

ASSESSMENT OF THE LEVEL OF CONFORMITY OF WUPA SEWAGE TREATMENT PLANT TO ENVIRONMENTAL STANDARDS

Ahmad Hadiza A. and Oludele, J. Ayoola

Department of Geography and Environmental Management, University of Abuja, Nigeria

Corresponding Author's email: abubakar.hadiza@uniabuja.edu.ng



Abstract

Over the last twenty years, Abuja, especially the Federal Capital City (FCC) and its neighbouring satellite towns have witnessed dramatic increase in human population which has exerted so much pressure on waste generation (liquid and solid waste) and surface and ground sources of portable water. It has become unbearable for the Federal Capital Territory Water Board to meet up with the ever increasing demand for portable water. Wupa treatment plant is the only plant that treats wastewater for the entire Federal Capital Territory. Abuja municipal area is designed such that all sewers from households, businesses, companies and government agencies collect together at the sewage treatment plant in Idu industrial Area, this wastewater is eventually released into the Idu River which is the only source of water for Idu community, an outbreak of epidemic from such plant can lead to serious loss to the country. Therefore, this research work focused on the assessment of the level of conformity of Wupa sewage treatment plant, Abuja Municipal Area Council, FCT, having the following objectives; assessing physiochemical analysis of the wastewater influent and effluent, assessing the bacteriological analysis of the wastewater influent and effluent, comparing the physiochemical and bacteriological properties of the water with Federal Ministry of Environment (FMEnv) standard for quality water and determine if the water of the sewage treatment plant conform with environmental standards. It made use of both primary and secondary data. Primary data were through water samples from the treatment plant, total of five (5) samples were collected randomly in selected point from Influent and Effluent of sewage treatment plant and information regarding physiochemical and bacteriological properties of water from the treatment plant was obtained from the laboratory, Microsoft Excel software, Clerk's (1984) Compliance Equation and one-way Analysis of Variance was used to analyzed data. Result obtained showed that value of turbidity (250), total suspended solids (218.7), Biochemical oxygen demand (122.5) and chemical oxygen demand (250) of influent water was higher than value obtained from effluent waste of 3.34, 19.4, 6.5 and 26 for turbidity, total suspended solids, BOD, and COD respectively. Also the value of Total plate count of the influent of 6000 was higher than value of effluent of 2000. The value of turbidity, TSS, COD of influent is higher than the FMEnv standard for quality water, the value of BOD, total plate count on both influent and effluent is higher than the FMEnv standard for quality water. The of values Physico-Chemical parameters of effluent water show 100% compliance with FMEnv standard and 50% for Microbial Bacterial of effluent water except for B.O. D5 which was at 0%. Assessing the level of compliance for sample water before treatment at the influent, value for turbidity, Total suspended solid, Biochemical oxygen demand and Chemical oxygen demand, total coliform and total plate count was at 0% compliance with the standard. Therefore, the following recommendation were made that a thorough and formal environmental audit of the facility be done as non has been done since the facility was setup in 2006, that more should be done with regards to the UV-radiation tank to ensure 100% conformity with FEPA standard of 0 CFU/100ml, effort should be made at improving the solid waste

management of the plant, sorting of waste at source should be made mandatory and a recycling policy be put in place.

Keywords: *physiochemical, heavy metal properties, Sewage treatment plant and Environmental Standards*

Introduction

Until environmental awareness intensified, a surprising number of large Nigerian cities had only a rudimentary sewage treatment system or no system at all. Raw sewage, untreated or nearly so, was simply discharged into rivers or oceans. A flowing, well aerated stream is capable of considerable self-purification. Therefore, until expanding populations and their wastes exceeded this capability, this casual treatment of municipal wastes did not cause problems. In Abuja, most cases of simple discharge in the Municipal Area Council have been improved upon. But this is not true in other area councils (Osi, 2003).

