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Quality of Drinking Water and Microbial Load of the Interior Components of Dispensing Machines at a Federal Training Centre, in Ibadan, Nigeria

Okundaye N. Oghomwen, *Oloruntoba O. Elizabeth and Adejumo Mumuni

Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria.

E-mail: li_zzyy@yahoo.com

*Corresponding Author:
Elizabeth O. Oloruntoba,
as above

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Abstract
This study assessed the quality of drinking water dispensed and microbial load of the interior components of 14 dispenser machines in a federal training centre in Nigeria. Water samples from dispensers were analysed for physico-chemical and bacteriological parameters before and after cleaning. Swab samples from the inner components of the dispensers were assessed for Total viable bacteria (TVB) and Total coliforms (TC) using standard methods. Information on perception and practices of users was obtained from key informants. The results were compared with WHO guidelines for drinking water quality. Data were analysed using descriptive statistics and t-test at 5% level of significance. The physico-chemical parameters of water from dispensers were all within permissible limits. Before cleaning, four (28.6%) and 9(64.3 %) of the water samples from dispensers had TVB and TC counts higher than permissible limits while all were free of TVB and TC after cleaning. Internal components of 12 machines had TVB count of $2.6 \pm 1.2 \times 10^2$ cfu/mL before cleaning while there was no TVB immediately after cleaning. Participants believed that no microorganism could grow inside the dispensers because water flows in it regularly, hence did not require regular cleaning. However, *Staphylococcus aureus* and *Psuedomonas auruginosa* were isolated from the internal components of the dispensers before cleaning. This could have implication for health. The study recommends regular cleaning of the machines and adoption of appropriate routine monitoring system to protect the health of users.

Résumé
Cette étude évalue la qualité d'eau potable et des composants microbiennes dans des machines à dispenser dans un centre d'entrainement fédéral au Nigeria. Des échantillons de l'eau ont été analysés pour des paramètres physico-chimique et bactériologique avant et après nettoyage. Ils ont été évalué pour bactéries total es viable (btv) et des coliformes total (ct). Information sur la perception et pratiques d'utilisateurs a été obtenues. Les résultats ont été comparés avec la qualité de l'eau potable. Le data ont été analysé avec l'utilisation de statistiques descriptifs et le 't-test' à 5% niveau de signification. Les paramètres physico-chimiques de l'eau ont été tout au sein de limites admissible avant nettoyage, quatre (28.6%) et 9 (64.3%) de l'eau des échantillons de

distributeurs avaient btv et ct qui compte supérieur que des limites admissibles. Tous ont été sans btv et ct après nettoyage. Des composants de 12 machines avaient btv qui comptent de 2.6 ± 1.2 x 102 cfu / ml avant nettoyage. Tout nà été aucun tvb immédiatement après nettoyage. Cependant, *staphylococcus aureus* et *psuedomonas auruginosa* ont été isoles des composants du distributeur avant nettoyage. Ceci pourrait avoir des conséquences graves pour la santé. Cette étude recommande des nettoyages des machines et l'adoption d'une surveillance appropriée à protéger la santé d'utilisateurs.

Introduction

Safe drinking water is "water that does not present any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages" (WHO, 2008). An adequate supply of safe drinking water is one of the most important factors for sustaining human life and achieving sustainable development. Safety and quality of drinking water is a great concern to Public Health (Hrudey and Hrudey, 2007; Reynolds *et al.,* 2008). Contamination is associated with spread of diseases which can result in serious illness and mortality (O'Reilly *et al.,* 2004). Although poor sanitation and food sources are integral to enteric pathogen exposure, drinking water is a major source of microbial pathogens in developing countries (Ashbolt, 2004). The safety of drinking water is generally monitored in a number of ways including direct measurement of its physical, chemical and microbial constituents. There are two major reasons for monitoring drinking water quality. First is to determine if the water supply system is operated correctly to ensure its safety for consumption (*Primary Assessment*). The second reason is to ensure water safety after it has been supplied. This includes monitoring for compliance (*Verification*) (Stevens *et al., 2*003).

