

Original Research Article

Assessment of upstream and downstream water quality of Ulas River, Okija, Anambra state During Rainy and Dry season

Abstract

The upstream and downstream water quality assessment of Ulas River, Okija, were evaluated for the influence of rural land use activities during the rainy and dry seasons. Triplicate samples were collected 50m apart from each location and the physico-chemical properties of these water samples were evaluated. Samples were stored in containers filled with ice packs and immediately taken to the laboratory to investigate some selected physico-chemical characteristics. Also, bacteriological study was carried out on the samples to check for the presence of coliforms. Results obtained were compared with World Health Organization (WHO) standard for permissible drinking water. Results obtained for turbidity are 205 ± 0.70 (downstream), 25.70 ± 0.00 (upstream) for rainy season and 138 ± 0.60 (downstream), 15.8 ± 0.03 (upstream) for dry season. Turbidity values were significantly higher ($p < 0.05$) during rainy season than dry season and downstream values were significantly higher ($p < 0.05$) than upstream values when compared with WHO standard. pH values were 5.90 ± 0.00 (downstream), 5.91 ± 0.31 (upstream) for rainy season and 6.10 ± 0.00 (downstream), 6.12 ± 0.11 (upstream) for dry season. The results of bacteriological study showed that all the sampling locations in downstream and upstream contained significantly higher ($p < 0.05$) numbers of coliform bacteria and *E. coli* in both rainy and dry seasons. The number of coliform bacteria and *E. coli* during rainy season was 25.00 ± 0.00 , 2.00 ± 0.00 (downstream), 17.00 ± 0.00 , 1.00 ± 0.00 (upstream), and 18.00 ± 0.02 , 2.00 ± 0.00 (downstream), 7.00 ± 0.01 , 1.00 ± 0.00 (upstream) respectively during the dry season. Iron, ammonia and TOC content were significantly higher ($p < 0.05$) when compared with WHO standard. This makes the water unsuitable for drinking and human usage and also a threat to the lives of the rural community.

Keywords: Ulas River, water quality, Rainy season, dry season, upstream, downstream.

Introduction

Water is one of the most important of all the natural resources available on the earth. It covers 71% of the earth's surface and is vital for all known form of life. Clean and safe water is both food and health! Potable, adequate and accessible water is therefore a public asset and a vital social welfare facility to measure levels of development in space ^[1]. The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life. Natural water which contains different types of impurities are introduced into aquatic system by different ways such as weathering of rocks and leaching of soil, dissolution of aerosol particles from the atmosphere and from several human activities, including mining, processing and the use of metal based materials ^[2].

However, access to safe water supply and sanitation is a global issue and varies significantly across the globe. The World Bank Group in their study argued that nearly half of the world population lack access to safe water supply and basic sanitation, and the situation is most

appalling among the developing countries ^[3]. Chemical analysis of the water quality indices of some Nigerian Rivers reveals that water which was once an abundant natural resources is rapidly deteriorating in quality, owing to population increase and industrialization. Industrial activities, urbanization, exploration activities, refining activities in developing countries like Nigeria are some major ways through which rivers, waterbodies, creeks, swamps have been contaminated. These contaminated rivers had in one way or the other constituted public hazards and socioeconomic hazards to the flora and fauna ^[4].

The aim of this study is to assess the upstream and downstream water quality of Ulasi River, Okija, for the influence of rural land use activities during the rainy and dry seasons. The Ulasi River is the main source of water for domestic and other uses in Okija community in area of Anambra state. It is a widely spread river found in southeastern Nigeria. The Ulasi river starts from the hills in Dikenafai (latitude 050 45'N, longitude 070 10'E), in Imo State, it flows through several towns in both Imo and Anambra States (Ezinifite, Urualla, Akokwa, Okija, Ihiala, Uli, Mgbidi) gathering tributaries in its course. It forms a confluence with the Oguta Lake at Oguta, before flowing parallel to the River Niger. At some point, as the river flows southward, the name changed, due to dialectic pronunciation, to Ulashi (or Orashi). Hence it continued its flow as River Ulashi through Obiakpo, Ebocha, Kreigani, Ukodu (Bayelsa State) and Mbama. Urashi takes another left at Okarki, flowing east to Igovia and then south-east to Egbama and Agunughan but more southerly into Orashi National Forest and Arukwa. The river overflows its banks every August and gradually recedes by subsequent months, depositing alluvial soils on its banks and floodplains, which are very fertile ^[5].

