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SEASONAL VARIATION IN WATER QUALITY OF ORLE RIVER BASIN, S. W. NIGERIA.

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ABSTRACT

The seasonal variation of water quality of Orle River and its tributatries in S.W. Nigeria was investigated forthnightly or two weekly interval for eight months from November 1987 to June 1988. A total number of 336 observations were taken in six study sites within the drainage basin. The rivers drain both basement complex and sedimentary rocks. This geological background and the anthropogenic nature of the environment are sufficient indication of pollutional stress on the rivers. The study reveal that the chemical indices of pollution such as Biochemical Oxygen Demand (BOD_5), and Dissolved Oxygen (DO) vary significantly between the seasons. Likewise, Biochemical Oxygen Demand (BOD_5), Dussolved Oxygen (DO) and Chemical Oxygen Demand (COD) show increase in the wet season and decrease in the dry season. On the other hand total hardness show increase in the dry season and decrease in the wet season. The rivers are considered to be more polluted in the wet season than in the dry season. Surface water quality has many effects on human use of water resources, water being a basic natural resource required by all human being and the modern technological society.

KEYWORD: water quality, river basin, wet and dry seasons; pollution.

INTRODUCTION

A water quality criterion is a quantity usually developed through scientific experiments upon which a judgment can be based. A criterion may be based on morbidity or on chronic toxicity of the various substances to human or aquatic life. The criterion may be related to techniques employed in removing the substances from water or based on people's visual preference.

Pollution is an undesirable change in the physical, chemical and biological characteristics of water that may or will harmfully affect human life, or that of other species, the industrial process, living condition, and cultural assets or that may or will waste or deteriorate our raw material resource, (Spilhaus, 1966, Ogbeibu et al, 1995, Ikhile, 2004). A river is said to be polluted if it is turbid, has foam on the surface, has an objectionable smell, does not support fish and other living organism.

Dix (1981) views water pollution as the condition in water which adversely affects the aquatic ecosystem in terms of the living organisms, oxygen content and the presence of toxins. He holds that a river is polluted when the water in it is altered in composition directly or indirectly as a result of the activities of man so that it is less suitable, for all or any of the purposes for which it would be suited in its natural state. Pollution is a natural or induced change in the quality of water which renders it unsuitable or dangerous as regards food, human and animal health, industry, agriculture or farming, fishing and leisure pursuit. Spilhaus (1966) has already grouped pollutants entering water courses into eight broad categories. These can be grouped into three major classes according to the sources:

1. Pollutants derived from the introduction of clay, through improper control of soil mining, lumbering and agricultural practices (Hussain et al, 2008)
2. Pollutants derived from in-flow of materials from industrial operations which directly poison the waters or otherwise make the environment uninhabitable Tobieszewski et al (2010) and
3. Pollutants originating from the dumping of domestic sewage or industrial waste (Kazi et al 2009).

These enter the biological processes and result in

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the lowering of the oxygen concentration below the limit of tolerance of the original inhabitants.

Natural waters which have not been polluted should contain clean water, with ambient temperature and should be free from most suspended solids, coloration, surface scum or foam, obnoxious odor or taste. It should contain adequate amount of oxygen, a correct balance of dissolved chemical nutrients to support life and an absence of excessive organic matter and toxic substances.

Some workers have discussed some aspects of river pollution. Thus Ajayi and Osibanjo (1981) studied twenty- six rivers during the dry season periods of 1977 and 1978.None of the rivers studied can be classified as excellent based on Prati et al (1971) classification.

