Appraisal of access to safe drinking water in southwest Nigeria

Adedayo A Badejo•, Julius M. Ndarnbuki•, Williams K. Kupolati•, Adebola A Adekunle\ Solomon A Taiwob and David 0. Ornole•

Civil Engineering Department, Faculty of Engineering and the Built Environment, Tshwane University of Technology, Pretoria, South Africa
Civil Engineering Department, College of Engineering, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria
**Corresponding author email: badejoaa@tut.ac.za*

The importance of developing effective water supply services is universally recognised as a basis for improving the overall health of the population. This study ascertained the quality of water supplied by a water treatment scheme in southwest Nigeria. One hundred and twelve samples were collected during the wet and dry seasons. Tests on physico-chemical and bacteriological parameters were conducted. Statistical analysis of variance was carried out on the results of the test. The effectiveness of the treatment processes on the parameters considered showed that the aeration, sedimentation and filtration processes were 70.13% effective in colour removal; sedimentation and filtration processes were 94.78% effective in turbidity removal; sedimentation and filtration process were 28.84% effective in the removal of total suspended solids (TSS) and 9.88% effective in the removal of total solids (TS); the disinfection and filtration processes were 100% effective in bacterial and coliform removal. The treatment system was found to be 71.38% effective in pollutant removal.

Keywords: raw water, sedimentation, settled water, water quality, water supply

Introduction

In Nigeria, one of the key elements of the Millennium Development Goals is the provision of water in every horne by the year 2015. At the global level, the target is to reduce poverty levels through adequate provision of potable water. There appears to be a multiplicity of challenges associated with the supply of fresh water to the cities and towns in the western region of Nigeria (Adeniji-Oloukoi, Urmilla, and Vadi 2013; Aderogba 1994; 2005).

The history of water pollution dates back to the nineteenth century when cholera outbreaks and other waterborne diseases occurred in Europe as a result of gross organic pollution of river water with raw human waste. A similar outbreak was reported in 1997 in Milwaukee, USA (Keller and Botkin 1997). However, the worst cholera outbreak, which led to the death of thousands of people, was experienced in Nigeria in 1971 (World Health Organisation 2012).

Inadequate access to safe drinking water constitutes a serious problem in Nigeria because only about half of Nigeria's population of above 167 million have access to improved water sources (Onabolu *et al.* 2011). Nigerians use a combination of alternative water sources. While many people spend substantial amounts of money buying water from vendors, most people have invested in boreholes, wells and storage tanks. On the other hand, some engage in rain water harvesting, while others depend on free or subsidised water owing to the commitment of the citizens to paying taxes. However, many people do not have access to piped water, whereas for those who have access to pipe-borne water, it is mostly irregular due to ageing infrastructure and deterioration of the available water schem es (Adekalu, Osunbitan, and Ojo 2002).

The task of producing and supplying safe drinking water to consumers at all times constitutes a major challenge to water managers and operators. This task is often compounded in tropical countries like Nigeria where strong climatic seasonal variations prevail. This variation can affect the quality of catchment water, efficiency of water treatment, water supply pattern (whether it is continuous or intermittent) and the quality of water in the water distribution system (Etchie *et al.* 2014).

Nigeria is endowed with natural water resources, but a salient issue is the conformity of the resources in their pure form to WHO and Nigerian drinking water standards for both industrial and domestic use. Therefore, it is necessary to assess the water treatment schemes in order to safeguard public health, the environment and ultimately satisfy the human need in the country. The objective of this study was to evaluate the efficiency of each of the components of the treatment plant of Ogun State Water Corporation at Arakanga Water Works in Abeokuta, southwest Nigeria and determine the reliability of the final treated water for human consumption in accordance with WHO and Nigerian drinking water standards.

Methodology

Study area

The Arakanga Main Scheme of Ogun State Water Corporation remains the main source of municipal water supply for the people of Abeokuta city of Ogun State, southwest Nigeria. The scheme was commissioned in 1988, with a designed capacity of 162 million litres per day (lvfLD). The maximum capacity attained since inception had been 48.6 MLD.

The source of the scheme's raw water is the Ogun River; while the final treated water is lifted via high-lift pumps to a reservoir situated on Asaran Hill in Abeokuta for onward distribution to consumers within Abeokuta metropolis.