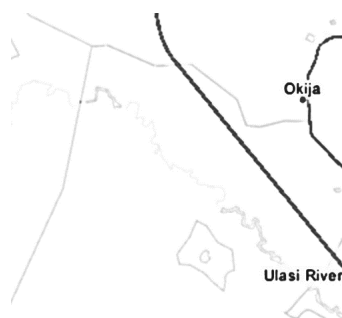


Figure 1: GPS Map Showing Ulasi River in Okija

Methodology

Sample Collection: Water samples were collected in triplicate from three different sampling locations 50m intervals along the Ulasi River. Samples were collected from the upstream and downstream during in both rainy and dry seasons. At the time of sample collection, each sample bottle was held at the base while a gloved hand was use to uncover the bottle. The bottle was them immersed to about 30cm below, with its mouth in upstream direction. The sample bottles were tightly capped, appropriately labelled and immediately conveyed to the laboratory and stored in refrigerator before analyses ^[6].

76 Analysis of sample

77 Standard analytical procedures were used in the determination of selected physical, chemical
 78 and biological water quality parameters of the sample. The Selected physio-chemical analysis
 79 carried out include pH, temperature, turbidity, electrical conductivity (EC), total suspended
 80 solids (TSS), Nitrites, Nitrates, total hardness, Magnesium hardness, Chlorides, dissolved
 81 CO₂, etc. The pH was determined using the procedure described with Jenway 3015 pH meter
 82 ^[7]. Calcium was determined using the flame atomic spectrophotometer. Iron and ammonium
 83 content of the sample were determined using spectrophotometer and photometer respectively.
 84 Nitrites and nitrates were measured using photometer. Bacteriological study was done using
 85 multiple tubes/ most probable number method. Turbidity was measured using turbidometer ^[8].
 86 Iron, Lead and Aluminium were measured using Spectrometer ^[9]. Calcium and Magnesium
 87 were measured using spectrophotometer ^[10]. Ammonium was measured using Photometer ^[11].
 88 Nitrites were measured using spectrophotometer ^[12]. Bacteriological study was done using
 89 most probable number method ^[13].

90 Statistical Analysis: Descriptive statistics, as well as T-test were used to statistically analyze
 91 the data generated from laboratory investigation.

92 Results and Discussion:

93 **Table 1: Physico-chemical parameters of Ulasi River water sample (downstream)**
 94 **during the rainy season**

Parameters	Results	W.H.O Standards
Appearance	Muddy	Clear
Colour In Hazen Unit	285 ± 0.54	5 Hazen Units
Turbidity (NTU)	205 ± 0.70	5 N.T.U
Odour	-	-
Taste	-	-
Conductivity(Us/Cm)	21.80 ± 10.96	1000 US/CM
Acidity(C.C) Of 0.5% Na ₂ CO ₃ (mg/l)	30.00 ± 0.00	
pH	5.90 ± 0.00	6.5-8.5
Chloride As Cl (mg/l)	35.50 ± 0.00	250mg/l
Chloride As NaCl (Mg/L)	58.50 ± 0.02	
Total Alkalinity As CaCO ₃ (mg/l)	15.65 ± 0.007	
Total Hardness As CaCO ₃ (mg/l)	56.00 ± 0.02	500mg/l
Calcium Hardness(mg/l)	22.00 ± 0.00	
Magnesium Hardness (mg/l)	24.00 ± 0.56	
Total Iron As Fe (mg/l)	2.70 ± 0.48	0.30mg/l
Sulphate As SO ₄ (mg/l)	12.04 ± 0.04	400mg/l

