	INCUBATION								
CHEMICAL OXYGEN DEMAND	COD	TITRIMETRIC								
DISSOLVED OXYGEN	DO	TITRIMETRIC			7.5					Indirect effect
AMMONIA	NH_3	COLORIMETRIC					50			Odour and taste

ORGANIC CARBON	OC	INFARRED ANALYZER								
FAECAL COLIFORM	FC		CFU/100ml	0	0	0	0			
TOTAL COLIFORM COUNT	CFC		CFU/100ml	3	0	0	0			
TOTAL PLATE COUNT	TPC		CFU/100ml	100		500				
SATURATION INDEX	SI					-1 to 1				
OIL/GREASE	O/G			0.01						Taste and potential damage to aquatic life

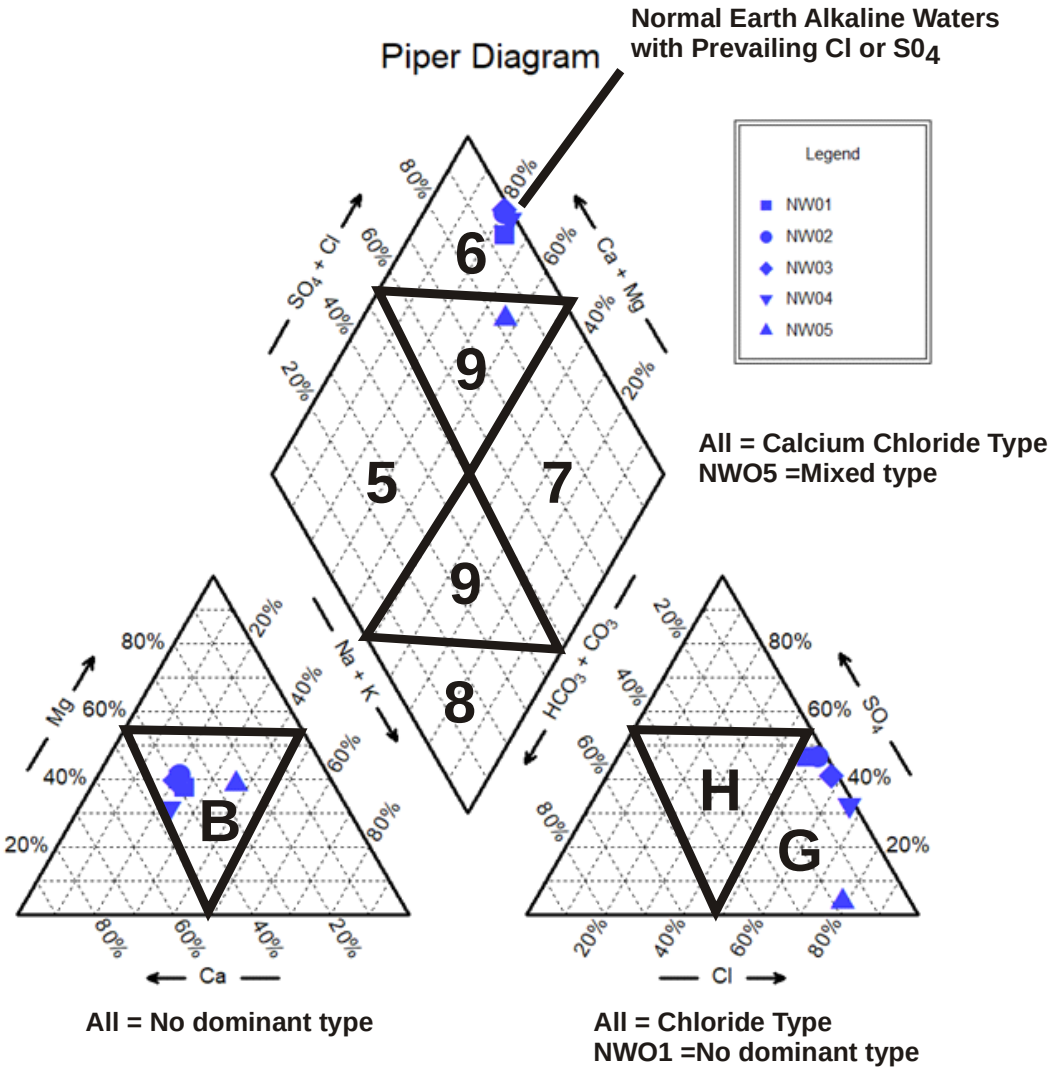
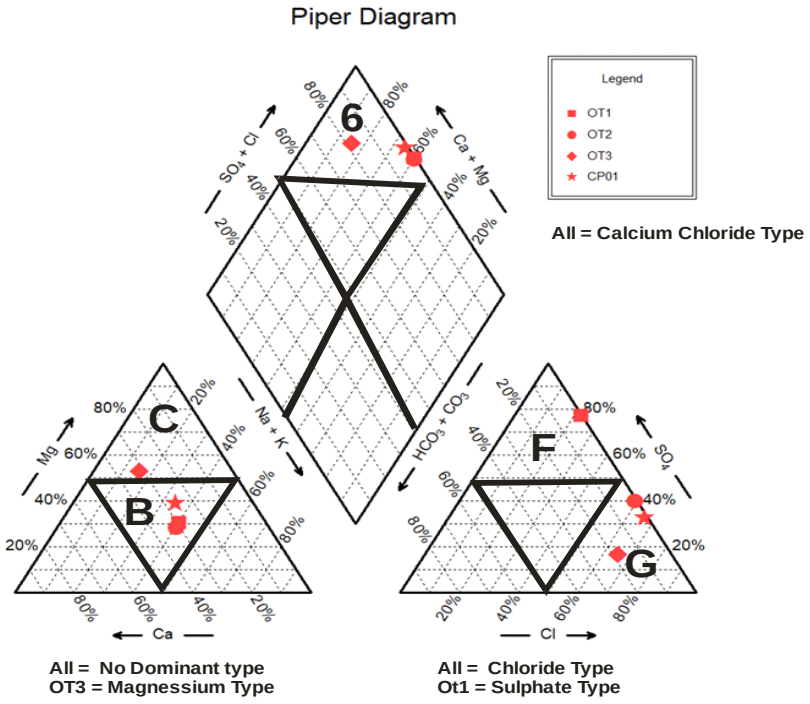


