Nigerian Journal of Engineering
Faculty of Engineering
Ahmadu Bello University
Samaru - Zaria, Nigeria

Vol. 25, No. 2, Dec. 2018
ISSN: 0794 - 4756

PERFORMANCE EVALUATION OF AHMADU BELLO UNIVERSITY WATER TREATMENT PLANT (ABUWTP)

***Y. Owoseni, S. B. Igboro, F. B. Ibrahim and M. I. Sanni**

Department of Water Resources and Environmental Engineering, ABU Zaria, Nigeria.
***Corresponding Author Email: yusufowoseni@gmail.com**

ABSTRACT

Water treatment processes involved in any surface water treatment plant has a direct effect on the quality of final treated water produced from the plant. This study is a comparative assessment of the overall efficiency of the New Ahmadu Bello University Water Treatment Plant (NABUWTP) and Old Ahmadu Bello University Water Treatment Plant (OABUWTP) treatment processes. Water quality parameters for water fit for drinking were evaluated with respect to World Health Organization (WHO) and Nigeria drinking water standards. The NABUWTP average Turbidity (1.4 NTU), pH (7), Electrical Conductivity (206.9 µS/cm) and Temperature (25.5^{0}C) as compared to the OABUWTP average Turbidity (2.4 NTU), pH (6.5), Electrical Conductivity (105.9 µS/cm) and Temperature (26.6^{0}C) are satisfactory for final treated water qualities except Residual Chlorine: 0.02 mg/l and 0.04 mg/l for NABUWTP and OABUWTP respectively which are below acceptable standard. The NABUWTP presently produces 1000 m^3 of potable water in 18 hours (0.015 m^3/s) and the OABUWTP produces 3876 m^3 per day (0.045 m^3/s). Bacteriological analysis of the final treated water in both plants revealed 0-0-0- cfu/100 ml sample coliform count which satisfies the requirement for ensuring a pathogen free water. The OABUWTP was found inconsistent in it operations resulting from Performance Limiting Factors such as: Inordinate quantity of Alum, Lime and Chlorine used, Insufficient water certified staffs, Unavailable flow measuring devices, Flash mixer at the flocculation chamber and Lack of chemical feed equipments. A Comprehensive Technical Assistance (CTA)/ Optimization exercise is needed at the OABUWTP due to it inconsistencies in performance. The NABUWTP (33.3%) has an overall average better performance compared to the OABUWTP (31.3%).

Keywords: *Treatment process, water standards, water plant, pathogen.*

INTRODUCTION

Water treatment is, collectively, the industrial-scale processes that make water more acceptable for an end-use, which may be drinking, industry, or medicine. Water treatment originally focused on improving the aesthetic qualities of drinking water. Methods to improve the taste and odor of drinking water were recorded as early as 4000 B.C (Das, 2013). The processes involved in treating water for drinking purposes to provide a safe source of water supply may be solids separation using physical processes such as settling and filtration, and chemical processes such as disinfection and coagulation.

Water is indispensible in the maintenance of life on earth. But our society continues to pollute this valuable resource. The pollution is attributed to industrialization, urbanization, population explosion etc. Insecure drinking water contributes to several health problems (Meghana and Manjunath, 2017). Drinking water should be essentially free of disease-causing microbes, but often this is not the case. A large proportion of the world's population drinks microbially contaminated water, especially in developing countries (Sobsey, 2000).

It is expected that all plants treating surface water for the consumption of more than 10,000 people should be able to produce desirable final treated water to satisfy all water quality parameters for drinking purposes (AWWA, 2000). Drinking water quality ensures the safety of the drinking water supplies and the protection of the public health (NIS, 2007). Arshad *et al.* (2012) explained that the regular monitoring of water quality being treated by surface water treatment plants, and performance evaluation of its unit operations and processes is very essential for the consumer health. Water treatment plants are known to remove turbidity and coliform. Treatment plant performance evaluation in Qom revealed that the treatment plant produces average turbidity and coliform counts within Iran's drinking water standard. Thus, confirming good plant's performance (Zahra, *et al.,* 2016).

The raw or treated water can be checked by studying and testing their physical, chemical and microscopical characteristics. The physical properties of water cover the study of turbidity, colour, taste, temperature, etc. In other case, chemical properties of water involves total solids and suspended solids, pH value, hardness, chloride content, nitrogen content, iron, manganese and other metal contents, dissolved gases, etc. Thus, pure water should be clean, transparent, tasteless and odorless.

The aim of water treatment is to produce and maintain water that is hygenically safe, aesthetically attractive and palatable (Das, 2013). Through the treatment, water would achieve the desired quality. The evaluation of its quality should not be confined to the end of the treatment facilities but should be extended to the point of consumer use. A combination selected from the following processes is used for municipal drinking water treatment worldwide (Eaton *et al.,* 2005): Pre-chlorination, Aeration, Coagulation, Coagulant aids, Sedimentation, Filtration, Desalination and Disinfection.