Table 1: Classification of Surface Water Qualities (after Prati et al, 1971)

	Class1 Excellent	Class11 Acceptable	Class 111 Slightly Polluted	Class 1V Polluted	Class V Heavily Polluted
pH	6.5-8.0	6.0-8.4	5.0-9.0	3.9-10.1	3.9-10.10
DO (MgO_2 1^{-1})	7.8	6.2	4.6	1.8	1.8
BOD (MgO_2 1^{-1})	1.5	3.0	6.0	12.0	12.0
NH_3 (Mg/l)	0.1	0.3	0.9	2.7	2.7
COD (MgO_2 1^{-1})	10	20	40	80	80
Cl (Mg/l)	50	150	300	630	620
Fe (Mg/l)	0.1	0.3	0.9	2.7	2.7

Only six of the rivers are definitely of acceptable quality, eleven were described as more or less polluted while the remaining nine were found to be "polluted naturally". The pollutional stress on these rivers was considered to arise from natural sources because they display low pH and Dissolved Oxygen (DO) and a high Biochemical Oxygen Demand (BOD), even though they were regarded as free from pollutional stress resulting from human activities. These rivers flow through the fresh water swamp forest area of South-Western Nigeria where the drainage and catchment areas are very rich in decaying organic matter and humus. This accounts in the main part for the poor quality of these rivers.

Ohagi (1983) conducted a study of the physic-chemical and micro-biological quality of the Ikpoba River. She worked on the pollutional extent of the Ikpoba River and checked the variations of some physic-chemical parameters which might affect the quality of the water as a raw source for the Ikpoba Dam water supply project. She noted that the physic-chemical parameters fall within the World Health Organisation (WHO, 1971) acceptable and permissible ranges, except that the water requires clarification to reduce the turbidity during the rainy season. She observed high Chemical Oxygen Demand (COD) values.

Similarly, Shrestha et al (2007) for the Fuji River Basin in Japan observed a large varifactors for 13 study sites for 8 years (1999-2005). The varifactors obtained from factor analysis indicate that the parameters responsible for water quality variations are mainly related to discharge and temperature (natural), organic pollution (point source: domestic wastewater) in relatively less polluted areas; (LP) organic pollution (point source: domestic wastewater) and nutrients (non-point sources: agriculture and orchard plantations) in medium polluted areas (MP); and organic pollution and nutrients (point sources: domestic wastewater, wastewater treatment plants and industries) in highly polluted (HP) areas in the basin. Discriminant analysis gave the best results for both spatial and temporal analysis. It provided an important data reduction as it uses only six parameters (discharge, temperature, dissolved oxygen, biochemical oxygen demand, electrical conductivity and nitrate nitrogen), affording more than 85% correct assignations in temporal analysis, and seven parameters (discharge, temperature, biochemical oxygen demand, pH, electrical conductivity, nitrate nitrogen and ammonical nitrogen), affording more than 81% correct assignations in spatial analysis, of three different sampling sites of the basin. More recent works on aspect of river pollution include Prior et al (2002), Sherestha et al (2008), Hussain et al (2008), Jones et al (2009), Kazi et al (2009), Tobiszewski et al (2010) amongst others. They all agreed that water pollution is occasioned by anthropogenic activities and natural causes.

The Orle River Basin with diverse geological background, multiple forest ecosystems, divergent environmental conditions, in addition to varied anthropogenic characteristics is bound to reflect the influences of the natural and socio-cultural environments. This therefore necessitated investigation of the chemical indices of pollution and potability of the river water. Also, in addition to personal use, water is for many other purposes amongst which are public water supplies used by domestic households for drinking, cooking, dish washing, general cleaning, laundering, personal washing and bathing, air conditioning, sewage disposal, car washing and garden watering.(ii) Industrial water supplies involves industrial processes which require large quantities of water for cooling , steam raising material processing and disposal of wastes.(iii)Water is used in large quantities for the generation of electricity by the Power Holding Company of Nigeria (PHCN) (iv) The agricultural industrial uses some quantities of water for dairy processing, animal hygiene, stock watering and land irrigation.(v) Water is also required for amenity and recreational purposes. Water is used for swimming, fishing, boating, sailing, and a means of transportation for pleasure or commercial purposes.

The Study Area

A description of the study area has been detailed in the works by Hockey et al, (1986), Ikhile et al (2003) and Ikhile (2004).