Sewage or Wastewater is water containing dissolved and suspended solids from municipal or industrial sources. Wastewater is about 99% water by volume and is generally referred to as influent as it enters the wastewater treatment facility. Wastewater implicitly is negatively valued: water that is wasted and that needs treatment prior to discharge into an environmental sink. Wastewater (sewage) is a serious source of water pollution due to its composition (Singleton, 1999). Pollution of water with sewage leads to the introduction of chemical contaminants and pathogenic organisms such as bacteria, viruses, protozoa and helminthic worms (Osi, 2003). One of the key issues in water-resource management is the (indirect) re-use of waste water for drinking water supply or for industrial or agriculture purposes because of the scarcity of pristine waters (Van Beelen, 2007).

Over the last twenty years, Abuja FCT, especially the Federal Capital City (FCC) and its neighbouring satellite towns have witnessed dramatic increase in human's population which has exerted so much pressure on waste generated (liquid and solid waste) and surface and ground sources of portable water. It is thus unexpected that quality of portable water in the area will remain unchanged. As population of the territory expands, it has become unbearable for the Federal Capital Territory Water Board (FCTWB) to meet up with the ever increasing demand for portable water. There is now some increasing exploitation of groundwater, by both public and private institutions through digging up of boreholes and open wells. In addition, sales of sachet and bottled water are a very common enterprise in the territory. In fact, many houses especially outside the FCC now rely on sources beside the tap water for their portable water supplies. Given the potential effects of human activities on quality of these various portable water sources, there is a valid reason to be concerned about the issue of water quality in the area.

Wupa Sewage treatment plant is the only plant that treats wastewater for the entire Federal Capital Territory, poor treatment of such plant can lead to contaminated of water at the receiving end leading to outbreak of disease. An outbreak of epidemic from such water can lead to serious health risk to community at the receiving end and Abuja at large. Abuja municipal area is designed such that all sewers from households, businesses, companies and government agencies collect together at the sewage treatment plant in Idu Industrial Area. This wastewater after treatment is eventually released into the Wupa River which is the main source of water for Wupa community.

To properly understand the quality of potable water in the area, studies that comprehensively look at the amounts of chemical constituents of the major potable water source are required (Ojutiku *et al.*, 2014). Before water can be described as potable, it has to comply with certain

physical, chemical and microbiological standards (USEPA, 2004). Also, integration of empirical studies from researchers, with policy and institutional support roles from government, would indeed provide a plausible and viable synergy necessary for tackling the complex potable water quality issues in Nigeria's urban and peri-urban areas (Akan *et al.*, 2010). These collectively constitute the research problem of this study.

Hence, this paper attempts to assess the level of conformity of Wupa Sewage Treatment Plant to environmental standards. The objective of this paper is to assess physiochemical analysis of the wastewater influent and effluent, assess the bacteriological analysis of the wastewater influent and effluent, compare the physiochemical and bacteriological properties of the water with Federal Ministry of Environment (FMEEnv) standard for quality water and determine if the water of the sewage treatment plant conform with environmental standards.

Conceptual Framework

The conceptual framework was based on the concept of water quality and water pollution by United Nations Environmental Programme/World Health Organization (1996). In the framework, the authors defined water quality as a term used to express suitability. The authors share a similar view with UNEP/WHO; they suggested that, since water is used for different purpose, each particular use will have certain requirements which must be met before the water can be considered good quality for that purpose. These requirements are categorized into physical, chemical and biological characteristics. A good example of these requirements are limits in levels of toxic substance, restriction of temperature and pH ranges in either drinking water or water supporting animal communities most especially invertebrate. The term water quality is not a new concept and the need for ion maintenance has been identified long before now.

Mc Gauley (1968) cited the riparian right which stated that the user of water will not be entitled to diminish it. Water quality is determined by concentration of biological, chemical and physical contaminants. Most water pollution is the result of human activities. Biological contaminants result from human and animal wastes plus some industrial processes. Chemicals enter the water supply from industrial processes and agricultural use of fertilizer and pesticides. Physical contaminants result from erosion and disposal of solid waste. Since all of these sources contribute to the degradation of water quality, standards have developed for drinking water by the US public health service. These standards strive to prevent health problems by defining the quality of water available for human consumption. Many local state and federal regulations have been instituted to prevent contamination of both surface and ground water supplies.