Over the past decade, scarcity of potable water has pushed residents in many parts of the world to source for drinking water from different sources. One of these alternative sources are the water dispensing machines which are now common in offices, commercial stores and homes. This system has always been presented as one that is not only easy to use and maintain but also able to improve drinking water quality by filtration or destruction of pathogens. However, the quality of water from individual water dispenser in many cases is related to the knowledge and perception of users towards its maintenance when installed. Due to the often sporadic or low flow rates in these types of units, bacteria can attach to the internal pipework surfaces, form a biofilm to protect them, and then start to multiply (Mena and Gerba, 2009). Studies have reported higher Total Coliform count in large bottles which was attributed to inadequate cleaning and disinfection of the reusable bottles at the manufacturing or refilling facility (Falcone-Dias *et al.,* 2012; Marzano and Balzaretti, 2013). Also, Williams *et al.,* (2015) pointed out in a review article that additional contamination or regrowth of both faecal indicator bacteria and total coliform may occur when bottles are installed on dispensers. Lévesque *et al.* (1994) linked such contamination with improper maintenance of dispenser which include, but are not limited to, infrequent and ineffective cleaning.

Furthermore, access to potable drinking water is a human necessity as well as an important health and environmental issue. In Nigeria, use of water dispensers has become a norm in many offices and homes. However, there is dearth of adequately documented information on the quality of water from dispensers and most importantly, the microbial load of the interior components. Hence, this study was designed to assess the quality of drinking water and the microbial load on the interior components of dispenser machines at a training centre in Nigeria.

Materials and Methods

Study Design and Location

This study adopted a cross-sectional design which involved laboratory analysis of water samples collected from dispensing machines, and

swab samples of the interior component of the dispensing machine at a Federal Training Centre in Ibadan, Nigeria. Data were also collected on the perception and practices of users towards the water dispenser machines.

Ibadan is the capital of Oyo State, one of the thirty-six states in Nigeria. It is strategically positioned on longitude 3°5 East of Greenwich Meridian, latitude 70° 23N west of the equator. This ancient city is located near the forest grassland boundary of south western Nigeria. The training centre which is owned by the Federal Government of Nigeria (FGN), is sited within Ibadan. It was established to train medical personnel and other healthcare professionals in the country and the West African Sub-Region. It has six schools: Environmental Health Tutors Course; Community Health Officers; Primary Health Care Tutors; Nursing Training; School of Information Health and the School of Midwifery. The training centre was purposively selected based on the availability of functional water dispensing machines. Fourteen water dispensing machines in use at the centre, had been installed for at least six months before the commencement of the study and were in use for not less than six months. Within the six months, the dispensers had been refilled, at least once in two weeks, and were connected to electricity constantly.

Data Collection Methods

Community entry: During the planning stage of the study, the researchers approached the authority in charge of the training centre and all the heads of the six schools that make up the centre. Contacts were made with the heads of the six schools and a good working relationship was established. Formal letters were written to all the contact persons to obtain permission to carry out the study in the training centre. The letters also explained the study objectives. Duly completed and signed consent forms were obtained from the authority in charge of the centre, heads of the schools and occupants of offices where some of the dispensers were located. Consenting key informants in the centre were interviewed using a validated key informant interview guide containing information on perception of the users on the quality of water dispensed as well as their attitude and practices in the use of the machines.

Collection and Analysis of Water Samples

Water samples were collected from water dispensing machines (Plate 1) with thoroughly cleaned plastic kegs of two-litre capacity for the physico-chemical analysis. Thoroughly washed and sterilized glass bottles were used to collect samples under aseptic conditions for bacteriological analysis while plastic sample bottles (PTFE) of 100 mL capacity were used to collect samples for heavy metal analysis. The water samples were not collected directly from the 19-litre bottle but through the faucet of the dispenser. The samples for bacteriological analysis collected in sterile bottles were kept at about 4°C and then analysed within 24 hours. Water samples were collected in duplicates and according to recommended standard methods described by the American Public Health Association, APHA (1998).