The essential features include a rich diverse forest ecosystem that release continuously decaying organic materials into the river systems. Also included is a diverse geologic setting made up of the basement complex rocks and sediments of different geological periods, e.g the main geologic units are:

- the crystalline basement complex rocks
- the cretaceous sedimentary rocks
- the tertiary sediments and
- the alluvial sands (Figure I)

The rivers take their sources from the area underlain by the Precambrian Basement Complex rocks in the northwestern fringes of the basin where the rocks are strongly folded. They consist of five sub-groups: (i) flaggy quartz-biotite and gnesis; (ii)the mica-schist; (iii) the quartz and the quartz-schist; (iv)the metaconglomerates and(v) calc-gnesis and marble (Nigerian Geographical Surveys Bulletin 39, 1986). The flaggy quartz-biotite and gnesis is the strongest here, they resist weathering to some extent and result in more pronounced topography than the others. The mica-schists contain biotite-schist and muscovite-schist, they are usually found as small exposures in stream channels and are strongly weathered. Due to their very low resistance to weathering compared with other rocks in the area, deep, active erosion has exposed them and they have become fine-grained.

At the source of Orle River, outcrops of metaconglomerate abound. Quartz and biotite are the essential minerals, although calcite, green hornblende, tremolite-actinolite, diopside and feldspar are also present. Other rocks of importance here are calc-gnesis and marble which are found in the streams and rivers. The second geologic region consists of Cretaceous Sedimentary rocks. This covers the western part of Orle River Basin (Figure 1). Important rock materials here are quartz, feldspar and sandstones.

The third geologic formation is the Tertiary Sedimentary. It covers the central and south-eastern portion of the Orle River Basin. The rocks belong to the Eocene-Paleocene epoch. The formation consists of Imo Shale group and a small portion of the Bende Ameki group. They consist of mudstone/lignite sequence. They therefore resemble the Nsukka formation in age, lithology and environment of deposition. The forth geologic region consists of alluvial sands found mainly at Alegbete where the Orle River enters the River Niger. They are rich in nutrients due to deposition, being derived from both the Pre-cambrian Basement Complex and Sedimentary rocks.

The foregoing discussion of the geology of the study area reveals that:-

1. The quartz-biotite-schist and gnesis contain rocks such as schist and gnesis. The proportion of biotite and quartz in this rock band is usually higher. They confer resistance to weathering. Quartz (SiO_2) is made up mainly of silica whilst biotite-$K(Mg.Fe)_3$ $[(AlSi_3$ $)010].(OH)_2$ contains among other minerals potassium, magnesium, iron, silica and water.
2. The mica-schists have low resistance to weathering and are such are heavily weathered. The main minerals are feldspars potash orthoclase and feldspars plagioclase abite – ($KAlSi_3O_8$, N $aAlSi_3O_8$ – $CaAl_2Si_3O_8$) and quartz. Feldspars are made up of potassium, aluminium, sodium, silica and calcium.
3. The quartzite and quartz schists are made up of muscovite, $KAl_3(AlSi_3)O_{10}.(OH)_2$ and

biotite – $K(MgFe)_3\ Al_3(AlSi_3)\ O_{10}.(OH)_2$. This contains magnesium, iron, potassium, and aluminium among others.

4. The metaconglomerate, calc-gnesis and marble contain hornblende (Ca, Na, Mg, Fe, $Al)_{7-8}\ [(AlSi)_8O_{22}](OH)_2$ and tremolite, diopside, and feldspars. Other common rocks in this group are plagioclase, sphene, zircon, epidote and magnetite. The sedimentary rocks also contain biotite and in some instances quartz.