Pollution is defined as to make unclean, impure, contaminate. Water pollution occurs when a body of water is adversely affected due to the addition of large amounts of materials to the water. When it is unfit for its intended use, water is considered polluted. Two types of water pollutants exist; point source and non-point source. Point sources of pollution occur when harmful substances are emitted directly into a body of water. The Exxon Valdez oil spill best illustrates point source water pollution. A non-point source delivers pollutants indirectly through environmental changes; an example of this type of water pollution is when fertilizer from a field is carried into a stream by rain, in form of run-off, which in turn affects aquatic life.

The pollution of rivers and streams with chemical contaminants has become one of the most crucial environmental problems within the 20th century. Waterborne chemical pollution entering rivers and streams cause tremendous amount of destruction to life of human beings and animals. The workers in California use special nets to clean up the California beach after an oil tanker spill. Tanker spills are increasing environmental problems because once oil has spilled, it is virtually

impossible to completely remove it. Even small amounts spread rapidly across large areas of water, because oil and water do not mix, the oil floats on the water and then washes up broad expanses of shoreline. Attempts to chemically treat or sink the oil may further disrupt marine and ecosystems (Brad and Krantz, 2007).

Materials and Methods

Study Area

The Wupa Sewage Treatment Plant is located within the IDU-Industrial Area on coordinates 7°23'00"E, 9°01'00"N next to the Wupa River. It covers an area of 29.79 hectares with surrounding rural settlements. The treatment plant is located at within Abuja Municipal Area Council (AMAC) (see Figure 1).