Figure... Piper Trilinear Plot of Nworie River Sample

Figure 1: Piper Trilinear Plot of Nworie River Samples



Figuare.... Piper trilinear plot of Otamiri River Sample

Figure 2: Piper Trilinear Plot of Nworie River Samples

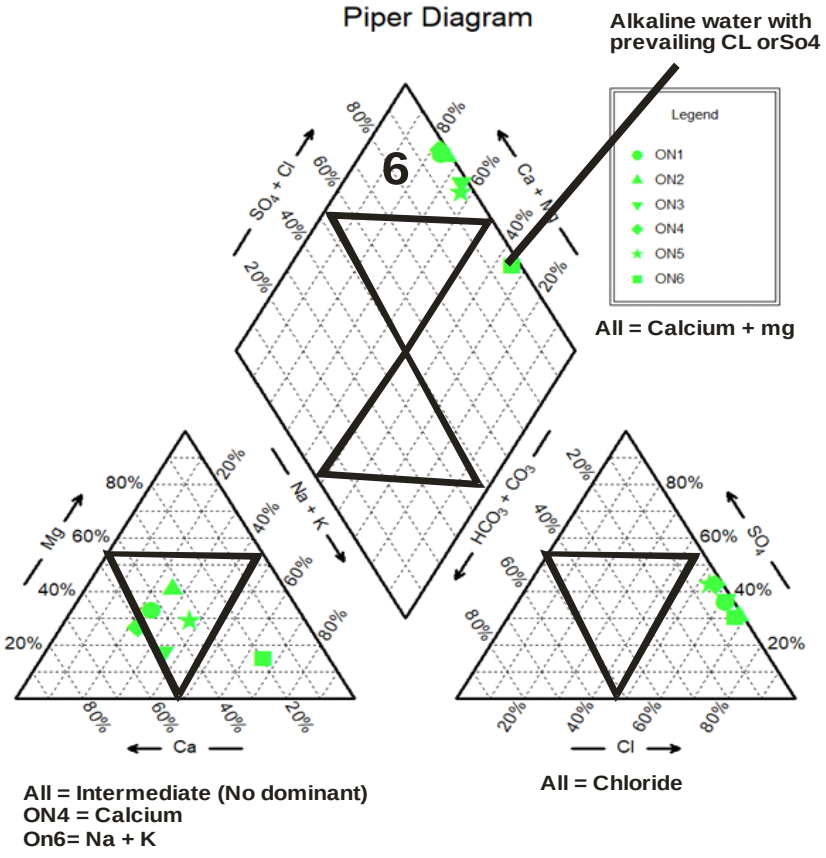


Figure... Piper Trilinear Plot of the Samples after the confluence of Otamiri and Nworie Rivers

Figure 3: Piper Trilinear Plot of the Samples after the Confluence of Otamiri and Nworie Rivers

The Piper trilinear diagram is a graphical representation of the water chemistry of samples. It helps to understand the sources of dissolved constituents in the water. It is based on the premise that the algebraic sum of the electric charges of cations and anions equals zero. The cations and anions are usually shown on separate ternary plots from which projections are made to the central Diamond, Calcium, Magnesium, Potassium, and Sodium cations occupy the apexes of the cation ternary plot whereas chloride, sulfate, and carbonate plus hydrogen carbonate occupy the apexes of the anion ternary plot. The Piper diagram assists in grouping water samples into hydrochemical facies.

From the Piper trilinear plot of Nworie River [figure 1], the cation ternary displayed no dominant type of water for the collected samples while the anion ternary showed dominantly chloride water type except NW01 which indicated no dominant water type. When projected to the demand structure, all the samples collected from the Nworie River showed predominantly calcium chloride water type except for NW05 which displayed a mixed water type.

Hence from the water piper trilinear diagram, Nworie River can be said to be of calcium chloride water facies. This facies type belongs to the soft water series devoid of pronounced hardness.

From the piper plot of Nworie River (Figure 1), the cation ternary showed all the samples falling within the no dominant type while all the anions fell within the no dominant type water. When projected to the diamond, the Nworie River water samples fell within the normal Earth Alkaline waters with prevailing Cl or SO4 ion. This indicates that all the samples from the Nworie River plot within the calcium chloride type water except NWO5 samples that fell within the mixed water type.

From the piper trilinear plot of the Otamiri River (Figure 2), the cation ternary displayed the samples as no dominant ionic type except for the OT3 sample which fell within the magnesium-type water. On the other hand, a closer look at the anion ternary displayed all the samples to be classed as chloride type `water except the OT1 sample which coincided with the sulfate-type water. A simple projection of the diamond block showed all the samples of the Altamira River falling within the calcium chloride water type.

For the downstream water samples collected after the confluence of the Otamiri and Nworie rivers (Figure 3) looking at the cation ternary, all the samples fell within the no dominant terrain except for ON4 and ON6 which fell within Calcium-rich and Sodium plus Potassium-rich waters. A simple projection to the central diamond classified the water to be normal Earth alkaline waters with prevailing Cl or SO4 ION water facies indicating that all are rich in calcium plus Magnesium.

CONCLUSION

The results from the research suggests that the Otamiri and Nworie rivers conform with some notable standards except for pH, total suspended solids [TSS], Turbidity, colors, Iron, Manganese, Nickel, and Zinc. The rivers are generally acidic with pronounced Bacteriological counts.

Most of the Parameters in the river were observed to be generally increasing downstream indicating continuous constituent loading along the river course as the water flow from the source of the rivers towards the mouth of the river.

The samples from the water bodies were classified as $CaCl_2$ water facies indicating a soft water with no observable encrustation to utensils and wares. Otamiri and Nworie rivers were seen to generally have Calcium as the dominant cation and Chloride as the dominant anion. Their origin was traced to rock dominance indicating that their sources originated from rocks. The water from the two rivers was seen to be excellent for irrigation but cannot be put into direct domestication because they have been adversely contaminated by heavy metals which chronic daily intake has been adduced to be quite hazardous to both Adults and Children.

The events/activities going on along the bank of the Otamiri and Nworie rivers. Those events contributed in no small measures to introducing pollutants to these rivers.

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