The discussion above reveals that the minerals found in Orle River are those, which have been found by the World Health Organisation (1971), Jones et al (2002), and Tobiszewski (2010) to affect the quality of river water. These minerals are released through surface water runoff to the streams. Some get to the stream later through underground water re-charge. These minerals affect the quality of the water body as the stream flows through these different geologic terrains (Ikhile et

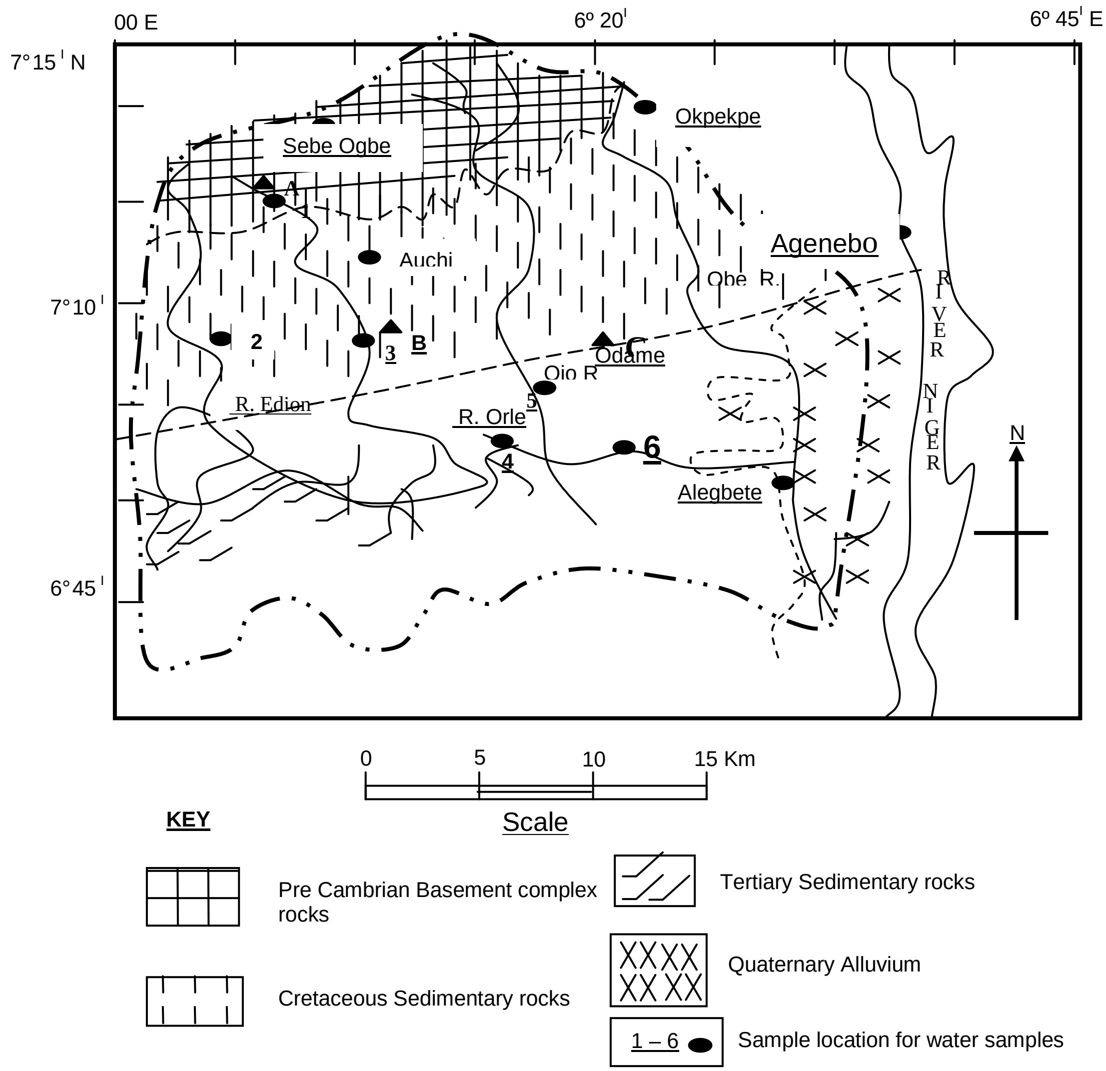
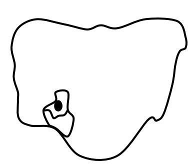


