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ASSESSMENT AND MODELLING OF ORHIONMWON RIVER, IKPE COMMUNITY, EDO STATE

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Abstract

Assessment and modeling of water quality is essential for ecosystem management. Ikpe community has an area of 120 km^2, its main land use is for fishery and agriculture. Orhionmwon River through the community is polluted mainly with untreated waste water discharged from the community and due to surface runoff from adjacent draining lands. River's water quality modeling is needed for this River.

Five sampling points were established along the river to investigate the effect of the community discharge on the river water quality. At each point several field measurements were conducted for stream velocity and flow, and water samples were collected monthly and analyzed for Colour, Taste, odour, pH, Temperature, DO, BOD, Alkalinity and Hardness. Water quality of the stream was modeled using QUAL2Kw. The model was calibrated for DO profile and BOD using measured values.

Considerable changes were detected along the stream as DO changed due to aeration in natural stream from an average 11.65 mg/l upstream to DO level of 10.70 and 10.30 mg/l at the following two sampling points of discharge, and also due to natural treatment in the river, the DO level rose to 12.1 mg/l at the downstream. Correspondingly, BOD changed due to significant discharge of organic products from 2.0 mg/l upstream to 6.1 mg/l at points of discharge, and gradually fell to 2.6 mg/l. Stream management and restoration techniques are recommended for Orhionmwon River, There should be a designated area for dumbing of wastes. River sanitation monitoring team should be set up to monitor and ensure the sanitation along the river course.

1.0 INTRODUCTION

All life on earth depends on water. Water is defined as a very essential part of protoplasm and that it creates a state for metabolic activities to occur effortlessly; therefore, no life can exist without water [1].

Access to safe water is a fundamental human need and therefore a basic human right. Contaminated water jeopardizes both the physical and social health of all people. It is an affront to human dignity. Yet even today, clean water is a luxury that remains out of the reach of many. Worldwide, more than a billion people have no access to improved water sources, while nearly two and a half billion live without basic sanitation, these people rank among the poorest in the world as well as the least healthy, the absence of a safe water supply contributes to an estimated 80 per cent of disease and death in the developing world.

Water quality refers to the chemical, physical, biological, and radiological characteristics of water [2]. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose [3]. It is most frequently used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact, and drinking water. Water is said to be portable if it is fit for human consumption. The World Health Organization (WHO) prescribed that water intended for human consumption must be free from diseases causing organism and from concentration of chemical substances that may be hazardous to human health [4]. A good water is described as wholesome and palatable (that is, it is free from diseases, organisms, poisonous substances and excessive minerals and organic matter). Similarly a good water must be significantly free from colour, turbidity, taste, odour and it should be well aerated.

Environmental degradation, deterioration and underdevelopment are top public issues both at national and international levels [5]. It has been noted that due to rapid industrialization and its associated effects on our environment, there have been an increase of instability in our aquatic ecosystem.

Water quality deterioration in rivers usually comes from excessive nutrient inputs, eutrophication, acidification, heavy metal contamination, organic pollution and obnoxious fishing practices. The effects of these "imports" into the reservoir do not only affect the socio-economic functions of the reservoir negatively, but also bring loss of structural biodiversity of the reservoir [6]. Inhabitants of Ikpe community and environs discharge their effluents into Orhionmwon River that flows through the suburb of the community, and this poses a serious threat to the lives of the residents that depends on the river as a source of water for their domestic uses.

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A major relevance of this research work is in the aspect that it gives a clear insight of the qualities of the Orhionmwon. River especially around the point where the sewage and organic effluents are discharge into the river. The research will assist in establishing a reliable monitoring and management policies. Also, this is of crucial importance as the water from the river is often used by the populace of the Ikpe communities and environs for drinking, domestic purposes and for fishing activities. This research is also expected to serve as a support aid to any further research about water quality modelling or any other related study and to experimentally ascertain the self-purification characteristics of the Orhionmwon River.

2.0 METHODOLOGY

2.1 Description of study area

Ikpe is a community in the suburb of Ikpoba Okha Local Government Area of Edo State. The major source of water to the community is the Orhionmwon River. Orhionwmon River is categorise as fourth order stream situated within the rainforest belt of Edo State, southern Nigeria. It serves as a source of water for commercial activities such as fishing, as a means of water transportation, as a means of recreation activities (such as swimming) especially for the indigenes. Its basin perimeter ranges from northern latitude $6^{0}12^{1}14.85^{11}$ and eastern latitude $5^{0}45^{1}36.44^{11}$(National Geospatial-Intelligence Agency).