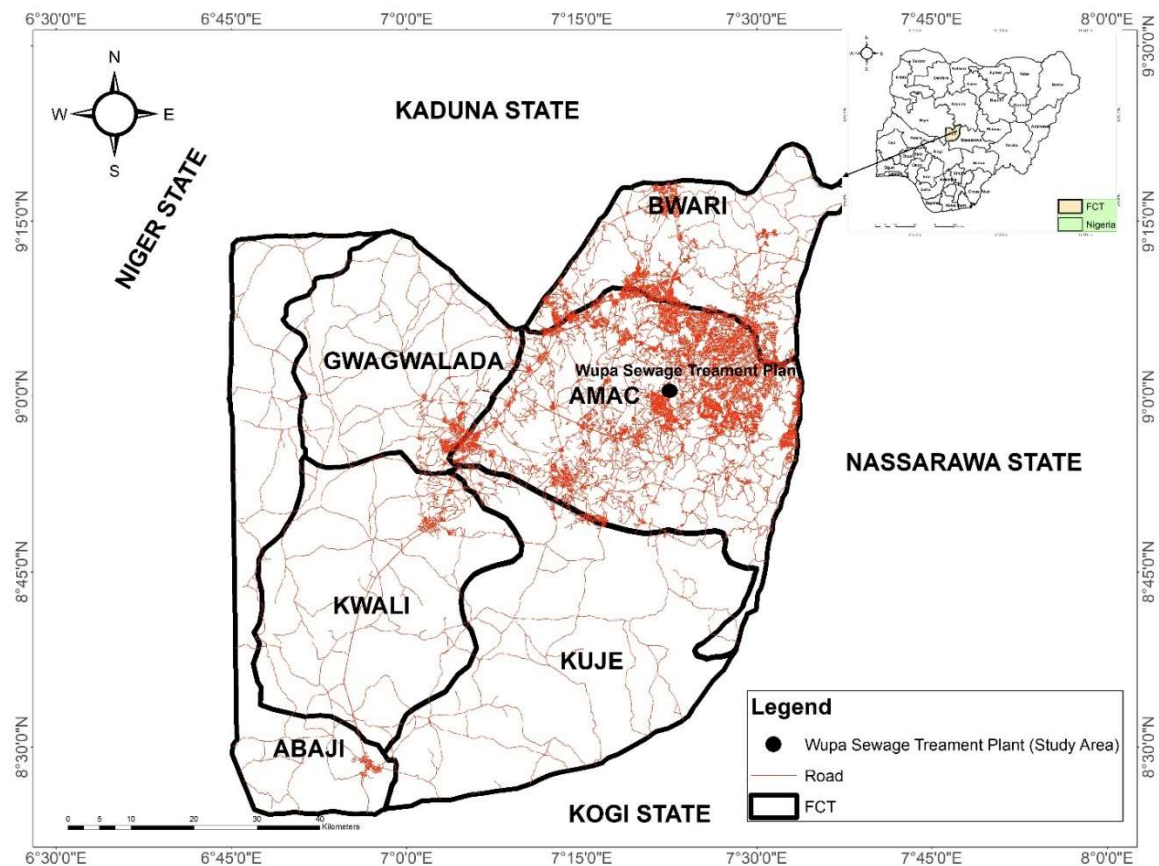


Figure 1: FCT Map showing location of Wupa Sewage Treatment Plant

The most important and largest river within the study area is river Wupa, which flows into to river Usuma which in turn is a tributary of river Gurara. This river is quite shallow for all parts of the year except during the peak of the raining season between July and September (Balogun, 2001).

Data Collection and Analysis

Simple random sampling method was adopted for the study. Samples were collected at influent, and effluent point of the sewage treatment plants. Five water samples were collected. The water

samples were collected in a plastic bottle of approximately 1.5 litre capacity. The bottle was rinsed three times with the sample water. The containers were filled to capacity and caps screwed tightly to eliminate bubbles. Masking tape was used to close any gap between the bottle and the cap. The bottles were fully labeled with location, date, operating condition of the source and the number of the sample. The samples were kept in coolers and transported for laboratory testing. The result obtained was used to determine the physical, chemical, and bacteriological content of the sampled water.

Water samples were analyzed for physical properties such as (Temperature, Sanility, Total dissolved solids (TDS) and total suspended solids (TSS)) chemical properties (Electrical Conductivity, pH, Sulphate, Chloride, Chlorine, Nitrite, Nitrate, Magnesium, Calcium and Phosphate), bacteriological properties (Total faecal coliforms and total plate count), other primary sources of data for this research include personal observations, laboratory analysis and field instrumentation.

Temperature, conductivity and pH, were determined in-situ using digital meters while other parameters like Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Oxygen Demand (OD), alkalinity, acidity, total suspended solids, confirmation of faecal coliforms were determined in the laboratory.

Compliance of the effluent was determined using Clerk's (1984) Compliance Equation,

$$\text{Clerk Compliance Equation } P.C = \frac{N_i \times P}{N}$$

Where;

PC = Percentage Compliance

Ni= Number of times parameter complied with the stated standard

P= 100% (Assumed maximum compliance limit).

One-way analysis of Variance was used to test level of significance difference between value of water tested at the sewage treatment plant and safety limit set by Federal Ministry of Environment (FMEnv).

Result and Discussion

Physico-Chemical Properties of Water Sample at Sewage Treatment Plant

The pH as shown in Table 1, show that influent and the effluent is in conformity with FMEnv standards as both value is within the 5.0 and 9.0 range. This agrees with the findings of Singh *et.al.*, (1998) and Ugoh *et.al.*, (2013). Although the findings of Siyanbola *et.al.*, (2011) showed recorded values is outside the tolerated Federal Ministry Environment standards, as these were from industrial activities and not sewage. The values of temperature of the water sample is 27.8°C for influent and 27.5°C for effluent, both values are found within the FMEnv standard of 40°C, this was also the case observed by Singh *et.al.*, (1998), Siyanbola *et.al.*, (2011) and Ugoh *et.al.*, (2013). This result indicates that the water from the plant is in conformity with standards.

The electrical conductivity is a function of the salinity of the wastewater and determines if the water is suitable for irrigation use or not as discussed by Singh *et.al.*, (1998) and Ugoh *et.al.*, (2013). Influent recorded 287 uS/CM and effluent recorded lower value of 236 uS/CM. The value of FMEnv does not have a specific value for the statutory limit, yet it was observed that the value

had decreased at the effluent point. This is also a function of salinity and it determines if the waste water is suitable for irrigation. The low values of salinity observed indicates that the effluent is within the FMEnv limit and conforms to the findings of Singh *et.al.*, (1998) and Ugoh *et.al.*, (2013). Salinity is the life capacity of the water body which should not be less than 2 but a value of 7.5 is recommended by FMEnv and both the influent and effluent are within range but the influent is of lower value indicating that the treatment facility is effective. The value of total dissolved solid at influent and effluent of 176mg/L and 131mg/L fall within FMEnv standard of 3500mg/L.