The scheme has an intake structure with four low-lift pumps and the aerator structure is a concrete cascade in two parallel units. The scheme has four reinforced concrete sedimentation!clarifier structures of 36 m diameter each. The filtration system is made up of twelve rectangular concrete structures, each of which is 7.6 m x 11 m in dim ension. The clear water tank has a capacity of 7 500 m^3, made of reinforced concrete of internal dimensions 48.2 m x 35.2 m x 4.4 m. The Asaran Hill Reservoir is made up of twin circular ground reservoirs interconnected on the hill, with 2 x 22 000 m^3 capacity and measuring 50 min diameter and 12.5 min height.

Sampling

During both the wet and the dry seasons, 112 representative samples were collected from the raw, aerated, settled and treated water. Tests conducted on physico-chemical and bacteriological parameters included: tern perature, pH, electrical conductivity, colour, turbidity, total solids, total suspended solids, total dissolved solids, acidity, alkalinity, hardness, chloride, iron, residual chlorine, bacterial counts and coliform counts.

All the samples were analysed according to internationally accepted procedures and standard methods (APHA 1994). Results of laboratory analyses were subjected to data evaluation by use of standard statistical methods using QI Macro. Statistical analysis of variance (ANOVA) was carried out on the mean values of each of the parameters to determine degree of variation in mean values between raw and final water, and comparison made with the WHO and Nigerian drinking water standards.

Results and discussion

pH

The observed pH of the raw water indicated that the source of abstraction is alkaline all year round. The pH of the raw water ranges between 7.7 and 8.0. There were significant differences in the mean value of the raw and treated water: the pH of raw and treated water was respectively 7.86 ± 0.12 and 7.42 ± 0.24. The pH obtained from the treatment plant fell within the acceptable range of the Nigerian Standard for Drinking Water Quality (NSDWQ 2007), as shown in Table 1. Within the period of the study, the pH was found to be at the lowest level after leaving the sedimentation tank due to the addition of aluminium sulphate, as shown in Figure 1. There was not much variation in the pH during the wet and dry seasons. It is recommended that the pH should be less than 8 for

Table 1: Comparison of the treated water with the Vv'HO and the Nigerian Drinking Water Standard

Chemical parameter	Unit	v'HO permissible standard	Nigerian drinking water standard	Raw water	Treated water
Temperature	0C	25	Ambient	28.0	28.44 ± 0.99
Ph		6.5-8.5	6.5-8.5	8.0	7.42 ± 0.24
Electrical conductivity	Us/em	180	1 000	85.1	118.90 ± 7.37
Colour	Hazen	15	15	16.74	5.00 ± 0.00
Odour		Unobjectionable		Unobjectionable	
Turbidity	NTU	5	5	20.75	1.18 ± 0.76
Total solids	mg!l			117.33	103.88 ± 15.18
Suspended solids	mg!l			75.24	52.25 ± 12.00
Dissolved solids	mg!l	600	500	33.1	52.04 ± 4.28
Acidity	mg!l			0.1	0.12 ± 0.03
Alkalinity	mg!l			0.1	0.01 ± 0.02
Total hardness	mg!l	500	150	37.0	46.43 ± 2.86
Calcium (Ca^{2+})	mg!l	100-300	150	24.8	31.31 ± 4.67
Magnesium (Mg^{2+})	mg!l		0.2	12.3	15.76 ± 2.22
Chloride	mg!l	250	250	25.5	31.01 ± 1.72
Iron	mg!l	0.3	0.3	0.26	0.01 ± 0.01
Chlorine residual	mg!l	0.5	0.2–0.25	0.0	0.34 ± 0.23
Bacterial counts	Counts/1OOml	0	0	120.00	0.00 ± 0.00
Coliform counts	Counts/1OOml	0	10	160.00	0.00 ± 0.00