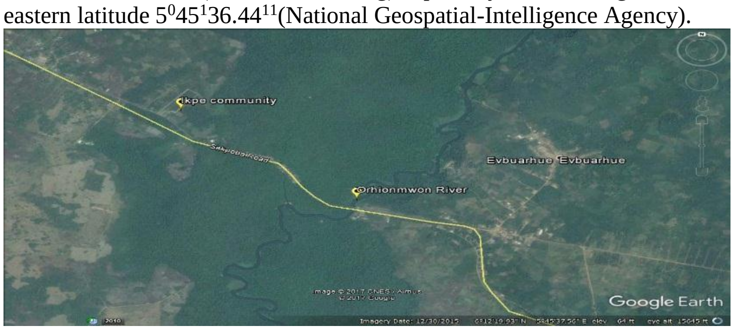

Figure 1. Google Map imagery showing Orhionmwon River, Ikpe community.

2.2 TESTING METHOD

In this study, laboratory testing method was sufficiently adopted for assessing and monitoring the selected water parameters as this method provides a favorable analytical environment for precision and accuracy of results.

2.2.1 SAMPLES AND SAMPLING METHOD

Samples were collected with wide mouthed 1-liter testing kit with cover at a considerable distance away from the river bank using a canoe. To obtain samples, the cover lids were removed and the container plunged below the water surface at a sufficient depth, neck downwards. The container was then titled until the neck pointed slightly towards the current.

The sample kit used to obtain samples were previously washed with distilled water and further rinsed with water collected at sample point three times before samples were collection. Labelling of sample container was done for easy identification. The samples were taken to the chemical laboratory where they were cooled in a freezer until physicochemical analysis was carried out. The samples were collected between the hours of 8.00am and 11.00am believing that domestic waste discharge and concentration are constant. It was also believed that the river water does not exhibit sudden change in flow and quality so that any sample obtained at any time on a particular day is a true sample.

2.2.2 LABORATORY ANALYSIS OF SAMPLES

These samples were taken to the laboratory for analysis of several key parameters which form the basis of the primary data used. These parameters include: temperature, pH, chemical oxygen demand (COD), suspended Solids (SS), biological oxygen demand (BOD), dissolved oxygen (DO) and turbidity. The results obtained from the laboratory investigations of the effluent samples collected along the stretch of the river at intervals of 50 m, were analyzed and subsequently used for calibration of the model for river simulation.

2.2.3 PHYSICOCHEMICAL TEST

The tests that were carried out to determine the physiochemical water quality parameters for the water samples include; Color, odor, taste, pH, temperature, alkalinity, dissolved oxygen, hardness, Biochemical oxygen demand.

2.3 DETERMINATION OF WASTE WATER AND STREAM CHARACTERISTICS

2.3.1 FLOW CALCULATION

During the sampling events, average river depth, width, and velocity were measured. Velocity measurements were done using floating object method. Distance and travel time was measured for partially submerged floating object (orange) to calculate the surface velocity of stream flow. The velocity measured was calculated using equation 1 shown below.

$$\text{Velocity} = \frac{Distance}{Time} \qquad (1)$$

Orhionmwon river flow was calculated by velocity area method, the product of velocity and cross sectional area gives the flow.

Orhionmwon River maximum width is about 12.5m, and depths of less than 5m, also the apparatus used in flow measurements (tape, handmade measuring rod, ropes), it couldn't give width and depth in more details for subsections or increments, and so the depth measured along the cross section and the average depth was calculated, this average depth multiplied by the total stream width according to equation 2:

$$A_{ave} = D_{ave} * W \qquad (2)$$

Where
A_{ave}: average cross section area, (m^2)
D_{ave}: average depth of water (m)
W : width of the stream (m).

2.4 WASTE WATER QUALITY PARAMETERS
Collected samples were analyzed in the Lab within 3hrs from collection for BOD, while pH was done within 24 hrs, Alkalinity, hardness and DO were done during 7days of sampling date. Test procedure in the laboratory was carried out according to standard method, in specific APHA 507 for BOD, ASTMD 888-92 for DO, ASTMD 1067-92A for Alkalinity, ASTMD 1126-96B for Hardness, ASTMD 1293B-90 for PH. Procedures of Standard methods EPA 1979 for temperature was followed.

