American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-11, Issue-02, pp-62-67
www.ajer.org
Research Paper Open Access

Effectiveness of Household Water Treatment Device for Improving Potable Water Quality of Groundwater in Nigeria

[1]AKINBOMI, J.G., [2]ODIKA, I.I, [3]DUDUYEMI, O., [4]AKINYEMI, O.P., [5]SALAMI, L., [6]ADESINA, A.A., [7]AMINU, K.A.
[1,3,4,5, 6]Department of Chemical Engineering, Lagos State University, Epe Campus,
[2]Centre for Environmental Studies and Sustainable Development,
Lagos State University, Ojo Campus,
Corresponding Author: AKINBOMI, J.G

ABSTRACT : *Inaccessibility to potable water supplies in most developing countries like Nigeria has forced people to resort to locating their own sources of water in form of borehole water and well water. However, borehole and well water supplies do not often meet the minimum standard for drinking water quality and need to be treated before usage as potable water. Therefore, the aim of this study was to evaluate the effectiveness of a designed household water treatment device for improving potable water quality of groundwater taken from three different sources including Ijanikin (Lagos State) borehole water, Sagamu (Ogun State) borehole water and Abeokuta (Ogun State) well water in Nigeria. Five litres of representative water samples collected from the three water sources were passed through the water treatment device. The experimental variables investigated for data acquisition were aeration period of untreated water samples; device backwashing operation cycles and retention times of water samples in the water treatment device. The results of the analysis showed both remarkable and non-remarkable changes in some of the measured parameters as the variables were being manipulated. The range of values for p-values within the different experimental variables studied were 0.163 – 0.263, 0.105 – 0.286 and 0.842 – 0.974 for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively. The p-values indicated the non-significance of the different values of the experimental variables used. However, the insignificant difference does not mean that the developed portable household water filter device is not relevant regarding the quality improvement of the various ground water sources tested. In future studies other experimental conditions will be tested in the application of the water treatment device which may indicate significant difference between untreated and treated water samples.*

KEYWORDS: *potable water, water device, well water, borehole water, accessibility*

Date of Submission: 05-02-2022 Date of acceptance: 18-02-2022

I. INTRODUCTION

It is quite unfortunate that the majority of people living on earth does not have access to potable water sources despite the fact that earth has an abundance of water [1]. Access to sufficient and potable water is very essential to man's survival as it is required for his domestic, agricultural and industrial activities. Besides, lack of improved drinking water has been linked to various diseases including cholera, dysentery and typhoid, among others, as a result of exposure to infectious agents, and chemical pollutants. According to World Health Organization [2], most diarrheal diseases and consequent 1.8 million deaths annually are caused by drinking contaminated water [3]. The growth in world population [4], as well as, man's induced climate change and water pollution have been the major factors responsible for the decrease in fresh water availability [5]. Many conflicts in some parts of the world have been attributed to fresh water shortage with increasing competition and claims to the scarce water.[6]. In view of the high demand for safe and clean water which far exceeds the available amount, many waste water treatment technologies including water distribution system, have been developed and set up in most countries, to improve clean water availability and supply potable water to various households. Even with the available water distribution system set up by government to provide potable water, most households in developing countries, still do not have access to potable water supply [7, 8] due to damaged or non-functioning water distribution system, poor maintenance culture, erratic power supply, security challenges, as well as, inadequate expertise, among others.

Consequently, the people in Nigeria now bear the responsibility of providing potable water for themselves with majority having to sink boreholes or wells in their homes. However, borehole and well water supplies do not often meet the minimum standard for drinking water quality and need to be treated before usage as potable water. It is therefore important for individual households to have handy household water treatment device for improving potable water quality of the available groundwater. Although many studies have been carried out globally regarding the development of portable water purification device [9, 10], relatively little is known about the development of the water treatment device for households in Nigeria, especially for the sole purpose of replacing the non-functioning conventional water supply network owned by the government. The aim of this study is therefore to assess the effectiveness of household water treatment device to improve the potable water quality of groundwater taken from three different sources in Nigeria, including Ijanikin (Lagos State) borehole water, Sagamu (Ogun State) borehole water and Abeokuta (Ogun State) well water.