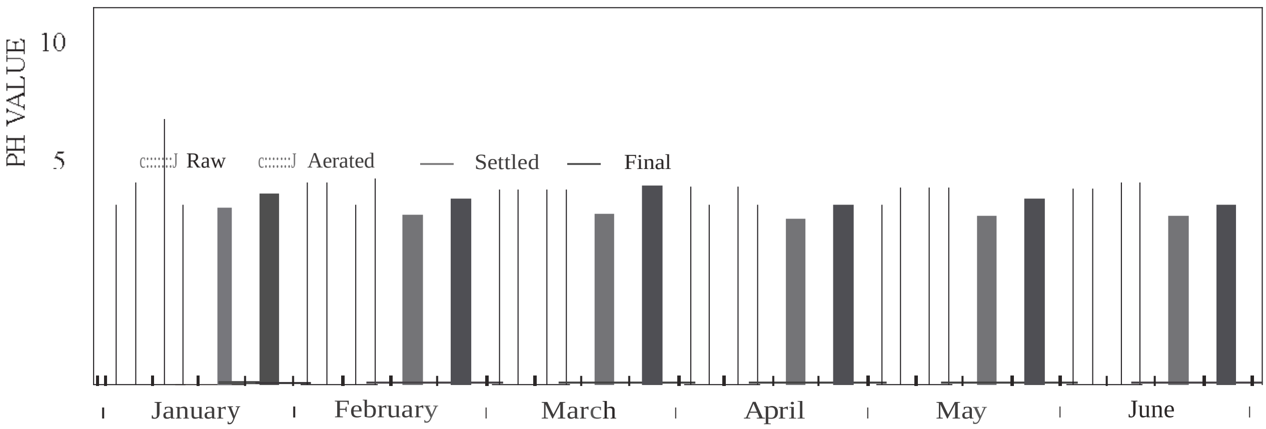

Figure 1: Variation in pH values within the treatment plant

effective disinfection with chlorine: the settled water from the sedimentation tank fell within this range.

Electrical conductivity

As shown in Table 1 and Figure 2, the average electrical conductivity values obtained from the analysis of raw and final water were 98.82 ± 12.04 and 118.90 ± 7.37 Us/em. This indicated a significant change in the value of electrical conductivity between raw and treated water. It was observed that the electrical conductivity level rises from raw to final. The increase in electrical conductivity was attributed to the coagulant and the lime dissolved to raise the pH of the water. These additions became dissolved solids in the water and thereby increased the electrical conductivity level of the water: the higher the dissolved solids in the water, the higher its electrical conductivity. However, this value falls within the permissible limit of less than 180 J..lmhos/cm specified by the WHO (2011), although the Nigerian standard still allows less than 1 000 J..lmhos/cm.

Colour

The mean values of colour of the raw and treated water for the assessment period were 16.44 ± 6.48 and 5.00 ± 0.00 Hazen respectively, as shown in Figure 3. These indicate a significant change between the raw and treated water, with a permissible colour limit of ⩽ 15 Hazen by the WHO (2011), as shown in Table 1. The treatment plant effectively removed the colour and made the treated water appealing to consumers.

The raw water source, the Ogun River, is of high colour during the wet season, as shown in Figure 3. The colour removal in the water treatment plant, illustrated in Table 2 and Figure 3, is partly a function of the aerator and mostly a function of the sedimentation tank and the filtration system. The reduction in colour shown in Figure 3 occurred mainly after sedimentation and filtration.

Turbidity

The average values of the raw and treated water during the study were 20.93 ± 9.80 and 1.18 ± 0.76 NTU respectively. These indicate significant differences in the raw and treated water. The result of the treated water fell within the Nigerian Drinking Water Standard (NSDQW 2007) permissible limits as shown in Table 1. The reduction in turbidity occurs mostly at the sedimentation and filtration tanks as shown in Figure **4.** Turbidity in water is caused by suspended particles or colloidal matter that obstructs light transmission through the water. This was seen to be higher during the wet season and lower in the dry season, as shown in Figure 4. The turbulence of flow from the tributaries of the river causes much agitation and mixture of debris with the water, thereby resulting in raw water of high turbidity.

Total solids

The mean values obtained for TS were 116.97 ± 28.97 and 103.88 ± 15.18 mg/1 for the raw and treated water respectively. The results showed that ISS were appreciably reduced during the treatment processes, with mean values of 75.42 ± 23.09 and 52.25 ± 12.00 mg/1 for raw and treated water respectively. This indicates that the settle-able and suspended particles had been appreciably eliminated from the treated water, thereby making it potable for consumption. The IDS were 42.38 ± 6.89 and 52.04 ± 4.28 mg/1 in the raw and treated water respectively,