Sodium As Na (mg/l)	23.00 ± 0.00	
Bicarbonate As HCO ₃	21.50 ± 0.00	
Free Saline Ammonia (Nh ₄) (mg/l)	0.185 ± 0.00	0.05mg/l
Nitrates As N (mg/l)	2.00 ± 0.01	10.00mg/l
Nitrites As N(mg/l)	0.01 ± 0.01	1.00mg/l
T.D.S (mg/l)	11.00 ±0.00	1000mg/l
Dissolved Free Carbondioxide As Co ₂ (mg/l)	10.56 ± 0.03	
Arsenic (mg/l)	0.00 ± 0.00	0.05mg/l
Benzene (mg/l)	0.00 ± 0.00	0.007mg/l
Fat And Oil (Mg/L)	0.00 ± 0.00	0.003mg/l
Biological Oxygen Demand (mg/l)	7.50 ± 0.06	
Chemical Oxygen Demand (mg/l)	35.00 ± 0.00	
Total Organic Compound (mg/l)	10.00 ± 0.01	5.00mg/l
Coliform	25.00±0.00	Absent in 100ml
<i>E coli</i>	2.00 ±0.00	Absent in 100ml

95

96 **Table 2: Physico-chemical parameters of Ulasi River water sample (Upstream) during**
97 **the rainy season**

Parameters	Results	W.H.O Standards
Appearance	MUDDY	CLEAR
Colour in Hazen Unit	33.00 ± 0.00	5 Hazen Units
Turbidity (NTU)	25.70 ± 0.00	5 N.T.U
Odour	-	-
Taste	-	-
Conductivity (US/CM)	23.90 ± 0.00	1000 US/CM
Acidity (C.C) OF 0.5% NA ₂ CO ₃ (mg/l)	28.00 ± 0.00	
pH	5.91 ± 0.31	6.5-8.5
Chloride as CL (mg/l)	42.60 ± 0.00	250mg/l
Chloride as NaCL (mg/l)	70.20 ± 0.09	

Total Alkalinity as CaCO ₃ (mg/l)	20.00 ± 0.00	
Total Hardness as CaCO ₃ (mg/l)	28.00 ± 0.06	500mg/l
Calcium Hardness (mg/l)	21.00 ± 0.00	
Magnesium Hardness (mg/l)	7.00 ± 0.10	
Total Iron as Fe (mg/l)	0.70 ± 0.04	0.30mg/l
Sulphate as SO ₄ (mg/l)	13.86 ± 0.21	400mg/l
Sodium as Na (mg/l)	27.60 ± 0.05	
Bicarbonate as HCO ₃ (mg/l)	15.65 ± 0.00	
Free Saline Ammonia (mg/l)	0.270 ± 0.00	0.05mg/l
Nitrates as N (mg/l)	0.092 ± 0.01	10.00mg/l
Nitrites as N (mg/l)	0.001 ± 0.00	1.00mg/l
T.D.S (mg/l)	11.30 ± 0.00	1000mg/l
Dissolved Carbondioxide CO ₂ (mg/l)	17.60 ± 0.11	
Arsenic (mg/l)	0.00 ± 0.00	0.05mg/l
Benzene (mg/l)	0.00 ± 0.00	0.007mg/l
Fat And Oil (mg/l)	0.00 ± 0.00	0.003mg/l
Biological Oxygen Demand (mg/l)	4.50 ± 0.01	
Chemical Oxgen Demand (mg/l)	21.00 ± 0.00	
Total Organic Compound (mg/l)	6.00 ± 0.04	5.00mg/l
Coliform	17.00 ± 0.00	Absent in 100ml
<i>E coli</i>	1.00 ± 0.00	Absent in 100ml

98

99

100

101 **Table 3: Physio-chemical parameters of Ulasi River water sample (Downstream) during**
102 **the dry season**