Dissolved oxygen concentrations in unpolluted water normally range between 8 and 10 mg/L and concentrations below 5 mg/L adversely affect aquatic life (DFID, 1999; Rao, 2005). DO standard for drinking purpose is 6 mg/L whereas for sustaining fish and aquatic life is 4-5 mg/L (Rao, 2005). The DO value from this study falls within recommended standard. For water quality variables such as dissolved oxygen, water quality criteria are set at the minimum acceptable concentration to ensure the maintenance of biological function. The turbidity for the influent is very high far above FMEnv accepted limit but after treatment it is within the permissible limit of FMEnv (see Table 2), excessive turbidity in water can cause problem with water purification processes such as flocculation and filtration, which may increase treatment cost (DWAF, 1998). The result of the study is in contrast to that obtained by Igbiosa and Okoh (2009) where they had high turbidity values for sewage discharged into streams and rivers in South Africa but the results conforms to the results obtained by Ugoh *et.al.*, (2013).

Total suspended solids just like the total dissolved solids showed a high value before treatment of 218.7mg/l which is above FMEnv limit of 30mg/l while values recorded at effluent of 19.4mg/l is within FMEnv limit. The biochemical oxygen demand (BOD) measures the amount of oxygen required by bacteria for breaking down to simpler substances decomposable. BOD of the effluent water is seen to be greatly reduced but slightly above the acceptable FMEnv limits of 4mg/l as against the value of the influent this is also in line with the findings of Ugoh *et.al.*, (2013).

The chemical oxygen demand of the effluent of 26mg/l is within limits of FMEnv of 40mg/l as against that of the influent which was way out of acceptable limits as shown in table 1. Since continuous discharge of effluent have impact on the receiving water body to some extent and this may have negative effects on the quality of the freshwater and subsequently cause harm to the aquatic life especially fish, downstream (Morrison *et. al.*, 2001) it is therefore important to keep the COD low at all times. The result of this study is in conformity with the findings of Ugoh *et. al.*, (2013). The values of both the influent and effluent for total phosphate is within the set FMEnv limits of 5mg/l as shown in table 1. High phosphate levels is found in effluent zone than in receiving waterbody, this could be a consequence of dilution effect. However, the level of phosphate in water systems that will reduce the likelihood of algal and other plant growth is 5 mg/L (DWAF, 1996c). The values of total nitrate recorded is within set FMEnv limits of 10mg/l for both the influent and effluent as shown in table 1.

Nitrate is commonly present in surface and groundwater because it is the end product of aerobic decomposition of organic nitrogenous matter. Unpolluted natural waters usually contain only minute amounts of nitrate (Jaji *et. al.*, 2007). It is important to note that nitrate level in the treated final effluent could be a source of eutrophication for receiving water body if the obtained values exceed the recommended limit, but for this study, the value is below set limit by FMEnv. The value of the sulphate, chloride and total solid is within limits for both the influent and effluent.

Table 1: Result of Physiochemical and Bacteriological Analysis of Wastewater from Wupa Treatment Plan

S/N	PARAMETERS	RESULTS		
		INFLUENT	EFFLUENT	FMEnv
1	pH	6.98	7.13	6.0 -9.0
2	TEMPERATURE (°C)	27.8	27.5	40
3	E.C(uS/CM)	287	236	Not Specific
4	TDS (mg/L)	176	131	3500
5	D.O(mg/L)	3.50	7.01	2-7.5
6	TURBIDITY(NTU)	250.00	3.34	5
7	COLOUR	GRAY	CLEAR	CLEAR
8	T.S.S(mg/L)	218.7	19.4	30
9	B.O.D ₅ (mg/L)	122.5	6.5	4
10	COD(mg/L)	250.0	26.0	40
11	PO ₄ ^P (mg/L)	3.00	2.00	5
12	NO ₃ ^N (mg/L)	2.50	6.0	10
13	SO ₄ -(mg/L)	48.70	37.89	100
14	CHLORIDES CL-(mg/L)	37.56	25.72	100-500
15	TOTAL SOLIDS (mg/l)	394.7	150.4	2030
16	APPEARANCE	GRAY	CLEAR	CLEAR
17	TOTAL HARDNESS mg/l	58.99		Not Specific
		INFLUENT	EFFLUENT	FMEnv
18	TOTAL COLIFORM (CFU/100ml)	4000	10	0
19	TOTAL PLATE COUNT (CFU100/ml)	6000	21	30