The Ahmadu Bello University Water Treatment Plant (ABUWTP) provides treated water to the University community for consumption, laboratory works, and other general domestic purposes. The ABUWTP presently have two plants; the New Ahmadu Bello University Water Treatment Plant (NABUWTP) and the Old Ahmadu Bello University Water Treatment Plant (OABUWTP) which is used simultaneously in treating raw water obtained from the Ahmadu Bello University Water Reservoir.

The comparative study is needed to establish whether the combination (because different treatment processes are involved) of both plants will give desired drinking water quality standards, as final treated water from both plants is first combined at the underground water reservoir before been discharge for consumption.

The aim of this study is to conduct a Comprehensive Performance Evaluation (CPE) study on the Ahmadu Bello University Water Treatment Plant (i.e NABUWTP and OABUWTP) so as to ascertain the efficiency of the treatment plant processes with objectives such as: evaluating the quality of potable water supplied into the university's community to meet WHO and Nigeria drinking water quality standards and to obtain baseline information for the NABUWTP.

Old Ahmadu Bello University Water Treatment Plant

The OABUWTP is a conventional water treatment plant which was constructed in 1972 and the construction of the NABUWTP was concluded in 2014. Presently both plants are used in producing potable water which the entire university's community consumes and for all general purposes.

The treatment processes involved in the OABUWTP has the following components:

1. Aeration
2. Pre disinfection/ Pre Chlorination
3. Coagulation, flocculation and sedimentation
4. Filtration through dual media filter
5. Post chlorination and

The treatment processes involved in the NABUWTP has the following components:

1. Aeration
2. Coagulation, flocculation and sedimentation
3. Filtration through multimedia filter
4. Filtration through an activated carbon
5. Filtration through an iron filter
6. Post chlorination

The use of activated carbon (charcoal treated with oxygen to open up millions of tiny pores between carbon atoms) filters have proven efficient in recent time as it is efficient in turbidity and TSS removal, filters up to 2.0 ppm suspended particles and it easy mode of operation and maintenance. Iron filters eliminate turbidity, suspended particles, color, odor and iron that are available in raw water. These iron removal filters are known for their easy operation and give crystal clear water. Iron filters are known to prevent bacteria, corrosion and clogging of pipe line. These filters usually consist of a layer of anthracite (1.25 – 2.5 mm) resting on a layer of fine sand (1-1.5 mm). Anthracite is coarse and has more dirt holding capacity as compared to sand (Micheal, 2009).

Technical Description of the NABUWTP

The New Ahmadu Bello University Water Treatment Plant (NABUWTP) has two (2) Low-lift pumps with a discharge capacity of 1100-3000 L/s. The two pumps work at an alternate interval of 6-mins automatically when in operation. Raw water from the Low-lift pumps passes through an aeration pipeline into the aeration basin located at the top of the treatment plant.

The overhead basin is divided into three (3) stages; each having a detention time of 9-minutes. As such, aerated water takes 27 minutes before flowing to the underground raw water reservoir. Aluminum Sulfate and Lime are added at the 3rd stage to enhance coagulation of the raw water. 100 kg of Alum and 50 kg of Lime is used for every 3-hours of raw water pumping operations. For every 3-hours of raw water pumping schedule, an approximate 1 million litres of raw water is collected in the underground raw water reservoir. A six (6) hour pumping operation is required to fill the underground reservoir to it volume capacity of two (2) million litres.

During raining season when the raw water turbidity is usually high, the pumped raw water is allowed to settle for 8-hours before water is lifted for further purification process, while the settling time is usually 6-hours during seasons with low turbidity water. During periods in which the raw water turbidity is excessively high, PolyAcrylamide/polyelectrolytes (EASYFLOC M20) which is a coagulant-aid is used to improve the floc formation process within the reservoir.

A high lift pump is used to draw settled water from the underground reservoir to the multimedia filter. The multimedia filter is a large cylindrical metal container with a filtering capacity of 108 m3/hour. Filtering media in the filter includes: Sharp sand and gravel. The multimedia filter has openings at it base for backwashing which is done after 3 months. There is a pressure meter provided at the top of the multimedia filter which is used in observing the flow pressure along the pipelines. A pressure scale reading of 50 psi is the optimum pressure at which the flow is been regulated.

The activated carbon filter (removes taste, colour and odour) is similar to the multimedia filter in shape and filtering rate. It also has a rated filter volume capacity of 108 m^3/hour but the filter medium here is an activated carbon in combination with sharp sand and gravel. From the activated carbon filter, water is then directed along a pipe to the iron filters which have valves that allow the passage of water in-and-out through them. In the iron filters; carbon and resins are used to further improve the removal of heavy metals and iron in the water. As water flows out from the activated carbon filters, chlorine is added before getting to the outside metal reservoirs. An automated chlorine dosing pump which doses at vol-9 is used for this operation. Chlorine is mixed in the ratio of 1.05 kg to 300 litres (3.5 g/l) of water into the chlorine tank. There is a mechanical mixer which continuously stirs the mixture to prevent the chlorine powder in the chlorine tank from settling. Hypochlorite is the chlorine used in the plant.

