Nigerian Journal of Technology (NIJOTECH)
Vol. 33. No. 1, January 2014, pp. **134 – 140**

University of Nigeria, Nsukka, ISSN: 1115-8443
www.nijotech.com
http://dx.doi.org/10.4314/njt.v33i1.18

COMPARATIVE STUDY OF HOUSEHOLD WATER TREATMENT IN A RURAL COMMUNITY IN KWARA STATE NIGERIA

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Abstract
This research presents the household treatment of drinking water samples in a rural community in Nigeria by boiling and water guard. The physicochemical parameters of the raw water samples with exception of chloride, BOD and dissolved oxygen were within the permissible limits of the World Health Organization (WHO) and Standard Organization of Nigeria (SON). The mean BOD value of the public tap water samples (5.3 mg L^{-1}) was lower that of the bore-hole water samples (9.1 mg L^{-1}). The major anions determined were within permissible limits. With exception of Zinc (Zn) and Iron (Fe), the other metals investigated were either not detected or had their concentrations below maximum permissible limits. There was no significant difference ($P<0.005$) in the concentration of metals from public tap as compared to the bore- hole water samples. The concentrations of Zn were 8.3 mg $L^{-1}$for the water `coliform bacteria but after treatment by boiling and water guard, it was observed that the coliform count was reduced to zero with boiling but remained as 1cfu 100mL^{-1} with water guard. Bacillus and Mucor species isolated from the water samples of public taps were removed by boiling and water guard treatments.

Keywords: Water quality, Water treatment, Coliform bacteria, Metals

1. Introduction
Water is an indispensable resource for supporting life systems. Often times, the major concerns are the bio-physico-chemical parameters and metals in the water, and their health and socio-economic impacts and implications on the end users and the environment [1]. Sadly, information on these parameters, let alone their continuous assessment, are grossly lacking in developing countries [2].Globally, not less than 780 million people representing more than 10% of the global population lack access to safe, improved drinking water. Sub-Saharan Africa (SSA) alone accounts for more than 40% of the global population without access to improved drinking water [3]. Based on WHO and United Nations Children's Fund (UNICEF) joint report, 66 million people in Nigeria do not have improved drinking water source, third after China (119 million) and India (97 million)[4].WHO's vision of achieving the goal of reduction by 50% the proportion of people without sustainable access to safe drinking water and sanitation by 2015, a target "7C" of the Millennium Development Goals (MDGs), is impossible without the use of the "WASH" (Water, Sanitation and Hygiene) interventions, a comprehensive and multi-disciplinary approach. Achievement of target "7C" of the MDGs has direct implications for meeting MDG4 (reducing child mortality), MDG5 (improving maternal health) and MDG6 (combating HIV/AIDS, malaria and other diseases) [5].

WASH interventions are essential to primary health care and is one of the seven-point strategies agreed by WHO and UNICEF and includes household water treatment and safe storage, community-wide sanitation and hand-washing promotion. Other strategies are monitoring and support of water suppliers and regulators, harmonization of sectoral policies and strengthening of institutional arrangements, water safety plan, operation and maintenance network and regulators network [5].Governments in developing countries lack serious approach to the provision of portable water for urban, peri-urban and rural areas [2; 6-7]. This is revealed by the uncoordinated efforts of the three-tiers of government (Federal, State and Local) in Nigeria towards addressing water challenges and the meager 24% access of rural communities to safe water [6-7]. Other challenges identified include poor level of service, inadequate reticulation network, inadequate monitoring of water-related projects, poor quality control, frequent power outage, low capacity building, poor maintenance culture, corruption, poor planning, population explosion and lack of political will [8-9].

These ugly scenarios suggest that without scaling-up various water intervention programs to address these challenges, potential catastrophic risks are transferred to future generations and developing countries may become alienated from sustainable development. Contaminated drinking water and poor sanitation were reported to rank third in the list of the twenty leading health risk factors in developing nations [10-11].

Recently, the quality of water from local wells was reported to be unsafe for human consumption except when treated [12]. This is in line with the report of Mukhopadhyay et al. [13] on the microbial quality of well water from rural and urban households in Karnataka India revealing that 93% of the wells investigated had water contaminated with coliform bacteria. This is usually the case in many developing nations. Presently, there has not been any published rigorous study on the effectiveness of common water treatment methods on the drinking water quality of rural communities in Nigeria. This study was therefore aimed at assessing the effectiveness of treatment by boiling and by using water guard (sodium hypochlorite) on the drinking water quality of Omu-Aran, in Irepodun Local Government Area of Kwara State Nigeria. The efficiency of the household treatments was assessed in terms of the physicochemical factors, biological factors and metals.