2.5 DATA ANALYSIS
QUAL2E model with its new versions (Q2K, Q2Kw). Model QUAL2Kw (Q2Kw) was used for Orhionmwon River modeling.
Q2K model represents a modernized version model QUAL2E where both are based on Streeter Phelps equation, and QUAL2Kw for Chapra and Pelletier1987 is adapted from Q2K. The model Q2Kw is implemented in Microsoft Windows environment, it is programmed in windows macro language visual Basic VBA, and it uses excel as graphical user interface, Q2Kw is one dimensional model (i.e. well mixed channel laterally and vertically), with steady state, non uniform flow, the heat budget, temperature and water quality variables are dynamically simulated on a dial time scale.
DETERMINATION OF THE DE-OXYGENATION CONSTANT $\boldsymbol{Kd}$ AND ULTIMATE (BOD) $\boldsymbol{Lo}$, USING THOMAS SLOPE METHOD
DO modeling for Orhionmwon River was carried out to determine the main processes and constants of reaction rate that affect DO level in Orhionmwon River. The first process considered is oxygen consumption of organic matter oxidation and secondly nitrification. Nitrogenous and carbonaceous rate constants of waste water oxidation were estimated using Thomas method, Results of rate constants and parameters are summarized below in the results section. Considering the Thomas Equation equation 3 below

$$\left(\frac{t}{y}\right)^{\frac{1}{3}} = (KLo)^{\frac{1}{3}} + \left(\frac{K^{\frac{2}{3}}}{6Lo^{\frac{1}{3}}}\right) \quad (3)$$

Modifying equation (3) by putting $K = 2.3K_d$ will yield

$$\left(\frac{t}{y}\right)^{\frac{1}{3}} = (2.3KdLo)^{\frac{1}{3}} + \left(\frac{K\,d^{\frac{2}{3}}}{3.44Lo^{\frac{1}{3}}}\right)t \quad (4)$$

Comparing equation (4) with the straight line equation Z = bt + a gave the following relationship

$$Z = \left(\frac{t}{y}\right)^{\frac{1}{3}} \quad (5)$$

$$a = (2.3KdLo)^{\frac{1}{3}} \quad (6)$$

$$b = \left(\frac{K\,d^{\frac{2}{3}}}{3.44Lo^{\frac{1}{3}}}\right) \quad (7)$$

Plotting $\left(\frac{t}{y}\right)^{\frac{1}{3}}$ as a function of t, the slope (b) and intercept (a) of the line of best fit can be use to estimate k_d and L_o as follows:

$$K_d = 2.61\frac{b}{a} \quad (8)$$

$$L_o = \frac{1}{2.3Kda^3} \quad (9)$$

Where y = exerted BOD
K_d = de-oxygenation rate
L_o = ultimate BOD
a and b are constant

3.0 RESULTS AND DISCUSSION
3.1 ASSESSMENT OF STREAM QUALITY
Table (1) shows the average values of field and laboratory results of parameters used in the model.
In Table (1), average DO in the river varied from 11.65 at upstream to 10.70 mg/l at Pt2, and also a decrease was noticed at Pt3, it was round 10.30 mg/l, and it increased until downstream to 12.10 and 10.75 at Pt4 and Pt5 respectively. The illustration of this DO changes, at upstream DO level is increased due to natural treatment and natural stream aeration, and DO reduction in the downstream might be resulted from the existence of diffused pollution sources in the discharge point.

Table 1. Average Field and Laboratory Result

Sampling location	Flow measurement			Average BOD_5 Mg/l	Average DO Mg/l
	# of Samples	Velocity m/s	Flow m^3/s		
Pt1	8	0.316	106.93	2.00	11.65
Pt2	8	0.316	60.50	6.10	10.70
Pt3	8	0.316	57.53	3.65	10.30
Pt4	8	0.316	63.00	2.60	12.10
Pt5	8	0.316	63.60	3.20	10.75

Table 2. Computation of $\left(\frac{t}{y}\right)^{\frac{1}{3}}$ using BOD values of point 1 for 21 days

Time (day)	**Y**	$\left(\frac{t}{y}\right)^{\frac{1}{3}}$
1	1.6	0.86
7	2.4	1.43
14	0.8	2.60
21	2.4	2.06

Using the values from the table, the graph of $\left(\frac{t}{y}\right)^{\frac{1}{3}}$ against Time is plotted in order to determine the values of L_o and K_d .