II. METHODOLOGY

A. Experimental materials

The experimental materials included weighing balance, funnel, measuring cylinder, calibrated bucket, sample bottles with stoppers, aluminium foil, autoclave, gas burner, alcohol solution, distilled water, fire extinguisher, and autoclave. The portable household water filter device developed was made of two components; the stainless filter component and the cartridge filter component (Plate 1). The dimensions of the portable household water filter device are shown in Figure 1. The operation of the water filter device was based on gravitational flow process, and as such, electrical power was not required for the operation of the water filter device. The filter beds comprised of 4mm gravel, 3mm gravel, 2 mm sand, activated carbon, green sand, birm, chlorine and caustic soda. The 2mm sand filter, 3 mm gravel and 4 mm gravel were responsible for filtration and removal of debris from water. The activated carbon removed water odour and tastes; green sand and birm helped in the removal of some of the compounds in water while chlorine helped to kill microorganisms in water and also act as a preservative for the water when stored. Caustic soda helped to boost the pH since the water samples are acidic in nature. The components of filter bed, as well as other chemicals for water treatment were stored in separate containers prior to the experimental process. The ground water sources included borehole and well water from three households in two Nigerian states including Lagos and Ogun State.

Plate 1. Household Water Treatment Device

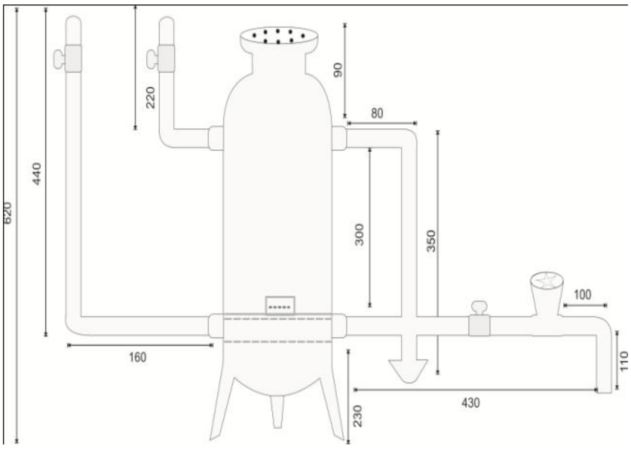

Figure 1. Schematic Diagram of the Household Water Treatment Device

B. Experimental procedure

The sample bottles were first prepared and sterilized before using them for the collection of the ground water samples to avoid contamination of the water samples. The bottles were washed thoroughly and rinsed with distilled water before sterilizing the bottles at 120ºC for 20 minutes. Screw bottle caps were loosely fastened to the sample bottles prior to sterilization in an autoclave. A strip of aluminium foil was placed inside the neck of each sample bottle to prevent the stopper from getting stuck during sterilization. The stopper was used to protect the sample bottles from contamination. The groundwater sources, including borehole and well water, were fitted with pumps. To draw water samples from each of the ground water sources, standard procedure was followed.

The pump was operated for 20 minutes to clear any standing water in the water column. The hands were washed and then pump outlet was cleaned thoroughly. The hands were washed again before opening the tap. The tap was then opened until it reached its maximum rate of flow. The water was allowed to flow from the tap for 1 to 2 minutes to clear the service line. The tap was then closed so that the tap spout could be sterilized by using a solution of alcohol. After the spout was sterilized, the tap was opened again to allow the water to flow for 1 to 2 minutes at normal rate. The sterilized bottle was then opened carefully (while keeping the fingers on the aluminum foil) and immediately put under the water jet until total volume of 5 litres was obtained from each groundwater source. The collected water samples were kept in a cool place [11].