2. Materials and methods

2.1 Study area description

Kwara State is located in the North Central Zone of Nigeria on latitude 8^0 30' N and longitude 5^0 0'E.Omu-Aran is one of the most populated communities in Irepodun Local Government Area of Kwara State located at 88km South of Ilorin, the capital of Kwara State on latitude 8.9^0N and longitude 5.6^0E. The climate is tropical maritime with a long wet season. The vegetation of Omu-Aran is pre-dominantly guinea savannah. The average annual rainfall, average temperature and annual mean relative humidity are 1235mm, 32.3^0C and 50% respectively [14].

2.2 Water Sampling

Water samples were collected from June 01 to June 30, 2013 from bore-holes, and public taps of water board from different households within the study area. New high-density PET screw-capped containers of 1.5 L capacity were used to collect the water samples. The PET containers and stoppers were thoroughly washed with distilled water three times and once with the water to be sampled before collecting the actual sample. As was described by Owamah et al.[3], at each site one bottle was filled with water having no acid while the other bottle was filled with the water from the same point and acidified by adding a few drops of 5% HNO_3 to arrest the activities of microorganisms. At the same time, samples for microbial analysis were collected using autoclave-sterilized sample bottles from the same locations. The water samples were transported to the Laboratory of the Chemistry Department of the University of Lagos, Lagos State, Nigeria. The water samples were preserved in a refrigerator at 4^0C to keep the water content intact until analyses were carried out.

2.3 Analytical procedure

The parameters of pH (HI 9024-C, Hanna Instruments, Smithfield, RI, USA), temperature (HI 98517, Hanna Instr.), salinity (HI 19311, Hanna Instr.), electrical conductivity (HI 2315, Hanna Instr.), and total dissolved solids (TDS)(VSI 22, VSI Electronics Private Limited, Punjab, India) were analyzed in- situ using the mentioned hand digital meters. Dissolved oxygen of the water samples were analyzed using the azide modification of Winkler's method [15]. As described in APHA [15], chloride was determined by titration. Ultraviolet spectrophotometer screening method was used in the determination of the major anions by strictly following the method described in APHA [15], using a UV spectrophotometer (DR 2800, HACH, Washington, USA). In order to ensure that the analyses were reliable and reproducible, blank, standard and pre-analyzed samples were analyzed after every 10 samples [3; 16]. Standard methods were used to count the total coliform bacteria as maximum probability number (MPN) in water samples [15]. Metals were analyzed with atomic absorption spectrophotometer (AAS) (Sens AA 3000, GBC, Australia) following the method in APHA [15].

2.4 Statistical analyses

Microsoft Office Excel 2007 software package was used to statistically analyze data with a significance level of $P < 0.005$ using the Analysis of Variance (ANOVA). The mean values of the parameters analyzed were computed for bore-holes and public taps water samples. The standard deviations address the variability between samples taken individually from the bore-holes and public taps.

3. Results and discussion

3.1 Physicochemical parameters

ANOVA shows that there was no significant variation ($p < 0.005$) in the values of the physical parameters. The physicochemical parameters with exception of chloride, BOD and dissolved oxygen are within the permissible limits of WHO and SON.The mean value of BOD of the public tap water sample (5.3 mg L^{-1}) was lower that of the bore-hole water samples (9.1 mg L^{-1}). For the water samples from the publictaps, boiling reduced the BOD value to 2.67mg/l, while treatment with water guard, reduced the BOD value to 0.1 mg L^{-1}. Likewise, treatment by boiling and water guard reduced the BOD value of the bore-hole water samples to 5.9 mg L^{-1} and2.9 mg L^{-1} respectively. According to Ademoroti [17], the maximum BOD_5 allowed is 6 mg L^{-1} with higher values indicating organic pollution.

The mean values of the dissolved oxygen in the water samples of the public taps and bore-holes were 4.4 mg L^{-1} and 6.8 mg L^{-1}. These mean values are within the permissible limit of the WHO which is 4 mg L^{-1}. However, after treatment of the raw water sample by boiling, and water guard, the value of dissolved oxygen increased appreciably. Moreover, water guard increased the dissolved oxygen better than treatment by boiling as shown in Table 1. This unusual increase in the dissolved oxygen after treatments by boiling and water guard could be attributed to the destruction of microorganisms in the water samples which could have been utilizing the dissolved oxygen for metabolic processes. The increase in dissolved oxygen could also be traced to the reduction in BOD. The temperature value ranged from 26.3^0C to 26.9^0C for the raw drinking water samples and is within the permissible limits of the WHO (Table 5). The value of pH for the raw public tap water sample is 6.5, while that of the bore-hole water sample is 4.7.