Figure 1: DRAINAGE AND GEOLOGY OF ORLE RIVER BASIN



Sampling and Analysis

Water samples were collected at six different sites labeled 1 – 6 chosen from the Geological map of Orle River Basin (Fig 1). These are areas where the geology changes from one rock type to another and/or at major river junctions. These locations were chosen so as to find out the effect of the geological background over which the major rivers flow within the basin. The locations were regarded as the most representative of these particular geologic formations. The confluences were mainly two and were the most obvious locations to be chosen so as to compare the quality of the water from the individual rivers before joining with any other river. For example, River Edion joins Orle River at the first confluence. They are later joined by the Ojo River. The water samples were collected in the middle of the river close to the bottom in the upstream direction. The water samples were collected in the upstream direction from where the natives normally fetch water. This ensures that the effects of soap for washing, oil in plates and even feaces are excluded. It is usually in the downstream directions of any location that these activities are carried out. In any study involving the seasonal variation in water quality of this sort, the information should be gathered and the quality monitored for at least six consecutive months (WHO, 1971). Water samples were therefore collected fortnightly for 8 (eight) months beginning from November 1987 to June, 1988.A total of 336 samples were collected within this period of investigation.

Water samples were collected with colourless 4 litre plastic bottles fitted with plastic stoppers. A 4-litre quantity of water was regarded as sufficient to determine the various parameters investigated in this study. The bottles were all washed with Teepol solution and rinsed many times with distilled water, and subsequently with the water they were to contain.

The total hardness of the water was determined using flame photometric methods according to standard methods (APHA, 1971).

The 250ml reagent bottles with glass stoppers were used in collecting water for Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD) Permanganate Value (PV) and Dissolved Oxygen (DO). The 250ml reagent bottle was used because this is the amount of water required for determining the oxygen content of the river. DO was fixed on the spot and measured according to Winkler's method (APHA, 1971).BOD_5 was determined in the laboratory by incubating at 20^0C for five days and the dissolved oxygen content re-measured. The difference between the initial DO and the final DO gave the BOD_5 of the water. Chemical Oxygen Demand (COD) was determined using the standardized potassium dichromate solution method (APHA, 1971).

Results of the analysis are presented on Tables 2-6 and Figures 2 and 3.

RESULTS AND DISCUSSION

The mean, minimum and maximum values of parameters measuring seasonal pattern of pollution in Orle River Basin is summarized on Table 2.

Table 2: Summary of Parameters measuring Seasonal Pattern of Pollution in Orle River Basin

Value of Parameters (Mg/l)

Parameters	Dry	Season		Wet	Season	
	Min	Max	Mean	Min	Max	Mean
DO	2.5	10.4	4.83	2.1	36.8	9.30
BOD5	-2.9	3.8	0.37	-5.1	23.8	3.83
COD	-1.8	2.5	0.49	-4.2	20.4	2.21
Total Hardness	5.2	42.7	34.60	4.5	38.5	25.02

Source:(Ikhile,1990)

Dissolved Oxygen (DO) Tables 2, 3 and Figure 2)

A total of eighty - four (84) samples gathered at the six study sites and subjected to analysis gave the results indicated on Table 2 for the dissolved oxygen. The dissolved oxygen (DO) values ranged from 2.5 mg/l to 10.4 mg/l. The minimum value recorded was 2.5 mg/l in the last week of march while the maximum value was 10.4 mg/l recorded in the last week of February. The dissolved Oxygen (DO) values are higher in the wet season than in the dry season, as much as 36.8 mg/l was recorded in May (Table 3).