The external metal reservoir/clear water reservoirs both have an individual volume capacity of 500,000 litres (i.e total volume is 1 million litres). Presently, the plant is being operated for 6-hours daily and it approximately requires 18-hours of operation to fill the clear water reservoirs to their capacity. Water stored in these reservoirs is then directed to the old water treatment plant's Clearwater tank which has a volume of 1.5 million litres.

A combination of both plants operations satisfies the daily water demand of the university's community.

MATERIALS AND METHODS

Materials

*Composite Correction Program CPE guide and checklist
*SWIFTLOCK AUTOCLAVE (Astell (Δ)
*Gallenkamp Incubator (IH-100)
*Turbidimeter (CAMLAB 2100N)
*Conductivity meter (JENWAY 4510)
*Dissolved Oxygen meter (Luton DO-5509)
*Palintest Comparator (SE212)
*Pipette, Burette, Beakers, Test tubes, Volumetric Flask
*O-Toloden, Lactose Broth, Mackonkey Broth, Eosin Methylene Blue (EMB)

Sampling

Raw and Treated Water samples were collected 100 ml plastic bottles daily at the NABUTP and OABUWTP laboratory sampling taps throughout the research period. Samples were collected using 100 ml plastic bottles pre-treated with methylated spirit from the Intake, underground raw water storage reservoir, immediately after chlorine addition, sampling tap and at the treated water reservoir were obtained at the NABUWTP. Samples were collected at the aeration tank; flocculation basin, sedimentation basin, filtration tanks, filter gallery, disinfection/clearwell and first distribution tap of the OABUWTP for bacteriological analysis with caution not to make contact with either the lid or top of the plastic bottles when opened.

Methods

Water quality parameters of old and new Ahmadu Bello University water treatment plant

Laboratory analysis was conducted using standard methods as described by AWL (2009) to determine the following parameters: Turbidity, pH, Conductivity, Residual Chlorine and Temperature for raw and treated water samples collected at the NABUWTP and OABUWTP. The values were then compared to the WHO (2011) and Nigeria drinking water quality standards (NIS, 2007).

Bacteriological analysis of OABUWTP and NABUWTP treatment processes

A bacteriological analysis was conducted at the Department of Water Resources and Environmental Engineering laboratory to evaluate bacteria removal at various sections (Raw Water Intake, flocculation basin, sedimentation basin, Filter tank, Filter gallery, clearwell and first distribution tap) of the OABUWTP.

Also, samples from the Intake, underground raw water reservoir, immediately after chlorine addition at the sampling tap and at the treated water reservoir were obtained at the NABUWTP.

Benchmark for the new Ahmadu Belllo University water treatment plant

Baseline information for the NABUWTP was generated by keeping records of raw water lifting schedule from the reservoir. As the raw water is been aerated, average detention time it took before aerated water flows down to the underground reservoir were noted. There are provisioned Alum and Lime (plastic) tanks that are used for Alum and Lime addition. Average quantity of chemicals used for every pumping schedule was recorded.

Comparative study of the NABUWTP and the OABUWTP

A comparative study was conducted between the OABUWTP and NABUWTP to ascertain the treatability efficiency of both plants at the same period. Water quality parameters such as: Turbidity, Residual Chlorine, pH, Temperature, Electrical Conductivity and Dissolved Oxygen were used. Comparative performance graphs were established through these parameters using Graper-9 software. Interpretations were made from WHO (2011) and Nigeria drinking water quality standards (NIS, 2007) to see which of the plants best satisfy each parameter.

RESULTS AND DISCUSSION

The study evaluated water quality parameters are shown in Table 1. During the research period, both plants performed well in terms of their final treated water turbidities. Turbidity values of 1.4 NTU and 2.5 NTU for the NABUWTP and OABUWTP respectively were all below the maximum (5 NTU) standard limit. The pH level in the OABUWTP treated water is slightly within the acidic range, although it is within the range (6.5 – 8) of acceptable limit. The Residual chlorine level of 0.02 mg/l and 0.04 mg/l in the NABUWTP and OABUWTP are deficient in the minimum (0.2 mg/l) allowable residual chlorine for water fit for storage. As such, there could be recontamination before treated water gets to the final consumer point. The conductivity, Temperature and Dissolved Oxygen level in both plants were within acceptable standards.