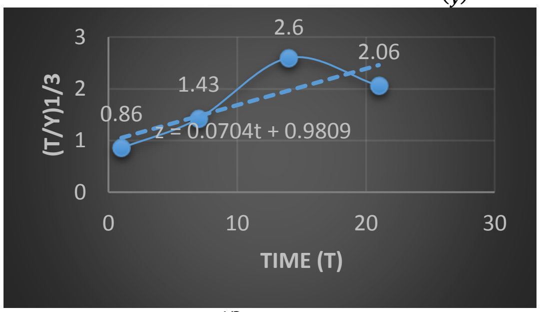

Figure 2. plot of (t/y) $^{1/3}$ against time (t)

From figure (2) Slope = 0.0704 while intercept = 0.9809

From equation (8) $k_d = 2.61^{\frac{b}{a}}$ where

a = 0.9809 and b = 0.0704

$K_d = 2.61^{\frac{0.0704}{0.9809}} = 1.072$

Estimating ultimate BOD from equation (9) yields

$L_o = \frac{1}{2.3 \: x \: 1.072 \: x \: 0.9809^3} = 0.431$mg/l

3.3 Determination of Re-Aeration Constant Using O' Connor Model

The re-aeration constant, K_r is determined using O' Connor model as shown in the equation below.

$$K_r = \frac{3.9 \mathcal{V}m^{0.5}\sqrt{(1.037)^{T-20^o}}}{Davg^{\frac{3}{2}}} \quad (10)$$

Where:

V_m = mean stream velocity = (0.3171m/s);

D_{avg} = average depth of river = (4.2 m);

And T = average temperature of stream.

Since the average temperature of stream is 28.82°C

$$K_r = \frac{4.58 \mathcal{V}m^{0.5}}{Davg^{\frac{3}{2}}} \quad (11)$$

Therefore

$K_r = \frac{4.58 \: x \: 0.3171^{0.5}}{4.2^{\frac{3}{2}}} = 0.30$

3.4 Computation of Hydraulic Characteristics Of The River

3.4.1 Sampling Location

The figure below shows the points the various samples were collected with respect points

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Pt 1 (150m) Pt 2(50m) Pt 3 (150m) Pt (50m) Pt 5

Figure 3. Sampling location

3.4.2 Flow calculation

3.4.2.1 Velocity area method

The discharge was measured using the velocity area method as shown below.

$$Q = V_{ave} * A_{ave} \quad (12)$$

Velocity measurement

Surface velocity, V_s; use of object float method

Mean velocity, $V_m = 0.85 \: V_s$ (13)

Surface velocity = $\frac{distance \: of \: object \: travel}{travel \: time}$ (14)

$= \frac{0.76m}{2.04s} = 0.372$m/s
Mean velocity = 0.85 * 0.372 =0.3162m/s
Area Measurement
$Area_{ave} = Depth_{ave} * Width$ (15)
= 8.0m * 42.3m = 338.4m^2
Therefore, river flow or discharge = 338.4 * 0.316 = 106.93 m^3/s

3.5 Model Implementation

3.5.1 Hydraulic data

The total 400m length of Orhionmwon River was discretized into 5 source points. The headwater data describes the upstream boundary condition. The steady state data measured from May to June 2017 were used in assessing the water quality, Table3 summaries the data below.

Table 3. Stream Hydraulic Characteristics

Source	Length (m)	Width (m)	Depth (m)	Velocity (m/s)	Flow (m^3/s)
Pt 1	0	42.3	8	0.316	106.93
Pt 2	150	35.0	6.0	0.316	60.50
Pt 3	50	33.1	5.5	0.316	57.53
Pt 4	150	33.3	6.3	0.316	63.00
Pt 5	50	33.4	6.5	0.316	63.60

3.5.2 Biological data

Orhionmwon River monitoring under current conditions was carried out for early dry season with minimum flow conditions, for four weeks. The weekly data monitored along with the respective sampling periods are summarized below in table (4) to table (7)

Table 4. Week one (1) result

Sampling location	# of samples	BOD (mg/l)	DO (mg/l)
Pt1	2	1.6	15.6
Pt2	2	9.2	12.4
Pt3	2	4.0	11.2
Pt4	2	4.0	16.4
Pt5	2	4.4	14.4

Table 5. Week 2

Sampling location	# of samples	BOD (mg/l)	DO (mg/l)
Pt1	2	2.4	8.0
Pt2	2	4.0	11.2
Pt3	2	4.4	11.2
Pt4	2	0.0	8.4
Pt5	2	2.4	8.6