Table 3: Forhtnightly Variation in DO and BOD_5 (mg/l) in Orle River Basin

Months	Nov	Dec	Dec	Jan	Jan	Feb	Feb	Mar	Mar	Apr	Apr	Apr	May	May	June
DO	4.2	4.1	3.3	6.3	4.8	5.5	4.8	3.3	2.6	9.4	10.8	10.4	36.8	4.35	5.3
BOD_5	-0.20	0.10	-0.40	2.80	4.30	-0.80	-1.70	-0.90	-0.20	4.50	6.20	4.80	23.80	0.35	1.50

Source: (Ikhile 1990)

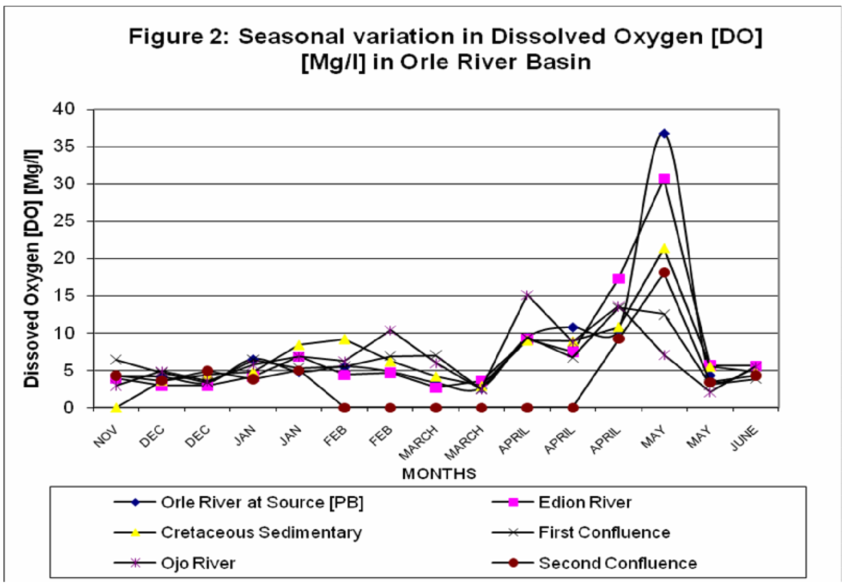


Figure 2: Seasonal variation in Dissolved Oxygen [DO] [Mg/l] in Orle River Basin

Between April and June when the water temperature was high (Ikhile, 2004) DO values also increased. There is a seasonal pattern of variation in DO and a significant difference between the seasonal values 4.83 mg/l and 9.30 mg/l for the dry and wet season respectively (Table 4)

Table 4: Seasonal Variation in Dissolved Oxygen (DO) in Orle River Basin

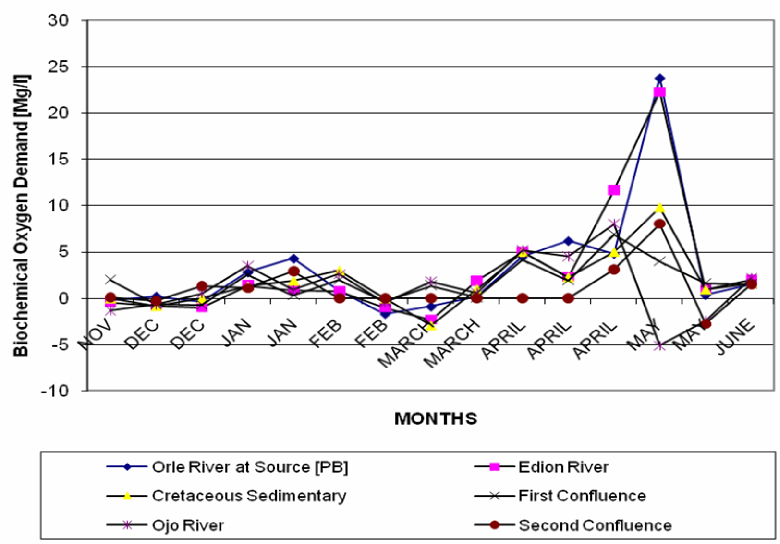
Seasons	No of Samples	Mean	Stand Error	Computed t-value	Degrees of freedom	Tabulated t-value (N-2)df	Remark
Dry	27	4.83	0.27	-4.46	43	2.02	Significant at 0.05
Wet	17	9.30	1.12				

This indicates that there is a significant difference between the dry and wet seasons at 0.05 for DO.