Parameters	Results	W.H.O Standards
Appearance	Muddy	Clear
Colour In Hazen Unit	325 ± 0.54	5 Hazen Units

Turbidity (NTU)	138 ±0.60	5 N.T.U
Odour	-	-
TASTE	-	-
Conductivity(US/CM)	29.80 ± 0.00	1000 US/CM
Acidity(C.C) OF 0.5% NA ₂ CO ₃ (mg/l)	33.50 ± 0.00	
pH	6.10 ± 0.00	6.5-8.5
Chloride as CL (mg/l)	39.00 ± 0.39	250mg/l
Chloride as NaCL (mg/l)	64.50 ± 0.00	
Total Alkalinity as CaCO ₃ (mg/l)	20.00 ± 0.06	
Total Hardness as CaCO ₃ (mg/l)	67.80 ± 0.05	500mg/l
Calcium Hardness (mg/l)	43.10 ± 0.00	
Magnesium Hardness (mg/l)	24.80 ± 0.46	
Total Iron as Fe (mg/l)	2.90 ± 0.00	0.30mg/l
Sulphate as SO ₄ (mg/l)	25.20 ± 0.00	400mg/l
Sodium as Na (mg/l)	25.00 ± 0.00	
Bicarbonate as HCO ₃ (mg/l)	27.70 ± 0.00	
Free Saline Ammonia (mg/l)	0.19 ± 0.00	0.05mg/l
Nitrates as N (mg/l)	4.20 ± 0.20	10.00mg/l
Nitrites as N (mg/l)	0.004 ± 0.00	1.00mg/l
T.D.S (mg/l)	21.00 ± 0.45	1000mg/l
Dissolved Carbondioxide CO ₂ (mg/l)	12.70 ± 0.00	
Arsenic	0.00 ± 0.00	0.05mg/l
Benzene	0.00 ± 0.00	0.007mg/l
Fat and Oil	0.00 ± 0.00	0.003mg/l
Biological Oxygen Demand (mg/l)	8.40 ± 0.07	
Chemical Oxgen Demand (mg/l)	35.00 ± 0.00	
Total Organic Compound (mg/l)	11.00 ± 0.00	5.00mg/l
Coliform	18.00± 0.02	Absent in 100ml
<i>E coli</i>	2.00±0.00	Absent in 100ml

103

104

105

106 **Table 4: physio-chemical parameters of Ulasi River water sample (Upstream) during**
 107 **the dry season**

Parameters	Results	W.H.O Standards
Appearance	Muddy	Clear
Colour In Hazen Unit	45 ± 070	5 Hazen Units
Turbidity NTU	15.8 ± 0.03	5 N.T.U
Odour	-	-
Taste	-	-
Conductivity(US/CM)	31.20 ± 0.00	1000 US/CM
Acidity (C.C) of 0.5% NA ₂ CO ₃ (mg/l)	30.20 ± 0.01	
pH	6.12 ± 0.11	6.5-8.5
Chloride as CL (mg/l)	48.20 ± 0.00	250mg/l
Chloride as NaCL (mg/l)	74.60 ± 0.03	
Total Alkalinity as CaCO ₃ (mg/l)	23.00 ± 0.00	
Total Hardness as CaCO ₃ (mg/l)	41.20 ± 0.00	500mg/l
Calcium Hardness (mg/l)	41.00 ± 0.32	
Magnesium Hardness (mg/l)	25.00 ± 0.00	
Total Iron as Fe (mg/l)	0.90 ± 0.00	0.30mg/l
Sulphate as SO ₄ (mg/l)	27.80 ± 0.30	400mg/l
Sodium as Na (mg/l)	28.00 ± 0.00	
Bicarbonate as HCO ₃ (mg/l)	17.30 ± 0.55	
Free Saline Ammonia (mg/l)	0.29 ± 0.78	0.05mg/l
Nitrates as N (mg/l)	1.90 ± 0.05	10.00mg/l
Nitrites as N (mg/l)	0.20 ± 0.08	1.00mg/l
T.D.S (mg/l)	21.60 ± 0.20	1000mg/l
Dissolved Carbondioxide CO ₂ (mg/l)	15.00 ± 0.00	
Arsenic (mg/l)	0.00 ± 0.00	0.05mg/l
Benzene (mg/l)	0.00 ± 0.00	0.007mg/l
Fat And Oil (mg/l)	0.00 ± 0.00	0.003mg/l
Biological Oxygen Demand (mg/l)	5.00 ± 0.00	