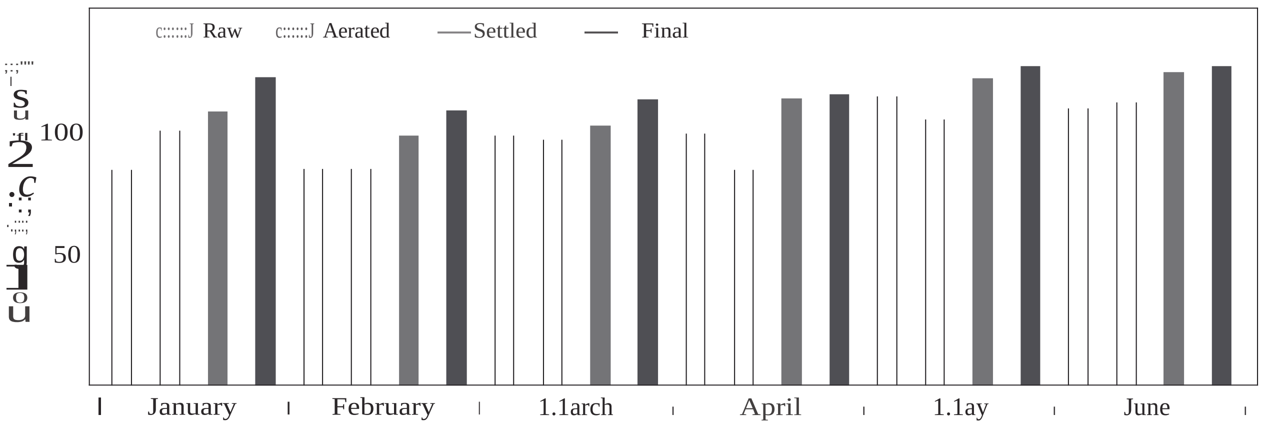

Figure 2: Electrical conductivity of the water after aeration, sedimentation, filtration and disinfection

Table 2: Effectiveness of the treatment processes on key parameters considered

Nature of sample	Raw	Final	% effectiveness	Treatment process(es)
Colom (Hazen unit)	16.74	5.00	70.13	Aeration, sedimentation and filtration processes
Tmbidity (NTU)	20.75	1.08	94.78	Sedimentation and filtration processes
Total solids (mg/1)	117.33	105.73	9.88	Sedimentation and filtration processes
Suspended solids (mg/1)	75.24	53.55	28.84	
Iron (mg/1)	0.26	0.01	96.06	Aeration, sedimentation and filtration processes
Bacterial counts/100ml	120 .00	0.00	100.00	Filtration and disinfection processes
Coliform counts/1OOml	160 .00	0.00	100.00	Disinfection process
Cumulative/average % effectiveness			71.38	Entire treatment system/processes