The operation of the water filter device was based on gravitational flow process, and as such, electrical power was not required for the operation of the water filter device. The stainless filter component was filled with 1000g each of 4mm gravel, 3mm sand and 2 mm sand while 500g each of birm, green sand and activated carbon were also loaded into the filter device. The stainless filter device and its contents were washed by passing excess water through the device to get rid of the powder component in the filter device bed. It was then backwashed for several times for total cleaning of the stainless filter device bed. After filling and cleaning of the stainless filter component, the cartridge filter component was connected to the stainless filter component. Two table spoons full of chlorine and 50 ml of caustic soda were added to the five litres of water sample before the water sample was passed through the stainless filter vessel component and cartridge filter. The resultant sample was collected and taken to the laboratory for analysis. This was done for the different samples depending on the variables being investigated.

The experimental variables investigated for data acquisition were aeration period of untreated water samples; device backwashing operation cycles and retention times of water samples in the filter device. Aeration was achieved by exposing the water sample to the atmosphere to absorb oxygen to aid in breaking the iron (II) (Fe^{2+}) to Iron (III) (Fe^{3+}). The water samples were first exposed to air for five minutes before they were passed through the portable household water filter device and the resultant treated water samples were collected for laboratory analysis. This was repeated again by exposing the samples for ten minutes, fifteen minutes and twenty minutes. Regarding retention time in the stainless filter component, it was achieved by passing the water samples that were exposed to the atmosphere at different time intervals through the portable household water filter device, (but the outlet valve before the cartridge filter component was locked) at four different time intervals of 5 minutes, 10 minutes, 15 minutes and 20 minutes and the resultant treated water samples were collected, respectively, for further analysis Retention time in the cartridge filter was achieved the same way it was done in the case of retention time in the stainless filter component. However, in this case, the outlet valve before cartridge filter was opened while the outlet valve after cartridge filter was closed at different time intervals of 5 minutes, 10 minutes, 15 minutes and 20 minutes. The resultant water samples were collected for further analysis. Back washing was carried out for four different cycles of five cycles, ten cycles, fifteen cycles and twenty cycles. After each backwashing, the water samples were passed through and the resultant water samples were collected for further analysis.

III. RESULTS AND DISCUSSION

The various water samples, including untreated and treated water samples, obtained during the experimental process were taken to the laboratory for chemical analysis. The results of the analysis conducted (Tables 1 to 3) showed great changes in some of the parameters as the variables were being

Table 1. Results of chemical analysis conducted on Ijanikin (Lagos State) household borehole water samples and the p-values for using the developed filter device for the water treatment

S/N				Barium	Free Chlorine	Chromium	Iron	pH	TDS***	Hardness	Chloride	P-values for using the device.
	Standard	NSDWQ*		0.7 mg/L	0.5 mg/L	0.05 mg/L	0.3 mg/L	6.5-8.5	500 mg/L	150 mg/L	250 mg/L	
		WHO**		0.7 mg/L	0.5 mg/L	0.05 mg/L	0.3 mg/L	6.5-8.5	500 mg/L	150 mg/L2	250 mg/L	
A	Backwashing (cycles)		0	0.25	0.01	0.06	0.16	5.8	279	85	50	
	Aeration (min)		0									
	Retention (min)		0									
B	Backwashing (cycles)		5	0.10	0.00	0.06	0.13	6.5	272	70	40	0.105
	Aeration (min)		5									
	Retention (min)		5									
C	Backwashing (cycles)		5	0.10	0.06	0.06	0.10	6.5	175	72	45	0.274
	Aeration (min)		5									
	Retention (min)		10									
D	Backwashing (cycles)		10	0.10	0.00	0.06	0.11	6.5	180	72	41	0.254
	Aeration (min)		10									
	Retention (min)		10									
E	Backwashing (cycles)		10	0.09	0.06	0.06	0.10	6.6	175	72	45	0.274
	Aeration (min)		10									
	Retention (min)		5									
F	Backwashing (cycles)		15	0.11	0.00	0.06	0.11	6.6	183	75	40	0.260
	Aeration (min)		15									
	Retention (min)		15									
G	Backwashing (cycles)		15	0.10	0.06	0.06	0.09	6.5	175	72	45	0.274
	Aeration (min)		15									
	Retention (min)		10									
H	Backwashing (cycles)		20	0.11	0.02	0.06	0.10	6.4	182	75	41	0.264
	Aeration (min)		20									
	Retention (min)		20									
I	Backwashing (cycles)		20	0.10	0.06	0.06	0.09	6.5	175	75	45	0.286
	Aeration (min)		20									
	Retention (min)		5									