Water samples collected were analysed for pH using Jenway pH meter, while conductivity and Total Dissolved Solids (TDS) were measured using combined Conductivity and TDS meter (Jenway 470). Total alkalinity, Chloride, Total and Calcium hardness were determined with appropriate titrimetric methods described by APHA (1998). The concentrations of NO_3-N and metals (Iron (Fe), Lead (Pb) and Cadmium (Cd) were determined with a UV/Visible spectrophotometer (at 410 nm) and Atomic Absorption Spectrophotometer respectively. Total coliform and *Escherichia coli (E. coli)* were determined using multiple tube fermentation technique at 37°C and 44°C respectively.

Heterotrophic plate count (Total Viable Bacteria, TVB) was determined using Pour plate technique (APHA, 1998). Adequate quality assurance procedures were put in place to ensure the integrity of the samples.

Estimation of Microbial Load of Interior Components of Dispenser Machines

Machines were dismantled by carefully removing the removable parts (Plate 2A). Surface samples were collected by rubbing sterile swab sticks over moist and hidden surfaces of the dispenser tanks before cleaning. The samples were kept at about 4°C and transferred to the Microbiology Laboratory of the University of Ibadan, Nigeria for culturing. The swabs were then suspended in sterile distilled

water and dilluted to 10^{-3}(1 in 1000). One ml of each sample was thereafter innoculated on nutrient agar and incubated at 37°C for 24 hours. Colonies from each swab sample were quantified as cfu/mL of the sample and identified using morphological characteristics and gram stain technique.

Key Informant Interview (KII)

A thirteen-item key informant interview guide was used to collect information on the perception of the users on the quality of water dispensed, as well as their attitude and practices in the use of the machines. Eleven (11) interviews were conducted among Lecturers, Assistant Course Coordinator, the Horticulturist, one Head of Department, and two secretaries involved in the maintenance of the dispensers. The interviews gave information such as the date of dispenser installation, last time dispenser machine was cleaned, average amount of water consumed, how long a bottle of water lasted, routine in mounting new water bottles when old bottles were empty, and if newly purchased water bottles were stored before use.

Cleaning of Water Dispensers and their Plastic Parts

The water cooler dispenser was disconnected from the electrical outlet. The empty water bottle was then removed and remaining water in the dispenser tanks was drained completely through the spigots. Thereafter, the removable parts (drip tray, spigot paddles, "no-spill" guard, baffles, and the exterior of the water cooler) were removed. Care was taken not to break or damage these components. A disinfectant solution was prepared in a large, clean container by diluting 2.5 ml of non-perfumed bleach (~5% chlorine) with two litres of clean water. The reservoir was then filled with the disinfectant solution and the interior of the reservoir scrubbed with a clean long-handled, soft-bristled brush. Thereafter, some of the disinfectant solution was drained through the spigots and the remaining solution allowed to stand for at least two minutes (to be effective) but no longer than five minutes (to prevent corrosion). The disinfectant solution was drained from the reservoir through the spigots into a bucket and disposed. Then, the reservoir was thoroughly rinsed by filling it with clean water four times to remove traces of the disinfectant. The rinsed water was then drained through the spigots into a bucket and disposed. Also, all removable parts (drip tray, spigot paddles, "no-spill" guard, baffles, and the exterior of the water cooler) were cleaned by washing in soapy water; rinsed with clean water and then disinfected with 5% chlorine solution and then rinsed (Plate 2B). The parts were allowed to dry thoroughly and then re-coupled. The detached components were replaced and a new water bottle was placed on the water dispensing machine. The spigots were depressed until the water flowed freely. Thereafter, the water dispenser was connected to the electrical outlets. The dispensers were filled with water and samples were collected immediately for microbial analysis.

Plate 1: A Dispenser Machine

Data Management

Quantitative data from the laboratory analyses were recorded on the spread sheet and transferred to the SPSS statistical package for statistical analysis. Descriptive statistics and t-test were used to compare the physico-chemical and bacteriological parameters obtained before and after cleaning the dispenser machines at 5% level of significance. Qualitative data from the Key Informant Interviews were analysed using content analysis and results were presented

using thematic approach with verbatim quotations.