Table 1: Physical water quality parameters at the NABUWTP and OABUWTP

PARAMETER	OABUWTP	NABUWTP	Relative Percentage Difference (%)	Plant with Better Performance	Overall Average Relative Percentage Difference (%)
Turbidity (NTU)	2.5	1.4	44	NABUWTP	33.3
pH	6.5	7	7	NABUWTP	
Conductivity (µS/cm)	105.9	206.9	49	NABUWTP	
Residual Chlorine (mg/l)	0.04	0.02	50	OABUWTP	31.3
Temperature (^{0}C)	26.6	25.5	4	OABUWTP	
Dissolved Oxygen (mg/l)	1	0.6	40	OABUWTP	

Laboratory results obtained from the bacteriological analysis in Table 2 revealed that the NABUWTP raw water have a coliform count of 1.18 x 10^6 cfu. A coliform count of 1.5 x 10^6 cfu recorded shows the combined effect of the multimedia filter, activated carbon filter and the iron filter to have 87.3% bacteria removal efficiency (there could possibly be some chlorine effect at this level). A further sample which was obtained and analyzed from the treated water reservoir recorded a '0' coliform count.

Table 2: Bacteria removal at various unit processes of the NABUWTP

Sample	Coliform count/100 ml (cfu)	Coliform % removal	Cummulative % removal
Underground Reservoir	118x10^4	-	-
Chlorine Tap	15x10^4	87.3	87.3
Treated water Reservoir (after 6 hours)	0	12.7	100
Distribution tap	0	-	-

Table 3: Bacteria removal at various unit processes of the OABUWTP

Sample	Coliform count /100 ml (cfu)	% of coliform removal	Cumm. % Removal
Raw Water	1.25 x 10^6	-	-
Flocculation Basin	2.2 x 10^5	25.2	25.2
Sedimentation Basin	1.5 x 10^5	21.6	46.8
Filter Tank	1.2 x 10^5	18.6	65.4
Filtrate	5 x 10^4	17.4	82.8
Clearwell	2-1-1 (9 x 10^3)	17.2	100
Tap	0-0-0	-	-

(n.b in the NABUWTP, when water has undergone the processes of filtration through the multimedia and activated carbon filters, there are usually recorded bacteriological content in the water. But water going into the reservoir with a coliform count of 15x104 cfu/100 ml, there is a post-chlorination tank which further injects chlorine into the water. It is in the reservoir that the post-chlorination becomes effective because water in the NABUWTP reservoir is first stored for 6 hours daily (since it requires 18 working house to fill it reservoir) before it is finally released into the OABUWTP reservoir. Hence, the reservoir plays a role in bacteriological content removal.

Bacteriological analyses from major units of operation at the OABUWTP are shown in Table 3. The raw water had 1.25x106 cfu/100 ml sample. Subsequent analysis conducted on sample collected at the flocculation basin after a detention time of 15 minutes showed 2.2x105 cfu/100 ml-sample (i.e showing 25.2% reduction from the total coliform count from the raw water). The sedimentation basin revealed a coliform count of 1.5x105 cfu/100 ml-sample (21.6% decrease from water in flocculation basin). Further analysis at the filtration tank showed 1.2x105 cfu/100 ml-sample (18.6% reduction from the water in the sedimentation basin). The analysis conducted from water immediately after filtration (i.e filtrate) showed 5x104 cfu/100 ml-sample (17.4% decrease from water in the filtration tank). The clearwell showed 9x103 cfu/100 ml-sample (17.2% decrease in the filtrate). After 15 minutes of contact time in the Disinfection/Clearwell, water sample analysed from the distribution tap within the OABUWTP revealed 0-0-0 cfu/100 ml-sample.

Comparative study between both plants treatment efficiencies are shown in Figure 1 - 6. The NABUWTP has overall better performance efficiency than the OABUWTP.

Turbidity removal

The New Ahmadu Bello University Water Treatment Plant (NABUWTP) performs better than the Old Ahmadu Bello University Water Treatment Plant (OABUWTP) in terms of turbidity removal as is observed from the final treated water turbidity in both plants. There is an observable consistent level of performance in the NABUWTP from the final treated water turbidity values recorded during the research period. All the treated water turbidity values recorded were below the Nigeria drinking water standard (NIS, 2007) and WHO (2011) maximum drinking water turbidity level of 5 Ntu.

Residual chlorine

The residual chlorine content in water from both the NABUWTP and OABUWTP are much lower than the minimum acceptable limit of 0.2 mg/l free chlorine. The NABUWTP has an average residual chlorine value of 0.02 mg/l while the OABUWTP have an average residual chlorine value of 0.04 mg/l. The OABUWTP performed better with respect to the residual chlorine during the study period by a margin of 0.02 mg/l. The residual chlorine results obtained here is an indication of low dosage in the amount of chlorine used for disinfection exercise (i.e. residual chlorine from both plants does not satisfy WHO (2011) and Nigeria drinking water standards (NIS, 2007).