*NSDWQ - Nigerian Standard for Drinking water quality
**WHO-World Health Organization

Table 2. Results of chemical analysis conducted on Sagamu (Ogun State) household borehole water samples and the p-values for using the developed filter device for the water treatment

S/N				Barium	Free Chlorine	Chromium	Iron	pH	TDS***	Hardness	Chloride	P-values for using the device.
	Standard	NSDWQ*		0.7 mg/L	0.5 mg/L	0.05 mg/L	0.3 mg/L	6.5-8.5	500 mg/L	150 mg/L	250 mg/L	
		WHO**		0.7 mg/L	0.5 mg/L	0.05 mg/L	0.3 mg/L	6.5-8.5	500 mg/L	150 mg/L2	250 mg/L	
A	Backwashing (cycles)		0	0.1	0.03	0.05	0.13	5.7	843	90	50	
	Aeration (min)		0									
	Retention (min)		0									
B	Backwashing (cycles)		5	0.04	0.00	0.03	0.12	6.6	230	0	0	0.974
	Aeration (min)		5									
	Retention (min)		5									
C	Backwashing (cycles)		5	0.05	0.02	0.03	0.12	6.6	231	10	10	0.885
	Aeration (min)		5									
	Retention (min)		10									
D	Backwashing (cycles)		10	0.04	0.00	0.03	0.11	6.5	238	15	2	0.873
	Aeration (min)		10									
	Retention (min)		10									
E	Backwashing (cycles)		10	0.07	0.02	0.03	0.10	6.9	230	10	10	0.887
	Aeration (min)		10									
	Retention (min)		5									
F	Backwashing (cycles)		15	0.08	0.00	0.03	0.10	6.5	240	16	5	0.850
	Aeration (min)		15									
	Retention (min)		15									
xdv G	Backwashing (cycles)		15	0.05	0.01	0.03	0.11	6.7	231	10	10	0.885
	Aeration (min)		15									
	Retention (min)		10									
H	Backwashing (cycles)		20	0.08	0.02	0.03	0.09	6.4	242	15	5	0.848
	Aeration (min)		20									
	Retention (min)		20									
I	Backwashing (cycles)		20	0.05	0.01	0.03	0.10	6.6	232	14;	15	0.842
	Aeration (min)		20									
	Retention (min)		5									

*NSDWQ - Nigerian Standard for Drinking water quality
**WHO-World Health Organization

Table 3. Results of chemical analysis conducted on Abeokuta (Ogun State) well water samples and the p-values for using the developed filter device for the water treatment

S/N			Barium	Free Chlorine	Chromium	Iron	pH	TDS***	Hardness	Chloride	P-values for using the device.
	Standard	NSDWQ*	0.7 mg/L	0.5 mg/L	0.05 mg/L	0.3 mg/L	6.5-8.5	500 mg/L	150 mg/L	250 mg/L	
		WHO**	0.7 mg/L	0.5 mg/L	0.05 mg/L	0.3 mg/L	6.5-8.5	500 mg/L	150 mg/L	250 mg/L	
A	Backwashing (cycles) Aeration (min) Retention (min)	0 0 0	0.24	0.01	0.05	0.23	6.5	267	110	30	
B	Backwashing (cycles) Aeration (min) Retention (min)	5 5 5	0.07	0.05	0.04	0.14	7.2	168	75	10	0.163
C	Backwashing (cycles) Aeration (min) Retention (min)	5 5 10	0.07	0.05	0.04	0.13	7.0	170	77	11	0.166
D	Backwashing (cycles) Aeration (min) Retention (min)	10 10 10	0.07	0.02	0.04	0.11	6.9	169	81	10	0.172
E	Backwashing (cycles) Aeration (min) Retention (min)	10 10 5	0.07	0.05	0.04	0.10	7.1	170	77	11	0.263
F	Backwashing (cycles) Aeration (min) Retention (min)	15 15 15	0.08	0.02	0.04	0.11	6.6	171	80	9	0.164
G	Backwashing (cycles) Aeration (min) Retention (min)	15 15 10	0.07	0.03	0.04	0.11	6.9	170	77	11	0.165
H	Backwashing (cycles) Aeration (min) Retention (min)	20 20 20	0.08	0.00	0.04	0.10	6.7	172	82	10	0.170
I	Backwashing (cycles) Aeration (min) Retention (min)	20 20 5	0.07	0.04	0.04	0.09	6.9	170	78	11	0.167