The lower values obtained in the dry season agree with those of Dix (1981) and Shrestha et al (2007) who are of the view that a slow moving river in summer/dry season has a low oxygen content than a fast moving river in the wet season.

Oxygen exists in water as dissolved oxygen (DO). The DO is vital for the respiration of nearly all biological life. It is therefore essential that water should be well aerated for the continuous survival of aquatic life. It is very important to maintain the DO regime, because by lowering the nutrient supplies, it is possible to promote a decrease in the plant (Encyclopedia of Science and Technology, (1982) Shretsha, (2007) Kazi, (2009) and Tobiszewski (2010)

Figure 3: Seasonal variation in Biochemical Oxygen Demand [BOD_5] [Mg/l] in Orle River Basin



Biochemical Oxygen (BOD_5) (Tables 2,3 and Figure 3)

The Biochemical Oxygen (BOD_5) values range between -1.70 and 23.8mg/l in December and May respectively in the drainage basin (Table 3). It ranges between -2.9 mg/l to 3.8 mg/l in the dry season and -5.1 mg/l to 23. 8 mg/l in the wet season. BOD_5 is higher in the wet season (3.83mg/l) than in the dry season (0.37 mg/l). Lower BOD_5 values (including negatives ones) were recorded generally in the dry season. This shows a progressive increase in BOD_5 from -1.70 mg/l in February in the dry season to 23.8 mg/l in May. The values obtained in Orle River Basin is attributed to pollutional stress from natural sources rather than human activities because the rivers flow through areas rich in decaying organic matter. The period also coincided with that in May when the highest DO value was recorded in the river. This probably marks the period when decaying organic leaves and other plant tissues are more in the water. For example, Ajayi and Osibanjo (1981) adopting Prati et al, (1971)'s method on the extent of pollution on Nigerian rivers observed that increased BOD_5 in the raining season lead to pollutional stress from natural sources such as temperature and from the decaying organic matter in the neighbourhood. Similarly, Shrestha et al (2007) investigating the Fuji River Basin in Japan observed the effect of non-point sources such as application of fertilizers in crop farming and decay from orchard plantations. He equally attributed the pollution to organic pollution from non-point sources of domestic wastewaters. But in Orle River basin, these are rural streams/rivers where the effects of domestic waste waters are minimal. In another study,in an irrigation project at Al-Fadhley, Eastern Province, Saudi Arabia, Hussain et al (2008) observed that hydrochemical variables in the quality assessment result from irrigation activities based on fertilizer application. This enhances the amount of decaying organic matter found in the water which increases the BOD_5 values of the water. Thus micro-organisms routinely utilize dissolved oxygen, thereby creating a higher Biochemical Oxygen Demand (Dix, 1981). This is supported by the lower DO values observed in the subsequent weeks following the rains. This caused consequential reduction in BOD_5 as well. BOD_5 values of up to 25.8 mg/l are considered slightly polluted (Prati et al. 1971). Thus the rivers in Orle River Basin are more heavily polluted in the rainy season than in the dry season. Statistical analysis using students "t" test shows that BOD_5 also vary significantly with season as DO at 0.05 level (Table 4).

Table 4: Seasonal Variation in BOD_5 in Orle River Basin

Seasons	No of Samples	Mean	Stand Error	Computed t-value	Degrees Of freedom (df)	Tabulated t-value (N-2)df	Remark
Dry	27	4.83	0.27				Significant
Wet	17	9.30	1.12	-4.46	43	2.02	at 0.05

The Biochemical Oxygen Demand (BOD_5) is one of the most important indices in stream and river pollution studies. It is a measure of polluting organic matter present in a sample of water. BOD_5 is the amount of dissolved oxygen consumed by chemical and microbial action when a sample of water is incubated for five days at 20^0C in the dark.