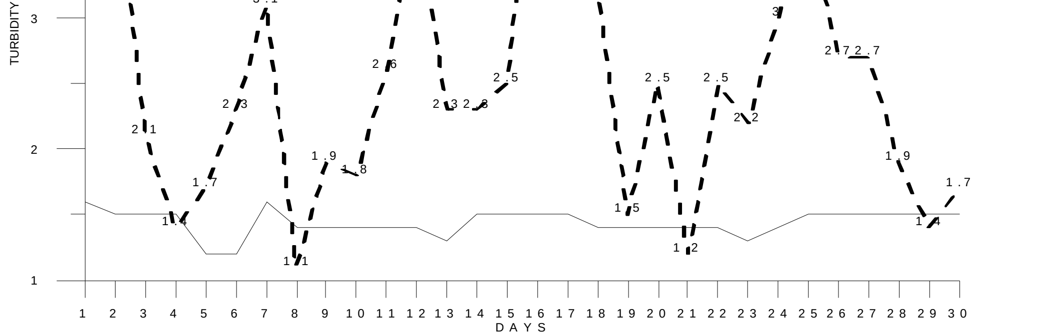

Figure 1: Comparative turbidity plots for NABUWTP and OABUWTP (14th Sept. 2015- 13th Oct.2015)

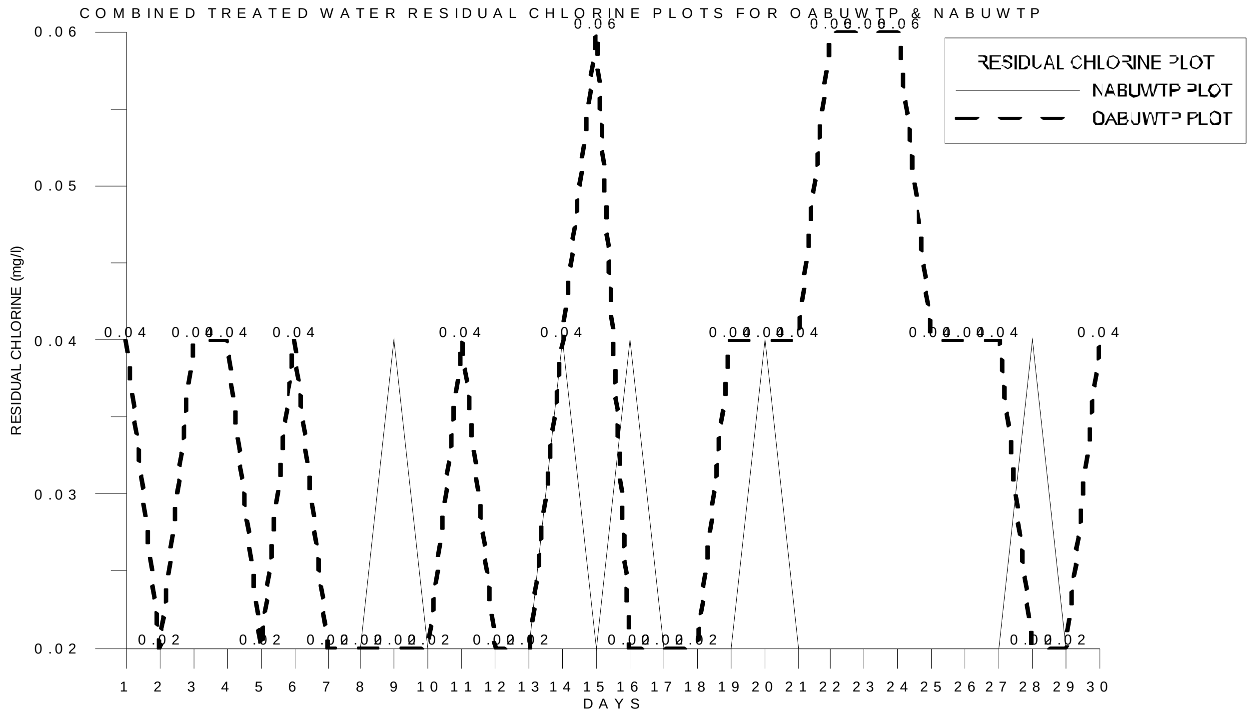

Figure 2: Comparative residual chlorine plots for NABUWTP and OABUWTP

pH

The pH values within both plants are satisfactory for adequate floc formations during the treatment processes. The pH of the final treated water from OABUWTP was 6.5 which that of the NABUWTP were 7. While the final treated water from the NABUWTP is observed to be neutral in terms of it pH level, the OABUWTP recorded a value slightly in the acidic region with a 0.5 margin.

Electrical conductivity

The electrical conductivity of the final treated water in both plants are within the acceptable limit of 300 µS/cm. Recorded values in both plants showed an average concentration of 105.9 µS/cm and 205.9 µS/cm in the OABUWTP and NABUWTP respectively. Increases in the conductivity results from the chemicals used in the treatment process. The NABUWTP significantly increases the conductivity of the final treated due more to the effect of filtering through carbon and iron filters. The electrical conductivities of water in both plants are not alarming and are safe for human consumption (WHO, 2011).