Table 1: The mean values of the physicochemical parameters in the raw and treated water samples from public taps and bore-holes (N=15)

Parameters	Public Tap (A)	(A) + Boiled	(A) + Water Guard	Borehole (B)	(B)+ Boiled	(B) + Water Guard
Temperature (^oC)	26.7±0.1	26.4±0.1	26.0±0.3	26.3±0.2	26.9±0.1	26.9±0.3
pH	6.5±0.0	6.0±0.3	6.7±0.1	4.7±0.1	4.6±0.4	5.1±0.2
Turbidity (NTU)	2.2±0.2	1.85±0.3	2.0±0.1	11.1±0.5	6.8±0.5	9.3±0.1
Conduct.(μScm^{-1})	197±2.4	142±5.1	230±3.8	129±2.2	127±3.0	201±5.4
TS (mg L^{-1})	98.5±3.6	71.1±2.6	116±1.5	65.2±2.0	64.3±3.6	101.3±4.2
TSS(mg L^{-1})	0.3±0.1	0.1±0.1	1.2±0.1	0.9±0.3	1.0±0.1	1.0±0.2
TDS(mg L^{-1})	98.3±2.8	71.0±1.7	114.7±3.9	64.3±3.2	63.3±2.6	100.3±4.6
BOD(mg L^{-1})	5.3±0.1	2.7±0.1	0.1±0.1	9.1±0.3	5.9±0.2	2.9±0.1
DO(mg L^{-1})	4.4±0.2	5.3±0.1	7.6±0.3	6.8±0.3	9.0±1.0	9.2±0.7

DO = dissolved oxygen; Results are expressed as mean ± standard deviation

Table2: The mean concentrations of anions in the raw and treated water samples from public taps and bore-holes (N=15)

Parameters	Public Tap (A)	(A)+ Boiled	(A) + Water Guard	Borehole (B)	(B)+ Boiled	(B) + Water Guard
Cl^{-1}(mg L^{-1})	601.8±20.4	708±2.6	885±3.1	123.9±5.6	336.3±6.3	141.6±2.4
Nitrate(mg L^{-1})	14.5±1.0	26.3±1.2	33.7±1.3	17.3±1.0	17.7±0.6	29.5±1.7
Nitrite(mg L^{-1})	1.2±0.1	1.3±0.0	1.7±0.0	1.0±0.1	1.9±0.1	1.1±0.0
SO_4^{2-}(mg L^{-1})	74.0±3.8	78.0±2.6	79.0±1.9	11.0±0.6	21.0±0.6	16.0±0.4
PO_4^{2-}(mg L^{-1})	28.1±1.7	26.5±1.4	34.1±1.3	27.5±0.9	36.8±2.6	32.0±2.8

Results are expressed as mean ± standard deviation

Table 3. The mean concentrations of metals in the raw and treated water samples from public taps and bore-holes (N=15)

Parameters	Public Tap (A)	Borehole (B)
Ca(mg L^{-1})	272.5±10.9	152.3±8.9
Mg(mg L^{-1}l)	74.2±3.6	41.5±0,4
Cu(mg L^{-1})	0.2±0.1	0.1±0.1
Mn(mg L^{-1})	0.02±0.0	ND
Fe(mg L^{-1})	0.6±0.1	0.3±0.1
Zn(mg L^{-1})	8.3±0.2	8.3±0.3
Pb(mg L^{-1})	ND	ND
Cd(mg L^{-1})	ND	ND
Ni(mg L^{-1})	0.01±0.0	0.01±0.1
Cr(mg L^{-1})	ND	0.1±0.1

Note: ND= Not detected; Results are expressed as mean ± standard deviation

The low pH value of the bore-hole water sample could be attributed to the geological formation of the area unlike the water sample from the public tap that is supplied from a central reservoir after some treatment. Water samples from the public taps and bore-holes had no objectionable taste and odour, contrary to the belief of the community dwellers.