Chemical Oxygen Demand (COD) (Table 2)

COD is higher in the wet season (2.21 mg/l) than the dry season (0.49 mg/l).The minimum value obtained in the dry season was -1.8 mg/l and the maximum value was 2.5 mg/l. In the wet season the minimum value obtained was -4.2 mg/l while the maximum value was 20.4 mg/l. The COD values in the dry and wet seasons fall within the WHO minimum limit of pollution. The rivers could be said to be excellent based on Prati et al(1971) classification (Table 1) using COD values obtained in Orle River Basin which are generally low (Ikhile, 2004). COD is higher in the wet season than the dry season. COD range between 0.16 mg/l to 1.04 mg/l. Similar reason for seasonal changes in BOD_5 holds for the occurrence of COD in Orle River Basin.

Total Hardness (Table 2)

The hardness of water is a measure of the capacity of the water for precipitating soap. Water hardness results from dissolved salts of Calcium and Magnesium as well as their chlorides. High values of water hardness as an index of water pollution has been found to lead to the formation of scales in water distribution pipelines (APHA, 1971, Akhionbare 1998, Ikhile, 2004).It has also been found that some water with high values of hardness can have laxative effects on the consumers (Ohagi, 1983, Akhionbare 1998, Ikhile 2004). Total hardness is higher in the dry season (34.6 mg/l) than in the wet season (25.02 mg/l) in the river basin (Table 2). High hardness is particularly noticed in the dry season when most of the elements especially calcium and magnesium are also high in the water. Ikhile (1990, 2004) has reported that calcium and magnesium have been washed out from the surrounding country rocks especially the Precambrian Basement Complex rocks and the Cretaceous /Tertiary Sedimentary rock formations that underlie the drainage basin. This is also the period, when lower temperatures were observed in the Basin (Ikhile, 2004). All these factors may have caused the higher total hardness observed in the dry season as compared with the lower hardness characteristic of the rainy season in Orle River Basin.

Table 5: Chemical Indices of Pollution in Orle River Basin compared with WHO (1971) Standards

Quality Parameters	Highest Mean Value for Orle River Basin (Mg/l)	WHOMaximum Acceptable Values (Mg/l)
Chemical Oxygen Demand (COD)	2.21	10
Biochemical Oxygen Demand (BOD_5)	3.83	6
Total Hardness as $CaCO_3$	34.60	500

Source: (Ikhile 1990/WHO 1971)

The values of the chemical indices measuring pollution obtained in Orlr River Basin compared with WHO (1971) maximum allowable standards indicate that the rivers in Orle Basin are not generally polluted. At certain times of the year however some of the values fall outside the maximum acceptable values of WHO (1971) Standards. For example, on Table 3 the BOD_5 recorded in the second week of April is higher than the maximum acceptable value (6.2 mg/l compared with 6.0 mg/l). Similarly, 23.8 mg/l was recorded in the second week of May as against 6.0 mg/l maximum acceptable value of WHO (1971).

CONCLUSION

Considering the results obtained for Orle River basin for the wet and dry seasons when compared with WHO (1971) Standards (Table 5) and the Classification of Surface Water Qualities after Prati et al (Table 1), the following conclusions can be made:

The Dissolved Oxygen (DO) levels of the rivers in Orle River Basin places the rivers in the range of acceptable to excellent rivers in the dry season and slightly polluted to heavily polluted in the wet season (Tables 2 and 3).

The Chemical Oxygen Demand (COD) values (Tables 2 and 3) make the river to fall into the category of excellent rivers. Although the values for water hardness were high throughout the year, they are still acceptable as compared with WHO (1971) standards.

On the average, the river water needs some form of pre-treatment for both domestic and industrial purposes. The natives hardly treat the natural water before use although some of them treat it with alum for domestic uses.

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