Table 6. Week 3

Sampling location	# of samples	BOD (mg/l)	DO (mg/l)
Pt1	2	0.8	8.0
Pt2	2	3.6	12.0
Pt3	2	2.4	10.4
Pt4	2	2.4	9.2
Pt5	2	3.2	10.4

Table 7. Week 4

Sampling location	# of samples	BOD (mg/l)	DO (mg/l)
Pt1	2	2.4	7.6
Pt2	2	2.0	6.8
Pt3	2	2.2	7.6
Pt4	2	2.4	7.2
Pt5	2	1.6	5.6

3.5.3 Physical parameters
Table 8. Result of other physical parameters

Sampling location	# of samples	Taste	Colour	Odour	pH	Temp (°C)	Alkal-inity	Hard-Ness
Pt 1	2	tasteless	colourless	odourless	6.01	28.6	12.2	3.2
Pt 2	2	tasteless	colourless	Odourless	5.90	28.7	24.4	6.4
Pt 3	2	tasteless	colourless	Odourless	5.91	28.7	18.3	9.6
Pt 4	2	tasteless	colourless	Odourless	5.86	28.8	6.1	4.8
Pt 5	2	tasteless	colourless	odourless	5.73	29.3	30.5	6.4

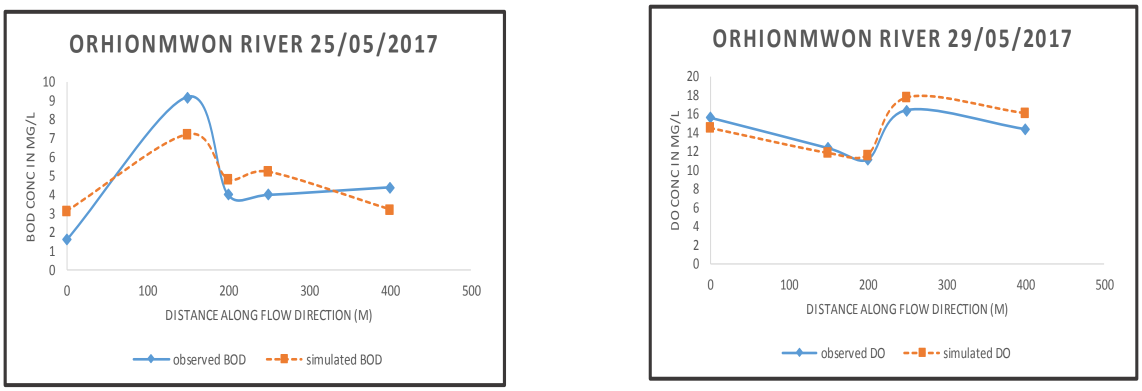


Figure4. Observed and simulated BOD AND DO against distance along flow direction for week 1

3.6 Stream Modelling Results

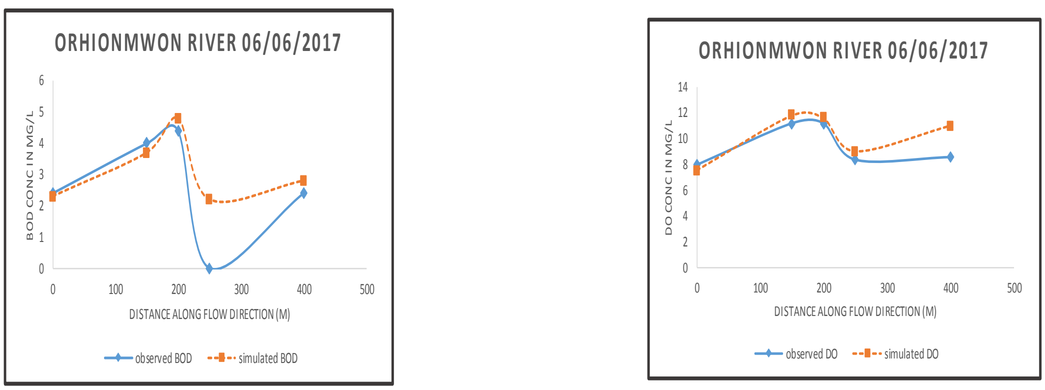


Figure5. Observed and simulated BOD AND DO against distance along flow direction for week 2