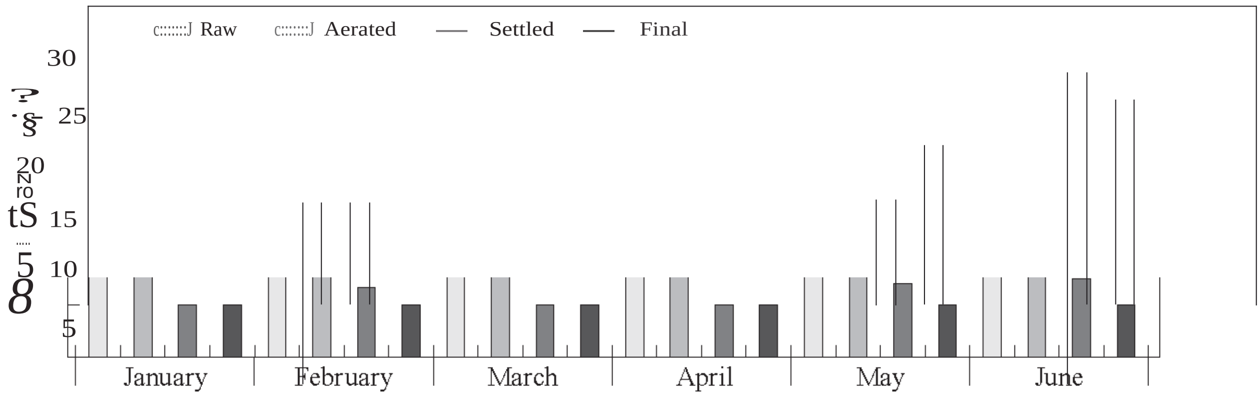

Figure 3: Variation in colour over the study period

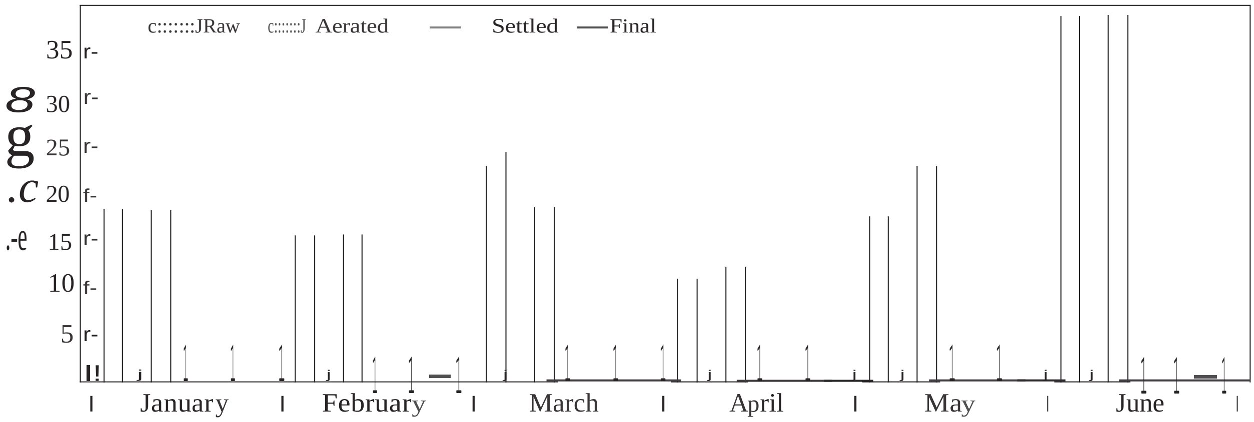

Figure 4: Turbidity level in the raw, aerated, settled and treated water of the treatment plant

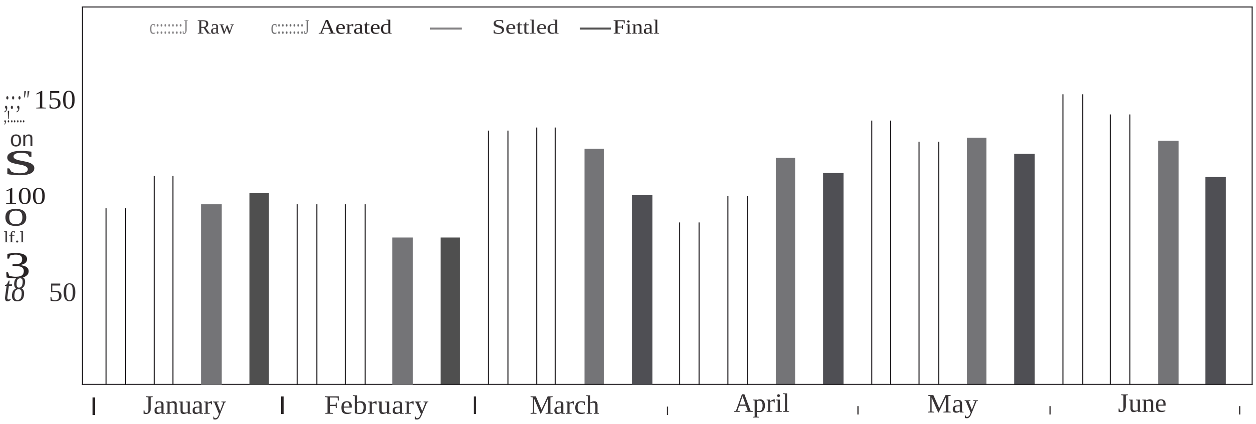

Figure 5: Total solids in the raw water, after aeration, sedimentation, filtration and disinfection

thereby showing an increase in the IDS from the raw to the treated water.

Total solids comprise of the ISS and IDS. The TS were higher during the wet season than the dry season, as shown in Figure 5. The WHO recommends IDS of less than 600 mg/1 at any point for the water to be consumed, while the Nigeria Drinking Water Standard recommends a maximum value of 500 mg/l, as shown in Table 1. It was observed that the TS were higher in the treated water than in the raw water. This increase was due to the addition of coagulant and the lime dissolved to raise the pH of the water. However, the amount of ISS was reduced, showing the effectiveness of the treatment process to remove harmful solids and bacteria.