Chemical Oxygen Demand (mg/l)	23.00± 0.05	
Total Organic Compound (mg/l)	8.90 ± 0.00	5.00mg/l
Coliform	7.00±0.01	Absent in 100ml
<i>E coli</i>	1.00±0.00	Absent in 100ml

108

109 Discussion

110 The concentration of various quality parameter varied with seasons and areas (downstream
111 and upstream), with dry season having higher values. Results obtained from this study shows
112 a significant increase ($p<0.05$) in temperature during the dry season than rainy season and
113 this could be attributed to the hot weather experienced during the dry season (hot season).
114 Water temperature regulates the metabolism of the aquatic ecosystem. High water
115 temperature makes metal more toxic to aquatic life. This in turn induces stress to aquatic
116 ecosystem by reducing the ability of water to hold essential dissolved gases like oxygen ^[14].
117 Also growth of micro-organism, taste, odour, colour and corrosion problem may increase ^[15].
118 Low temperature has the effect of decreasing the efficiency of treatment.

119 Turbidity values were significantly higher ($p<0.05$) during rainy season than dry season. This
120 is probably due to the waste material, solid waste material and soil particles transported by
121 runoff from urban activities into the river. From the results obtained, turbidity of both dry and
122 rainy season was higher than the standard limit for drinking water as recommended by WHO.
123 According to Park ^[16], turbidity affects fish and aquatic life by interfering with sunlight
124 penetration. In drinking water, the higher the turbidity level, the higher the risk that people in
125 that area may develop gastro intestinal disease. In aquatic life, high turbidity level affects the
126 ability of fish gills to absorb dissolved oxygen.

127 The total organic carbon values obtained for the dry season were significantly higher
128 ($p<0.05$) than the value for the rainy season. The higher value observed during the dry season
129 could be as a result of the influence of season, dry season is characterized by low
130 precipitation, higher atmospheric temperature and evaporation but during rainy season there
131 the water dissolves the organic compounds. Organic compounds causes eutrophication of the
132 river which is the sudden bloom of algae due to the presence of limiting nutrients in excess
133 ^[17].

134 The general concentration of iron from this study were within 0.30mg/l, however there was
135 significant difference ($p<0.05$) between the dry (2.70) and rainy season (2.70). The presence
136 of iron in water aids iron utilizing and reducing bacteria like *thiobacillus ferrooxidans* and
137 *leptospirillum ferrooxidans* to increase causing diseases relating to the microorganism. Iron
138 bacteria in water can cause unpleasant odour and taste.

139 The values of pH for dry season (6.10) were significantly higher ($p<0.05$) than rainy season
140 (5.90). The values for both dry and rainy season did not fall within the stipulated limits for
141 drinking water which is 6.5-8.5 according to WHO pH standard for drinking water. The low
142 pH value may probably due to built-up of organic materials. Keith ^[18] reported that
143 degradation of organic wastes by aerobic microbes produces carbon dioxide as a by-product,

carbon dioxide then dissolves in water to yield carbonic acid, hence, increasing the acidity of the water. Some fish cannot tolerate low pH^[19] and pH has synergistic effect on heavy metal activity. Acidic pH encourage the growth of acidophiles which are organism that are able to live at pH below 7, and such organisms are dangerous to human health, since freshwater is buffered at pH of 7.