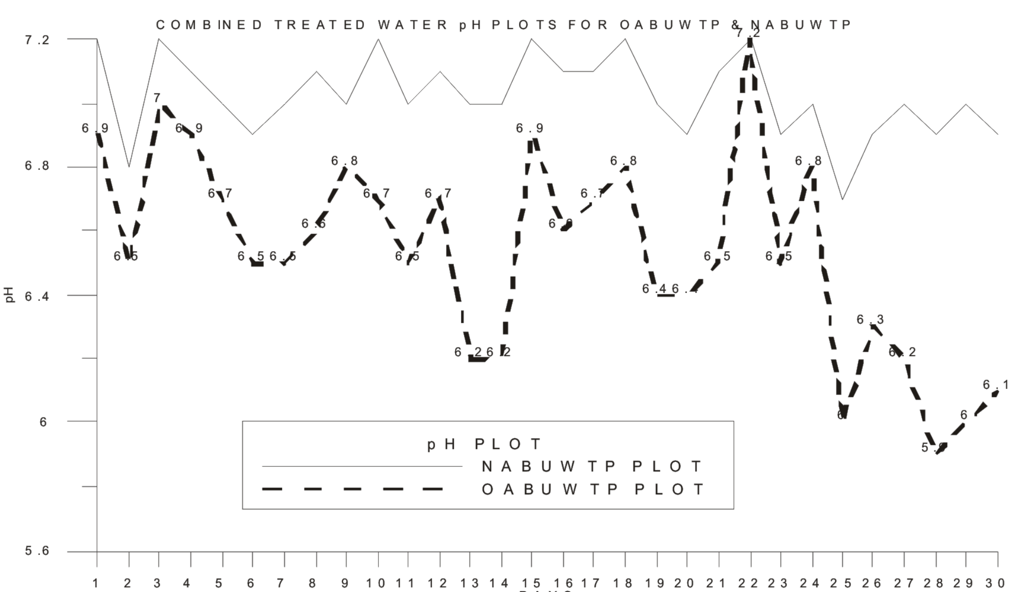

Figure 3: Comparative pH plots for NABUWTP and OABUWTP

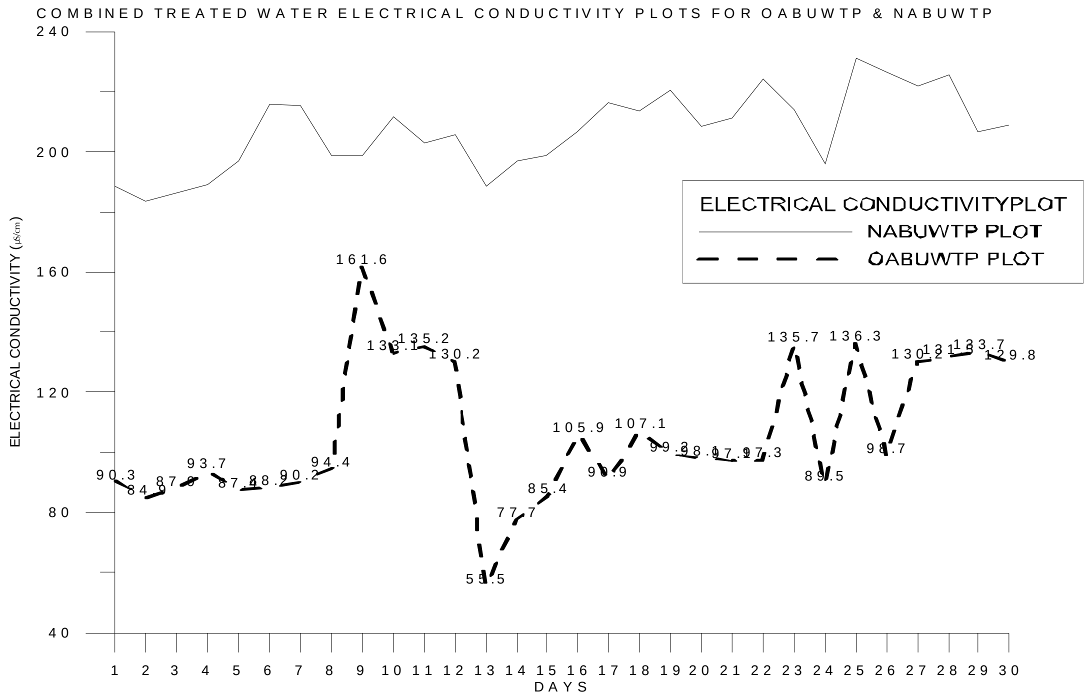

Figure 4: Comparative electrical conductivity plots for NABUWTP and OABUWTP

Dissolved Oxygen and Temperature

Dissolved oxygen concentration in the treated water at the OABUWTP is greater than that observed in the NABUWTP. An average treated water dissolved oxygen concentration of 1 mg/l in the OABUWTP compared to the 0.6 mg/l dissolved oxygen concentration in the NABUWTP. This shows a better performance in the OABUWTP to absorb more atmospheric oxygen during the treatment processes. As such, oxygenation is better enhanced at the OABUWTP than the NABUWTP.