Total hardness

Data analysed in this study indicated significant changes in the values of the total hardness from raw to final water, with mean values of 40.02 ± 4.72 and 46.43 ± 2 .86 mg/l respectively. Hardness in water is caused by a high mineral content. The rise in value of the total hardness from raw to final as shown in Figure 6 was caused by the chemical treatment using alum ($Al_2(SO_4)_3$) during coagulation, and the lime ($Ca(OH)_2$) introduced to regulate the pH to an acceptable

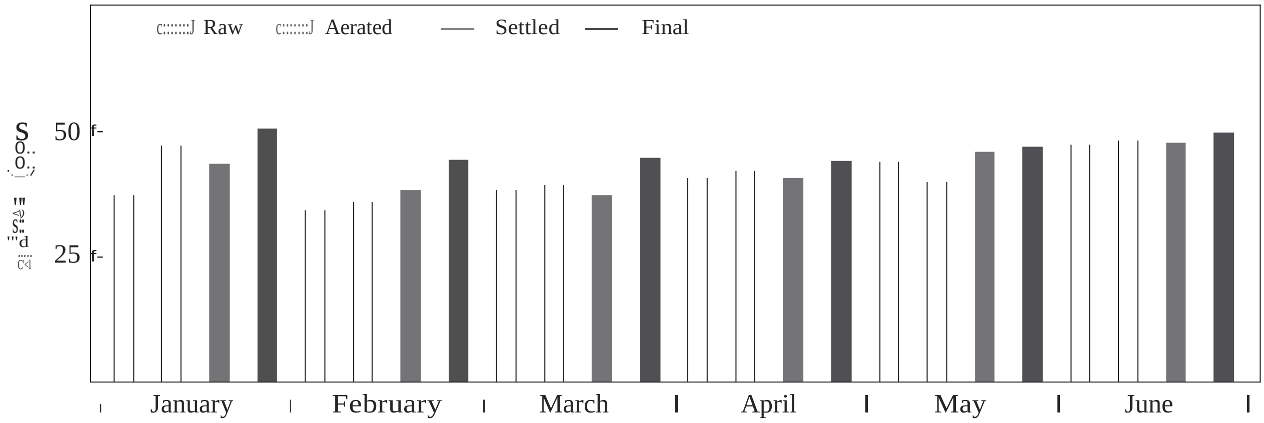

Figure 6: Variation of total hardness in the raw, aerated, settled and treated water

standard. However, the values of the total hardness fell below the maximum permissible value of 150 mg/1 by the WHO, as shown in Table 1, thereby affirming the acceptability of the treated water hardness level.

Coliform counts

As in bacterial counts, the WHO recommends a permissible value of nil counts/1OOml, as shown in Table 1, of the total coliform counts in drinking water after treatment and adequate disinfection. The initial coliform count of 175.00 ± 7.07/100 ml was completely eliminated after treatment. This conforms to WHO standards for drinking water. The removal was attributed to the filtration system and the disinfection process at the scheme.

Efficiency of the treatment plant

The breakdown of percentage effectiveness of the treatment processes in removing key parameters indicating the capability for the removal of impurities is highlighted in Table 2. The results of the analysis put the efficiency of the treatment plant to remove (partially or totally) key parameters indicating impurities in the raw water at 70.13% for colour removal, 94.78% for turbidity, 96.06% for iron and 100% for bacteria and coliforms.

Based on the study carried out on the water samples collected and analysed, from the raw water source to the treated water, it was observed that the treatment plant is operating at a 71.38% effectiveness of pollution removal. The values of various parameters for which data were collected, processed and analysed in comparison with WHO standards for potable drinking water indicate that, with proper upgrading, the designed capacity of 162 million litres per day is attainable.

Treated water from Arankaga main water scheme was seen to be within the WHO (2011) and NSDQW (2007) acceptable limit, as shown in Table 1.

Conclusion

The study showed that the aeration, clarification, filtration and disinfection processes at the Ogun State Water Corporation, Arakanga Water Works in Abeokuta, southwest Nigeria is 71.38% effective in pollution removal. The research also confirmed that the quality of the treated water from the water scheme is acceptable for human consumption in accordance to World Health Organisation (WHO 2011) standards and the Nigerian Standard for Drinking Water Quality (NSDWQ 2007). However, upgrading of the scheme is desirable in order to meet the required designed capacity of 162 million litres per day.

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