Result of Sulphate concentration of SO₄ obtained from this study was within the 400mg/l limit recommended by WHO. However there was significant difference (p<0.05) between the dry and rainy season value. The value vary along the sampling point with the uphill having higher value than the downhill. The source of sulphate to the water could be from effluents from industries, runoffs, dumpsites and organic matters decomposition. According to WHO^[20] the presence of sulphate in drinking-water can also result in a noticeable taste; the lowest taste threshold concentration for sulphate is approximately 250mg/litre as the sodium salt. Sulphate may also contribute to the corrosion of distribution systems. In the light of these considerations, no health-based guideline value for sulphate in drinking water was proposed. However, there is an increasing

Result of Chloride concentration obtained was generally below WHO permissible limit (250mg/g) for both dry and rainy season. Although there were inputs of pollutants from municipal waste into the river, the level was not high enough to significantly increase chloride level above limit. Thus the negative impact of high concentration of chloride in water such as causing canned or frozen food to taste funny, killing aquatic lives and giving salty taste to water will not be experienced^[21].

Water in the study area varied in their microbial quality especially the coliform group. The values were significantly higher (p<0.05) in downstream but low in upstream. The variation was probably due to the level of municipal waste received by the respective area. Similarly, there was significant difference (p<0.05) between the dry season and rainy season bacterial count, with the rainy season having higher value due to the significant increase in organic and bacterial load after rain storm^[22]. Coliform count was higher than the permissible limit of 0.2mpn/100ml and could be considered polluted. The presence of coliform bacteria in Ulasi River is an index of the presence of other pathogenic microbes in the river. This result agrees with the report of^[23]; their study revealed that Okpauku River in Yala, Cross River State contains high number of coliform bacteria. Similarly, a study by^[24] reported the presence of coliform bacteria in Otamiri-oché River in Etche Ethnic Nationality of Rivers State, Nigeria. Bacterial polluted water causes both in humans and animals numerous water borne diseases like dysentery, either as a result of ingestion or direct contact or inhalation or aerosol generated by contaminated water.

Conclusion

Many rivers draining rural environment are negatively impacted by various land use activities in these areas. This study demonstrates the influence of rural land use and seasonal effect on water quality in Ulasi River. The data clearly shows that the downstream is more polluted than upstream. The upstream though less polluted than the downstream is not still suitable for aquatic life and drinking and human consumption, the downstream too is highly polluted and should not be used for agricultural or human use.

A management plan to restrict the dumping of wastes into Ulasi River is needed in order to reduce the impact on water quality and pollution related health problem. This can be achieved through effective waste management strategy and provision of reliable public water supply. Educating people in Okija on the health effect of Ulasi River and the effect on crops is suggested to avoid diseases and mortality rate in Okija.