*NSDWQ - Nigerian Standard for Drinking water quality
**WHO-World Health Organization

manipulated, though some of the parameters did not show much significant change. For example, barium, chromium and pH showed a little or no change in values as the variables were being manipulated. When the aeration was carried out for 5 minutes, 10 minutes, 15 minutes and 20 minutes, the changes shown by these parameters (chromium, barium, free chlorine, chloride and ph) were insignificant. The same scenario was observed with 5 times backwashing with 5 minutes retention time in the vessel and cartridge filter, 10 times backwashing with 10 minutes retention time in the reactor and cartridge filter, 15 times backwashing with 20 minutes retention time in the reactor and cartridge filter. When the aeration time and other variables were increased, the changes observed were still not much larger than the original amount though there were noticeable changes in some other parameters such as iron, total dissolved solids (TDS) and hardness. For example, the changes were noticeable when using the variables such as 5 minutes aeration with 5 times backwashing and 5 minutes retention time in the vessel and cartridge filter, 10 times backwashing with 10 minutes retention time in the reactor and cartridge filter, as well as, 15 times backwashing with 20 minutes retention time in the reactor and cartridge filter.

When the water samples were exposed to the atmosphere for 5 minutes aeration, the iron contents in the original sample were found to be 0.23, 0.16 and 0.13 mg/L for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively. After the analysis, the results for iron content were found to be 0.13, 0.10 and 0.12 mg/L for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively. For 10 minutes aeration, there were some reductions in iron content of the water samples with Abeokuta, Ijanikin and Sagamu groundwater sources having 0.10, 0.095 and 0.10 mg/L, respectively, after the treatment. For 15 minutes aeration, the iron content values after the treatment were 0.11, 0.09, amd 0.11 mg/L for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively. Regarding 20 minutes aeration, the values for Abeokuta, Ijanikin and Sagamu groundwater sources were 0.085; 0.09 and 0.10 mg/L, respectively. However, the initial TDS for the water samples increased as the retention times of the samples in the reactor and cartridge filter were increased. When the water samples were allowed to stay in the reactor for 5 minutes, the values were different from when the water samples were allowed to stay for 10, 15 and 20 minutes. The initial TDS for the untreated water samples were 267, 270 and 843 mg/L for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively. For 5 minutes retention time in the reactor, the values were 170, 175 and 230 mg/L for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively. For 10 minutes retention time, the values were 170, 175 and 231 mg/L for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively while for 15 minutes retention time; the values were 267, 279 and 843 for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively. When the retention time was 20 minutes, the TDS for the treated water samples were 178, 179 and 239 mg/L for

Abeokuta, Ijanikin and Sagamu groundwater sources, respectively. Similarly, the hardness value of the treated water samples also increased when compared to the untreated water samples. For 5 minutes retention time; the hardness values were 77, 72 and 10 mg/L as against the original hardness values of 110, 85 and 90 mg/L for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively. For both 10 and 15 minutes retention times, the hardness values of the treated water samples were 77, 72 and 10 mg/L while for 20 minutes retention time, the hardness values of the treated water samples were 77, 72 and 15 mg/L for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively.