Temperatures in final treated water from both plants were recorded as 26.6^0C and 25.5^0C in the OABUWTP and NABUWTP respectively. The temperature variation in both plants also shows the effect of atmospheric exposure and impacts in which the OABUWTP experiences more than the NABUWTP. The average raw water temperatures in both plants are sufficient to enhance proper floc formations.

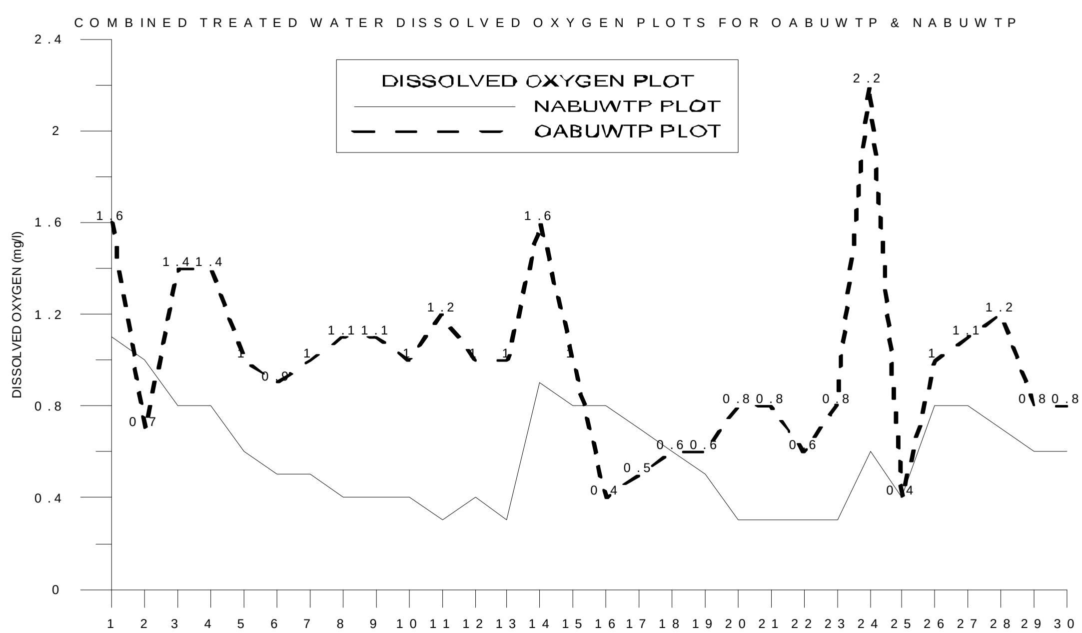

Figure 5: Comparative dissolved oxygen plots for NABUWTP and OABUWTP

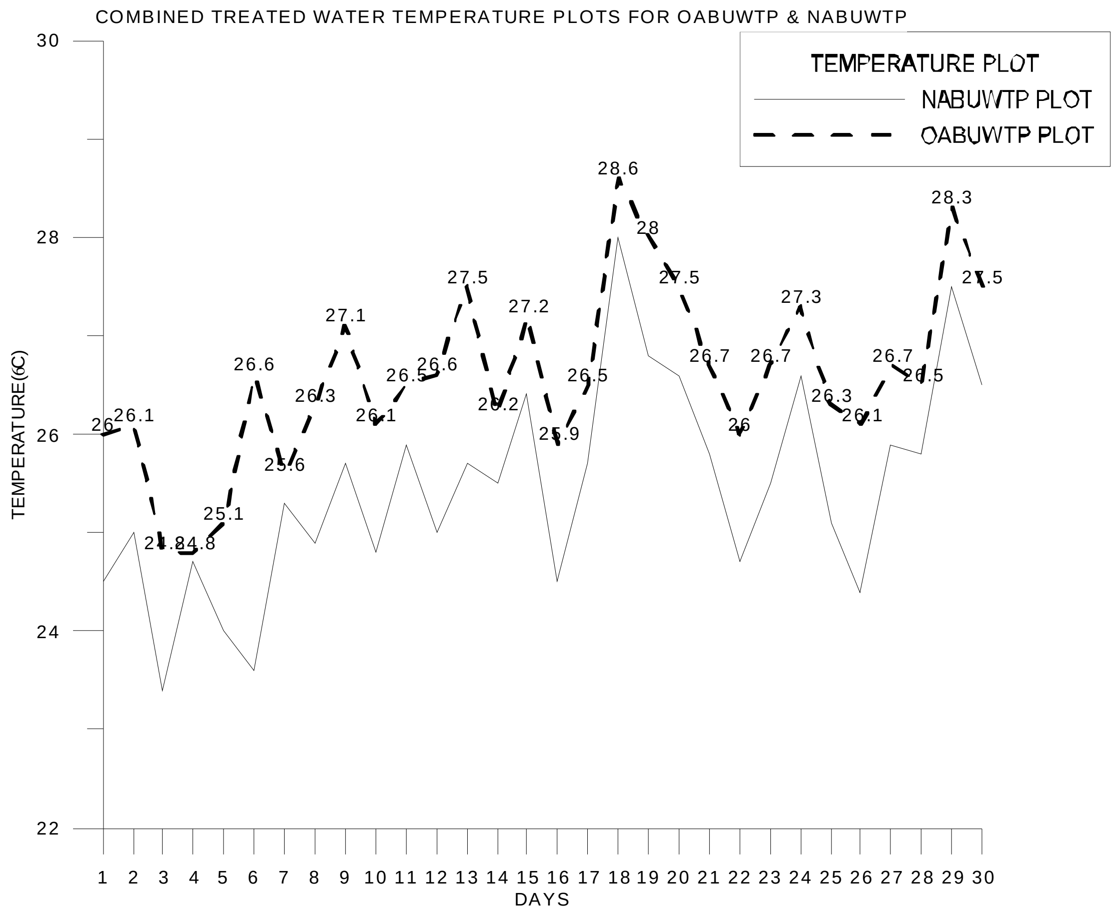

Figure 6: Comparative temperature plots for NABUWTP and OABUWTP

CONCLUSIONS

From the comparative study conducted on both plants in the Ahmadu Bello University Water Treatment Plants, the following conclusions are valid.

The NABUWTP (33.3%) has an overall better average relative water treatment efficiency compared to the OABUWTP (31.3%). The OABUWTP performance is inconsistent and sometimes produces treated water with drinking qualities above WHO and Nigerian standards. The Residual Chlorine in the final treated water from both plants is below the minimum (0.02 mg/l) level allowable for potable water storage. Bacteria removal in all the major units of water treatment from both plants is adequate and satisfactory. The NABUWTP presently produces one (1) million litres of treated water in 18 hours (i.e 0.015 m^3/s) and the OABUWTP produces 3876 m^3/day (i.e 0.045 m^3/s).

REFERENCES

APHA, AWWA, WEF (2000). "*Standard Methods for the Examination of Water and Wastewater"* 21st ed. Washington, DC, American Public Health Association, American Water Works Association and Water Environment Federation, pp. 7-15.