Reference

1. Arokoyu S.B. and Ukpere D.R.T. Access to Safe Water Supply and Sanitation in Lower Orashi River Basin, Rivers State, Nigeria. *ARPJ Journal of Science and Technology*. 2014; 4(11):639-646.
2. Asaolu, S. S., Ipinmoroti, K. O., Adeyinowo, C. E. and Olaofe, O. Interrelationship of heavy metals concentration in water, sediment and fish samples from Ondo State coastal Area, Nigeria. *African Journal of Science*. 1997; 1(5): 5-61.
3. World Bank. Access to safe water: Research and Explore. Washington D. C.: World Bank Group. 2001.
4. Akaninwor, J. O., Anosike, E O. and Egwim, O. Effect of Indomie industrial effluent discharge on microbial properties of new Calabr River. *Scientific Research and Essays*. 2007; 2:1-5.
5. http://en.wikipedia.org/wiki/Urashi_River
6. Rao, K.D.S., Ramakrishniah M., Karthikeyan M. and Sukumaran P.K. Limnology and Fish Yield Enhancement Reservoir (Cauvery River System). *Journal of Inland Fisheries Society of India*, 2004; 35, 20-27.
7. Jaiswal, P. C. Soil, Plant and Water Analyses. Kalyani Publishers Ludhiana, New Delhi – Norda Hyderabad, India. 2003; 1 – 399.
8. Eltre L.S. and Snell F.D. Encyclopedia of Industrial Chemical Analysis. Vol 19. Wiley Pub., New York. 1971; 356-392.
9. Bhatia, S.C. Environmental Pollution and Control in Chemical Process Industries. Khanna Publishers, New Delhi. 2009; 164-431.
10. Adeyeye, E.I. & Abulude F. O. Analyneal Assessment of Some Surface and Ground Water resources in Ile-Ife, Nigeria. *Journal of Chemical Society of Nigeria*. 2004; 29: 98-103.
11. Puri, P.J., Yenkie, M.K.N., Sangal, S.P., Gandhare, N.V., Sarote G.B. & Dhanorkar, D.B. Surface water (lakes) Quality Assessment in Nagpur City (India) Based on Water Quality Index (WQI). 2011; 4(1), 43-48.
12. Association of Analytical Chemists (AOAC). Official methods of analysis. 8th ed. Washington, USA. 2000; 598 -590.
13. Crowther, J., Kay, D. & Wyer, M.D. Relationship between the Microbial Water Quality and Environmental Conditions in Costal Recreational Waters: The Fylde Coast, UK. *Water Research*. 2001; 35:4029-4038.
14. Kumar, M. and Puri. A. A review of permissible limits of drinking water. *Indian Journal of Occupational and Environmental Medicine*. 2012; 16(1): 40–44.
15. Ezemonye, M.N. Surface and Groundwater Quality of Enugu Urban Area. Unpublished PhD Thesis. Department of Geography, University of Nigeria, Nsukka. 2009.

- 229 16. Park, K. Park's Textbook of Preventive and Social Medicine. Servicon Services,
230 India, M/S Banarsidas Bhanot, 2009; 659-661.
- 231 17. Ideriah, T.J.K, Amachree O. and Stanley H.O. Assessment of Water Quality along
232 Amadi Creek in Port Harcourt, Nigeria. *Scientia Africana*. 2010; 9(1): 150-162.
- 233 18. Keith Bellingham, Physicochemical Parameters of Natural Waters; Stevens Water
234 Monitoring Systems, Inc. <http://www.stevenswater.com>.
- 235 19. United State Environmental Protection Agency (USEPA). Drinking water standard
236 and health advisories. 2012; 3 – 4.
- 237 20. World Health Organization. (WHO). Sulfate in Drinking-water: Background
238 document for development of WHO Guidelines for Drinking-water Quality.
239 WHO/SDE/WSH/03.04/114. 2004; 1-8.
- 240 21. Okeke, P. N. & Adinna, E. N. Water Quality Study of Otamiri Otamiri-oché River in
241 Owerri, Nigeria. *Universal Journal of Environmental Research and Technology*,
242 2013; 3(6): 641-649.
- 243 22. Kistemann, T. ClaBen, T. Roch, C., Dangendorf, F., Fischede, R., Gebel, J., Vacata,
244 V., and Exner, M. Microbial Load of Drinking Water Reservoir Tributaries during
245 Extreme Rainfall and Runoff. *Applied and Environmental Microbiology*. 2002;
246 68:2188-2197.
- 247 23. Akpan – Idot, A. U., Ibrahim, A. & Udo, J. A. Water Quality assessment of Okpauku
248 Otamiri-oché River for Drinking and Irrigation uses in Yala Cross River State,
249 Nigeria. *Research Journal of Environmental Science*, 2012; 6(2): 210-221.
- 250 24. Onyegeme-Okerenta, B. M., Obia, C. & Wegwu, M. O. Physicochemical properties of
251 water quality of Imeh, Edegelem and Chokocho communities located along Otamiri-
252 oché River in Etche Ethnic Nationality of Rivers State, Nigeria. *Journal of Applied
253 Science and Environmental Management*, 2016; 20(1): 113-119.