The results of the statistical analysis carried out to determine if there were significant differences between the values of chemical contents of untreated and treated water samples from the various groundwater sources tested, are also presented in Tables 1 to 3. Minitab 17 paired T-test was used to determine the significant differences between the chemical contents of untreated and treated water samples. From the results obtained, it was observed that, within the various experimental conditions of aeration periods, backwashing cycles and retention times, the p-values ranged from 0.163 – 0.263, 0.105 – 0.286 and 0.842 – 0.974 for Abeokuta, Ijanikin and Sagamu groundwater sources, respectively. Based on the criterion p-value of α level = 0.05; the differences between the values of parameters of the untreated and treated water samples under the various experimental conditions investigated were not significant since the associated p-values obtained were greater than the α level = 0.05. However, the insignificant difference does not mean that the developed portable household water filter device is not relevant regarding the quality improvement of the various ground water sources tested. It could even be observed from the results obtained that under the investigated experimental conditions, the values of some parameters for the untreated and treated water samples were not the same; the treated water samples had improved quality level when compared to untreated water samples. Besides, the application of the water treatment device may be justified using other experimental conditions of aeration period, backwashing cycles and retention times. Therefore, effort will be made in future research work to try other means of improving potable water quality using the same water treatment device. The importance for every household in Nigerian to have access to potable water supply cannot be understated given the fact that most Nigerians consume contaminated water which often results in people having diseases such typhoid, dysentery and cholera, among others. The accessibility to potable water could be made possible through the use of household water treatment device.

IV. CONCLUSION

This study was set out primarily to evaluate the effectiveness of household water treatment device developed to improve potable water quality of contaminated water supply. The results of the analysis conducted showed some changes in some of the parameters as the variables were being manipulated. Although the statistical analysis of the results indicated the insignificant differences between the values of the parameters of untreated and treated water samples, there was improvement in the quality of the treated water samples when compared to the untreated water samples. To further justify the significance of using the portable household water filter device, other experimental conditions will be investigated in future studies. It is believed that by adopting and properly implementing the policy of household usage of the portable water treatment device in Nigeria, all households in Nigeria will have access to clean and safe drinking water.

REFERENCES

[1]. Oki, T. and Kanae, S., *Global hydrological cycles and world water resources* Science, 2006. **313**(5790): p. 1068–1072.

[2]. WHO-2008, *Guidelines for Drinking-Water Quality. Third Edition incorporating the first and second Addenda.vol.1(Geneva World Health Organisation)*

[3]. Tumwine, J.K., Thompson, J., Katua-Katua, M., Mujwajuzi, M., Johnstone, N., and Porras, I., *Diarrhoea and effects of different water sources, sanitation and hygiene behaviour in East Africa.* . Trop Med Int Health, 2002. **7**: p. 750-756.

[4]. Akinbile, C.O., *Borehole Construction Technology in the Riverine Areas. A case study of Igbokoda, Ondo State, Nigeria.* World Journal of Biotechnology, 2004. **5**(1): p. 771-778.

[5]. Cohen, B., *Urbanization in developing countries: current trends, future projections, and key challenges for sustainability.* Technol Soc, 2006. **28**: p. 63-80.

[6]. Mesinzen-Dick, R. and Bakker, M., *Water Rights and Multiple water users.* Irrigation and Drainage system, 2001. **15**: p. 129-143.

[7]. Chan, C.L., Zalifah, M.K., and Norrakiah, A.S., *Microbiological and physiochemical quality of drinking water.* Malaysian J Analyt Sci 2007. **11**: p. 414-420.

[8]. Abdel-Moety, N.M., Al-Fassi, F.A., and Ali, M.A., *Health aspects of virological water quality: an overview review.* J. Appl Sci Res, 2008. **4**: p. 205-215.

[9]. Ekwue, E.I., Dhanraj, V., and Bircg, R.A., *A Simple Portable Potable Water Treatment Plant in Rural Areas.* The Journal of the Association of Professional Engineers of Trinidad and Tobago 2013. **41**(1): p. 29-34.

[10]. El-harbawi, M., Sabidi, A.B., Kamarudin, E.B., Abd-Hamid, A.B., Harun, S.B., Nazlan, A.B., and Yi, C.X., *Design of a portable dual purposes water filter system.* Journal of Engineering Science and Technology, 2010. **5**(2): p. 165 - 175.

[11]. Madrid, Y. and Zayas, Z.P., *Water sampling: traditional methods and new approaches in water sampling strategy.* Trends in Analytical Chemistry, 2007. **26**(4): p. 293-299.