Ethical Consideration

This study was approved by the joint Ethical Review Committee of University of Ibadan and University College Hospital, Ibadan, Nigeria before the commencement of the field work. Also, permission was obtained from the authorities in charge of the training centre and the heads of the six schools that make up the centre. Key informant interviews, water collection and washing of the dispenser machines were only started after the purpose of the study had been clearly explained to the participants and informed consent obtained. Participation was made voluntary and no form of coercion was adopted. There was no undue influence on the participants. Participants were assured of confidentiality of all information obtained from them. To ensure their high level of objectivity, participants were not asked to mention their names in order to ensure anonymity.

Results

Physico-chemical Quality of Water Dispensed Before and after Cleaning

Table 1 presents the levels of physico-chemical parameters and heavy metals in dispensed water before and after cleaning, as well as permissible limits recommended by NIS and WHO for potable water. The mean values for pH, Electrical Conductivity (µS/cm), TDS (mg/L), Nitrate (mg/L), Alkalinity (mg/L), Chloride (mg/L), Calcium hardness (mg/L) and Total hardness (mg/L) of water samples before and after cleaning the dispensing machines were (7.16±0.40 Vs 6.65±0.36), (12.50±7.97 Vs 9.13±3.63), (5.90±2.70 Vs 5.44±3.79) (0.02±0.01 Vs 0.05±0.02), (33.33±10.04 Vs 49.52±24.89), (4.44±3.85 Vs 4.97±3.38), (48.00±23.66 Vs 59.91±26.92) and (53.14±27.63 Vs 65.14±32.06) respectively. All the values were within the SON standard and WHO's recommended guideline limits. Concentrations of Lead (mg/L), Iron (mg/L) and Cadmium (mg/L) in water samples before and after cleaning the dispensing machines were below detection limit.

Table 1: Physico-chemical and Heavy Metal Concentration in Water Before and After Cleaning the Dispensing Machines

Parameters	Before cleaning dispenser Mean±SD	After cleaning dispenser Mean±SD	*SON Guideline	*WHO Guideline
Physico-chemical				
pH	7.16±0.40	6.65±0.36	6.5 – 8.5	6.5 – 8.5
Electrical Conductivity (µS/cm)	12.50±7.97	9.13±3.63	1000	1000
TDS (mg/L)	5.90±2.70	5.44±3.79	500	1500
Nitrate-Nitrogen (mg/L)	0.02±0.01	0.05±0.02	10	10
Alkalinity (mg/L)	33.33±10.04	49.52±24.89	-	100
Chloride (mg/L)	4.44±3.85	4.97±3.38	-	250
Calcium Hardness (mg/L)	48.00±23.66	59.91±26.92	-	-
Total Hardness (mg/L)	53.14±27.63	65.14±32.06	150	100
Heavy metals				
Lead (mg/L)	ND	ND	0.01	0.01
Iron (mg/L)	ND	ND	0.3	0.3
Cadmium (mg/L)	ND	ND	0.003	0.003

ND: Not Detected

***SON = Standard Organization of Nigeria, WHO= World Health Organization**

Note: 0.05, 0.01 and 0.05 are the instrument's Detection Limit for Lead, Iron and Cadmium (in mgL^{-1})

Microbial load of Water Dispensed Before and after Cleaning

Table 2 reveals the microbial load (TVB and Total coliforms) of the water samples before and after cleaning the dispenser unit. Before cleaning the dispensing machines, the mean TVB (cfu/ml) in the water samples from all the 14 (100%) dispensing machines was *77.02±75.3*; while 9 (64.3%) machines had mean Total coliform count (MPN/100 ml) of 4.2±3.6 in their water samples. No *E. coli* was detected in any of the samples. Although only 4 (28.6%) of the water samples had TVB count higher than the recommended limit of 1 x 10^2 cfu/ml, the total coliform count was higher than 0 MPN/100ml permissible limit in 9 (64.3%) water samples.

Immediately after cleaning, no TVB, TC, or EC was detected in any of the water samples from the dispensing machines. However, two weeks after the cleaning, thirteen (92.8%) of the dispensing machines had mean TVB (cfu/ml) of 6.2±4.4 in their water samples, but none had Total coliform organism or *E. coli.* Thirteen (92.8%) samples had TVB values below the recommended limit of 1 x 10^2 cfu/ml by the SON.