Turbidity values were 2.2 mg L^{-1} and 3.1 mg L^{-1} for the water samples from the urban taps and bore-holes respectively. The turbidity values of the public tap and bore-hole water samples were within the permissible limit of the WHO (Table 5). The mean turbidity values obtained from the raw public tap water sample (2.2 NTU) was below the mean value obtained for Kwara State (4.1NTU) [2]. The values of TSS and TDS were 0.3 mg L^{-1} and 98.3 mg L^{-1} for the public tap water samples and 0.9 mg L^{-1} and 64.3 mg L^{-1} for bore-hole water samples. The mean TDS values of the raw water samples were below the average TDS value of 553.7mgL^{-1} obtained for Kwara State [2]. Furthermore, the bore-hole water samples in Omu-Aran had less TDS values as compared to the public tap water sample. For the raw water samples of the public taps and bore-holes, conductivity values were 197 mg L^{-1} and 129 mg L^{-1} respectively are within the permissible limit of the WHO (Table 5).

3.2 Anions

The concentrations of the anions determined in this study are shown in Table 2. The mean chloride concentrations in the water samples from the public water taps and bore-holes were 601.8 mg L^{-1} and 123.9 mg L^{-1}.

Table 4. Number of coliform bacteria in the raw and treated water samples from public taps and bore-holes (N=15)

Water Source	Coliform count per 100ml
Public Tap (A)	1.0 ±0.1
(A)+ Boiled	0.00
(A) +Water Guard	1.0±0.2
Borehole (B)	0.00
(B) + Boiled	0.00
B + Water Guard	0.00

Table 5. Drinking water guidelines by the WHO and SON

Contaminant	[a]WHO	[b]SON
Cd (mg L^{-1})	0.003	0.003
Cl (mg L^{-1})	-	250
Cr (mg L^{-1})	0.050	0.050
Cu (mg L^{-1})	2.000	1.000
Fe (mg L^{-1})	-	0.300
Pb (mg L^{-1})	0.001	0.010
Zn (mg L^{-1})	-	3.000
Ni (mg L^{-1})	0.020	0.020
NO_3 (mg L^{-1})	-	50.000
pH	-	6.5-8.5
SO_4^{2-} (mg L^{-1})	500	100
Electrical Conductivity	1000	1000
TSS(mg L^{-1})	-	-
TS(mg L^{-1})	-	-
TDS mg L^{-1}	500	500
Total coliform cfu mL^{-1}	0 x 10^2	10

[a]=Maximum permissible limits of the WHO (2011); [b]=Maximum permissible limits of the SON (2007)

However, after treatment by boiling and water guard, the mean chloride concentrations of water samples from the public-taps were708 mg L^{-1} for boiling and 885 mg L^{-1} for water guard and that of bore-holes were 336.3 mg L^{-1} for boiling and 141.6 mg L^{-1} for water guard. Result from the treatment of the water samples from the public taps shows that the concentration of chloride in the drinking water was increased by boiling and water guard treatment possibly as a result of vaporisation during boiling and the presence of chlorine in the water guard. The maximum permissible limit by SON is 250 mg L^{-1}.Cl^- concentrations were significantly higher ($p< 0.005$) in public tap than bore-hole water samples.

The higher chloride concentration in the water samples from the public taps could be linked to the use of chlorine for disinfection during the treatment of water by the Urban Water Board before distribution. The mean concentrations of nitrate were 14.5 mg L^{-1} and 17.3 mg $L^{-1}$for the water samples of the public taps and the bore-holes respectively. These values are within the permissible limit of 50 mg L^{-1} by the WHO and SON.The mean values obtained for the raw public tap water samples (14.5 mgl^{-1}) and the raw bore-hole water samples (17.3 mgl^{-1}) were below the average value (27.3mgl^{-1}) obtained for Kwara State [2].

The mean nitrite concentrations were 1.2 mg L^{-1} and 1.0 mg L^{-1} for the raw water samples of the public tap and bore-hole respectively. These mean values are within the permissible limit of WHO (Table 5). Hence, nitrite does not pose any health challenge in the area. The concentrations of sulphate are 74 mg L^{-1} and 11 mg $L^{-1}$for the water samples from public taps and boreholes respectively.

Sulphate is one of the least toxic anions but cathartic effects have been reported for people consuming drinking water exceeding concentration of 600 mg L^{-1}sulphate. Ingestion of excess sulphate could cause dehydration and laxative action [3]. Sulphate values obtained in this study are below the guideline value of 200 mg L^{-1} stipulated by WHO (Table 5). Phosphate concentrations are 28.1 mg L^{-1} and 27.5 mg L^{-1}l for the water samples of the public taps and boreholes respectively. These mean values are within the permissible limit of the WHO. Table shows that boiling and water guard treatments increased the concentrations of the anions in water and hence will not be an effective means removal.