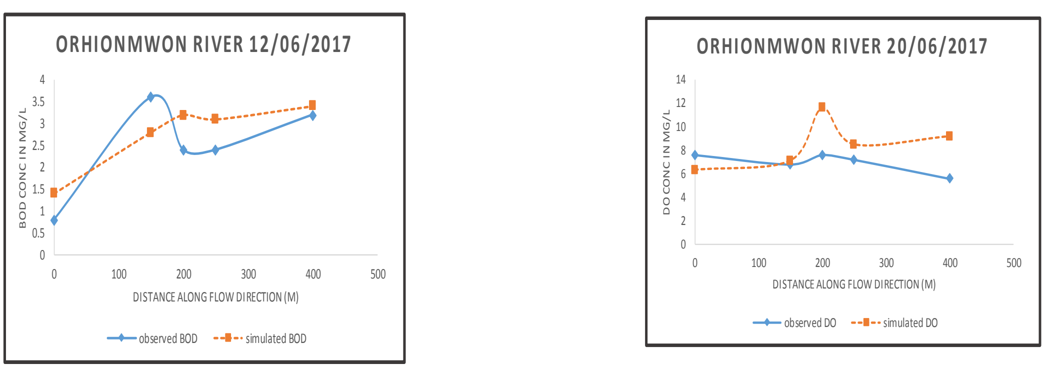
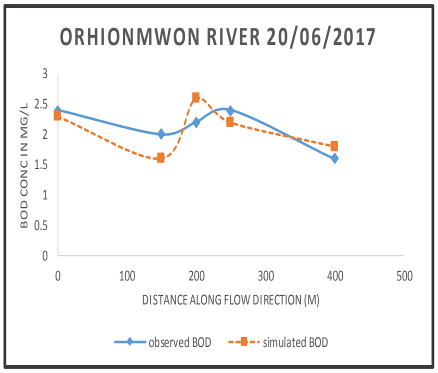


Figure6.observed and simulated BOD AND DO against distance along flow direction for week 3



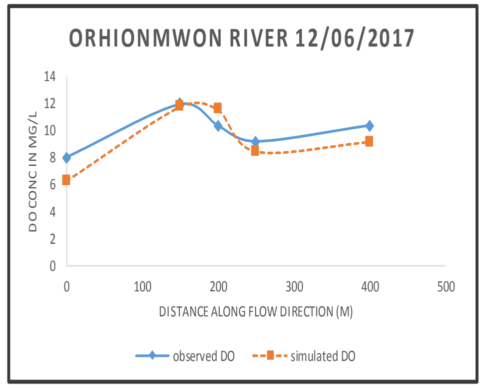


Figure7. Observed and simulated BOD AND DO against distance along flow direction for week 4

Assessment of water quality for Orhionwmon River indicates that untreated wastewater discharged at upstream is the main source for pollution as results of the measured quality parameters revealed. For example, BOD_5 was in the range of 9.2 – 0 mg/l along the stream, average BOD_5 of 2.0 mg/l at upstream, a significant increase to 6.1mg/l is shown at the point of organic discharge, there is an observed decrease at downstream to 2.6mg/l. The increase in quality parameters with decreasing DO level happened at points 2 and 3, may be due to diffused pollution sources at the reaches, with an average value of 11.65 mg/l at point 1, 10.30mg/l at point 3 and sudden increase is observed at point 4 of the river downstream by natural treatment. pH range along the stream was 5.73-6.01 which is considerably beyond recommended standards.
As quality indicator, increasing flow was consistent with low BOD at downstream, but no such relation can be indicated discharge point as the flow is wastewater only, and the increasing flow did not mean that there was dilution. Modeling for the stream was done for conditions of minimum DO level with minimum flow.

CONCLUSION
Assessment of water quality for Orhionmwon River indicates that untreated Waste Water discharged at the discharge point is the main source of pollution, as it was shown by very high values of water quality parameters at the upstream which causes stream degradation. Other sources of pollution can be illustrated due to human activities and sanitation conditions of stream‘s surrounding communities, or due to land use, that cause unstable and in some instances decreased DO level.
At downstream with increasing flow, BOD concentration decreased, but at upstream increased flow was not consistent with BOD reduction. This is because the increased flow at upstream is mainly Waste Water, and increasing flow does not mean that there was dilution to get low BOD values.
Modeling Orhionmwon River for early dry season and critical conditions of minimum flow gave good results compared with measured ones for DO and BOD. The results of DO profile showed increased DO level at upstream conditions, a significant decrease at discharge points, followed with an observed increase at downstream. A reverse condition was observed for BOD. There should be a designated area for dumbing of wastes. River sanitation monitoring team should be set up to do amongst other things 1. Monitor and ensure the sanitation along the river course 2. Appropriate sections of the river course for different uses, such as bathing, recreation, domestic and Agricultural use.

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