Microbial Bacterial Isolates of Water Sample at Sewage Treatment Plant

The bacteriological test for total coliforms showed a very high level of 4000Cfu at the influent and low value at effluent level of 10Cfu. The plant also records high value of total plate count of 6000Cfu at the influent level and lesser value of 30Cfu at effluent. The result shows that the value recorded at influent and effluent for total coliform count is above FMEnv value of 0Cfu. This conforms to the findings of Ugoh *et. al.*, (2013). While value of total plate count at influent is higher than FMEnv standard, value recorded at effluent is below the standard of 30Cfu. The result indicated that the treatment although greatly reducing the presence of total plate count and coliforms, it does not completely remove or eliminates coliforms or bacteria.

Level of Variation between value of water at the Treatment plant and set standard by Federal Ministry of Environment.

Analysis in Table 2, show that the F-calculated is 0.69, while the table value at $\alpha=0.05$ is 3.22. It then means that since the calculated value of 0.69 is lower than the table value of 3.22, therefore

means there is no significance difference between the mean values of water properties from the influent and effluent with the set standard by Federal Ministry of Environment.

Table 2: Test of variation between values obtained in influent, effluent and Federal Ministry of Environment

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2071519	2	1035760	0.692468	0.505961	3.219942
Within Groups	62821499	42	1495750			
Total	64893018	44				

Level of Compliances of Water Sample at Sewage Treatment Plant

The compliance level was computed for the Physico-Chemical and Microbial Bacterial of the sampled water. The data on table 3 show 100% compliance for all Physico-Chemical and 50% for Microbial Bacterial except for B.O.D₅ which is at 0% for effluent. Assessing the level of compliance for sample water before treatment at the influent, value for turbidity, Total suspended solid, Biochemical oxygen demand and, Chemical oxygen demand, total coliform and total plate count is at 0% compliance.

Table 3: Level of Compliances

S/N	PARAMETERS	INFLUENT		EFFLUENT	
		Ni	%	Ni	%
1	pH	1	100	1	100
2	TEMPERATURE (°C)	1	100	1	100
4	TDS (mg/L)	1	100	1	100
5	D.O(mg/L)	1	100	1	100
6	TURBIDITY(NTU)	0	0	1	100
8	T.S.S(mg/L)	0	0	1	100
9	B.O.D ₅ (mg/L)	0	0	0	0
10	COD(mg/L)	0	0	1	100
11	PO ₄ ^P (mg/L)	1	100	1	100
12	NO ₃ ^{-N} (mg/L)	1	100	1	100
13	SO ₄ ⁻ (mg/L)	1	100	1	100
14	CHLORIDES CL ⁻ (mg/L)	1	100	1	100
15	TOTAL SOLIDS (mg/l)	1	100	1	100
18	TOTAL COLIFORM (CFU/100ml)	0	0	1	50
19	TOTAL PLATE COUNT (CFU100/ml)	0	0	1	50

Conclusion

From the results obtained in the study and observations made, the effluent coming out from the treatment plant is in conformity with FMEnv standards and can be safely released into the river without adverse effect to the Wupa river. Bacteriological test shows that the treatment plant greatly reduces faecal coliforms, even though the total coliform count at the effluent is still above FMEnv standard. The general water sample reports and data generated at the treatment plant are actually in conformity with environmental standards with an environmental management system in place, all the operating areas secured and operations going on smoothly. It is therefore recommended that more should be done with regards to the Ultra-Violet-radiation tank to ensure 100% conformity for total coliform count with FMEnv standard of 0 CFU/100ml and a thorough and formal environmental audit of the facility should be done as none has been done since the facility was setup in 2006. More also a tertiary filtration system be put in place, so as to use the water to service the industrial layout instead of depending on the city water supply.