3.3 Metals

Metals Cu, Mn, Fe, Zn, Pb, Cd, Ni and Cr were analysed for the drinking water samples of public taps and boreholes respectively, in the area of study. With exception of Zn and Fe, the other metals were either not detected or had their concentrations below the maximum permissible limits of the WHO (Table 5). ANOVA indicated that there was no significant difference ($P<0.005$) in the concentration of metals from public tap as compared to the bore- hole water samples. The mean concentrations of Fe were 0.6 mg L^{-1} and 0.3 mg L^{-1} in the water samples of the public taps and boreholes respectively. The values are above the 0.3 mg L^{-1}maximum permissible limit of the WHO and SON.

The concentrations of zinc were 8.3 mg $L^{-1}$for the water samples of the public water taps and boreholes respectively (Table 3).Pb and Cd were not detected in the water samples from the public taps and bore-holes. This could be attributed to the absence of processing and production industries in the area. Though Cr was not found in the water samples from the public tap, a significant amount of 0.1 mg $L^{-1}$was found in the bore-hole water samples above the maximum permissible limit of 0.1 mg L^{-1} set by the WHO.. Cu and Mn concentrations in the public water tap sample (Table 3) were within the permissible limits of the WHO (Table 5).The mean concentrations of Cu in the raw bore-hole water sample (0.1mgl^{-1}) and the raw public tap water sample (0.2mgl^{-1}) were higher than the range (0.01-0.023mgl^{-1}) obtained for the neighboring Offa community [18].

Mn was not detected in the bore-hole water sample. Exposure to high dose of Pb could lead to kidney and brain damage and miscarriage in pregnant women. Elevated levels of Pb in children can lead to convulsion, organ and neurological damage e.t.c [3, 16, 19]. High level of Pb in men can damage male organs of reproduction. Cd is a highly toxic metal that is naturally found in soils and rocks. Cd and compounds of cadmium are carcinogenic. Vomiting and diarrhea could be experienced from the ingestion of very high levels of Cd. Exposure to lower levels of Cd for a long time could lead to a build-up of Cd in kidneys and subsequently to kidney diseases. Cd could also cause lung damage [3; 20; 21]. Metals could cause impairment of metabolic functions in man [22]. Treatments by boiling and water guards were found to be ineffective for the removal of heavy metals from the drinking water samples as the amount of heavy metals in the water samples before treatment were approximately the same with the amount present after treatments. Adsorption onto activated agro-waste materials was reported to be efficient and cheap for heavy metals removal from water and wastewater [23].

3.4 Bacterial Contamination

Water samples from the public taps had mean total coliform count per 100ml of 1.0. From Table 5, the WHO stipulates zero count per 100ml, which means that the water samples from the public taps were contaminated by coliform bacteria. However, after treatment by boiling and water guard, there was absence of coliform bacteria with boiling but 1cfu per 100ml with water guard (Table 4). This suggests that boiling could be a better inexpensive means of removing coliform bacteria from the drinking water of rural communities in developing nations than treatment by water guard.

In addition, coliform bacteria were not detected in the borehole water sample indicating that the bore-holes could serve as potable water sources for the people of Omu-Aran community. Isolated micro-organisms in the water samples of the public taps are *Bacillus* and *Mucor* species. These organisms were removed in the water sample after treatment by boiling and water guard. The raw borehole water samples contained only *Bacillus* species which was also removed by boiling and treatment with water guard. The community dwellers are therefore advised to always treat their drinking water by boiling and or water guard before consumption as it is risky health wise to consume water contaminated with coliform bacteria due to the possibility of the outbreak of waterborne diseases and infections. Pathogenic organisms can cause diseases such as cholera, hepatitis, intestinal disorders etc [3, 16].

4. Conclusion

The determined concentrations of Fe and Zn in this study were found to be above permissible limits. The physicochemical parameters of the raw water samples with exception of chloride, BOD and dissolved oxygen were within the permissible limits of WHO and SON. Coliform bacteria were found only in the water samples from public taps. Treatments by water guard, and boiling were found effective for improving the quality of drinking water at household level. Boiling was comparatively better than water guard treatment in the removal of coliform bacteria from the drinking water samples.

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