Arshad A., Hashim N. H., Naseem B., Shahid I., Khurram M. (2012). "*Performance evaluation of the water treatment plants of Islamabad – Pakistan*" ARCH. ENVIRON. SCI. (2012), 6, 111-117.

Eaton, A.D., L.S. Clesceri, E.W. Rice, A.E. Greenberg, and M.A.H. Franson. (2005). *Standard Method for the Examination of Water and Wastewater* Centennial edition. Washington DC: American Public Health Association. 1368p.

Meghana M. and Manjunath N. T. (2017). *Performance Evaluation of Water Treatment Units AtBhadravathi, Karnataka: A Case Study*. International Journal Of Engineering Sciences And Research Technology 6.7 (2017): 928-31. Web. 25 July 2017.

MichealO'Hehir (2009). *Chemical-Free Iron Removal and Disinfection Unit of Drinking Water for Single House Application* Dublin Institute of Technology.

Nigerian Industrial Standard (2007). *Nigerian Standard for Drinking Water Quality*NIS 554: 2007 ICS 13.060.20.

Piyali Das (2013). *Study on the Performance of Dual Media Filter for Surface Water Treatment* Thesis, School of Water Resources Engineering, Faculty of Engineering and Technology Jadavpur University, Kolkota-70032, India.

Shin G., K. G. Linden, G. Faubert, M. Arrowood and M. D. Sobsey (2000). *Inactivation of Cryptosporidium Parvum Oocysts and Giardia Lamblia Cysts by Monochromatic UV Radiation.* The First World Congress of International Water Association. Paris, France.

World Health Organisation (2011) b. *Guidelines for Drinking Water Quality* 4th ed. WHO Library Cataloguing-in-Publication Data ISBN 978 92 4 154815 1 (NLM Classification: WA67a).

Zahra Ahmadlia, Mohammad Fahiminiab, ShahramArsangJangc, Reza Ansarid, Maryam Savadkouhia, AzitaAnbaza and Akbar Escandari (2016). *Performance Evaluation of Qom Water Treatment of Plant During 2005 to 2014, Iran.* ARCHIVES OF HYGIENE SCIENCES, (1): 58-65.