References

- Akan, J.C., Abdulrahman, F.I., Yusuf, E. (2010). Physical and chemical parameters in abattoir wastewater sample, maiduguri metropolis, Nigeria. *The Pacific Journal of Science and Technology*, 11(1), 640 – 648.
- Balogun, O. (2001). The Federal Capital Territory of Nigeria: Geography of Its Development. University of Ibadan Press Limited. Basil Blackwell, New York.
- Brad K. and Krantz, D. (2007). Water pollution and society. <http://www.umich.edu/-gs265/society/waterpollution.htm>
- DWAF, (1996c). South African Water Quality Guidelines, Aquatic ecosystems (1st. Ed.). Department of Water Affairs and Forestry, Pretoria, Vol. 7.
- DWAF, (1998). Quality of Domestic Water Supplies. Assessment Guide. 1 (2nd. Ed.) Department of Water Affairs and Forestry, Department of Health and Water Research Commission South Africa.
- DFID, (1999). A Simple Methodology for Water Quality Monitoring. G. R. Pearce, M. R. Chaudhry and S. Ghulam (Eds.), Department for International Development Wallingford. 100.
- Igbinsola, E. O. and Okoh, A. I. (2009). Impact of discharge wastewater effluents on the physico-chemical qualities of a receiving watershed in a typical rural community. *International Journal Environmental Science Technology*, 6 (2), 175-182, ISSN: 1735-1472
- Jaji, M. O.; Bamgbose, O.; Odukoya, O. O.; Arowlo, T. A., (2007). Water quality assessment of Ogun River, south west Nigeria. *Environ. Monit. Assess.*, 133 (1-3), 447-482
- Mc Gauley S.E. (1968). Mechanical properties of cocoa butter in relation to its crystallization behavior and microstructure. *Lebensm Wiss Technol* 36:525–532
- Morrison, G.; Fatoki, O. S.; Persson, L.; Ekberg, A., (2001). Assessment of the impact of point source pollution from the Keiskammahoek sewage Treatment Plant on the Keiskamma River–pH, electrical conductivity, oxygen demanding substance (COD) and nutrients. *Water SA.*, 27 (4), 475-480
- Ojutiku, R. O., Kolo, R.J. and Mananoso, C. A. (2014): Composition and Dynamics of Some Nutrient and Physicochemical Parameters in Lower Course of Gwagwalada River in Federal Capital Territory, Abuja, Nigeria. *American Journal of Agriculture*, 4(12), pp1480-1491.
- Osi, B (2003). The Environmental and Human dimensions of Water use. *Bulletin*.
- Rao, P. V., (2005). Textbook of environmental engineering. Eastern Economy Ed., Prentice-Hall of India Private Limited, New Delhi, Chapter 3, 280.
- Singh, K.P., Malik, A.D. Mohan, S. Sinha, S. (1998) "Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India) — a case study," *Water resources*, 38(18): 3980-3992.
- Singleton, P (1999). *Bacteria in Biology, Biotechnology and Medicine*. 4th edition. Wiley. England pp 284-295.
- Siyanbola, T.O, Ajanaku K.O, James O.O, Olugbuyiro J.A.O, Adekoya J.O. (2011). Physico-Chemical Characteristics Of Industrial Effluents In Lagos State, Nigeria *G. J. P & A Sc and Tech.*, 2011v01 (49-54).

Ugoh, S.C., Nneji, L.M. and Atoyebi, B.A (2013) Bacteriological and Physico-Chemical Assessment Of Wastewater From Wupa Wastewater Treatment Plant, Abuja World Rural Observations; 5(11) 74-79]. ISSN: 1944-6543 (Print); ISSN: 1944-6551 (Online). <http://www.sciencepub.net/rural>.

United State Environmental Protection Agency (USEPA) (2004): Drinking Water Treatment Safe Drinking Water Act(1974-2004).Protect Our Health from Source to Tap.

Van Beelen (2007). EAIE Professional Development Series for International Educators 2: Implementing Internationalization at Home. Published by the European Association for International Education (EAIE) Copyright © 2007 EAIE

WHO (1996): Guidelines for Drinking Water Quality, Second Edition Volume 3: Surveillance and Control of Community Supplies