Microbial Load of Internal Components of Dispenser before Cleaning

The internal components of all the fourteen dispensing machines were dirty (Plate 2A) and grossly contaminated with microbes (Figure 1) before cleaning. From the 14 water dispensers, 85.7% of the swab samples had TVB count greater than 100 cfu/ml, while only 14.3% had total TVB counts of 100 cfu/ml and below(Figure 1). Also, the result of laboratory analysis of swab samples collected from the internal components of the dispensing machines before cleaning revealed that 12 (85.7%) of the dispensing machines had mean TVB count of 2.6 ± 1.2 x 10^2cfu/ml (range= (1.7-3.5) x10^2cfu/ml). The mean value is greater than 1 x 10^2cfu/ml recommended by the SON for drinking water quality. The major bacteria isolated from the internal component of the dispensing machine before cleaning were: *Staphylococcus aureus* and *Psuedomonas auruginosa.*

Table 2: Microbial Load of Water Dispensed Before and After Cleaning

Parameters	n (%) with positive result	Mean±SD (Range)	*SON Guideline	*WHO Guideline
Before Cleaning dispensing machines				
TVB (cfu/ml)	14 (100.0)	77.02±75.3 (9-263) 263)	1 x 10^2	-
Total coliforms (MPN/100ml)	9 (64.3)	4.2±3.6 (2-14)	0	0
E. coli (MPN/100ml)	0	0	0	0
Immediately after Cleaning dispensing machines				
TVB (cfu/ml)	0 (0.0)	-	1 x 10^2	-
Total coliforms (MPN/ml)	0 (0.0)	-	0	0
E. coli (MPN/100ml)	0 (0.0)	-	0	0
Two weeks after cleaning dispensing machines				
TVB (cfu/ml)	13 (92.8)	6.2±4.4 (1.3-16.7)	1 x 10^2	-
Total coliforms (MPN/ml)	0 (0.0)	-	0	0
E. coli (MPN/100ml)	0 (0.0)	-	0	0

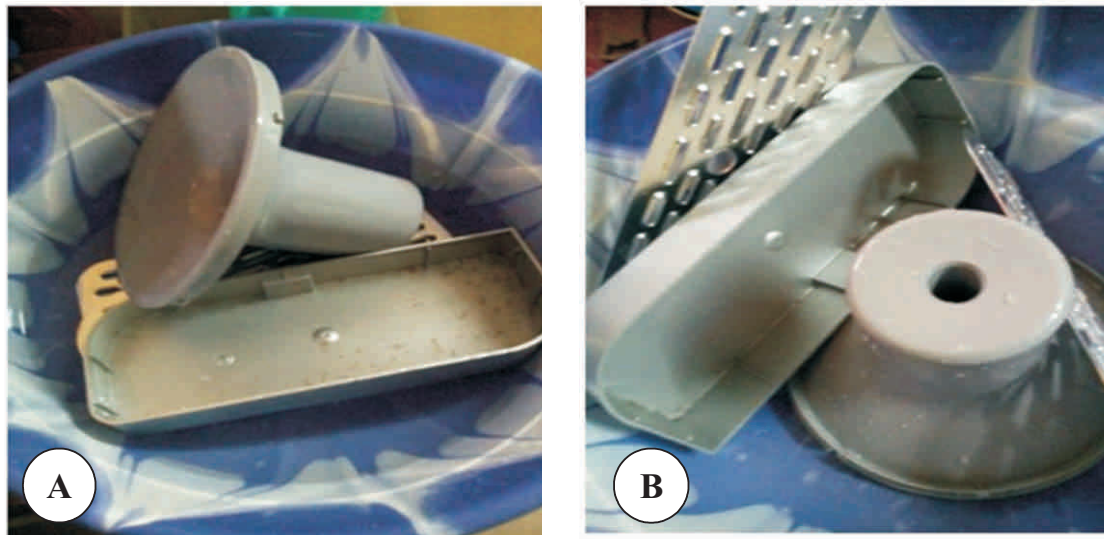

Plate 2: Dispenser interior component (A=before cleaning; B= After cleaning)

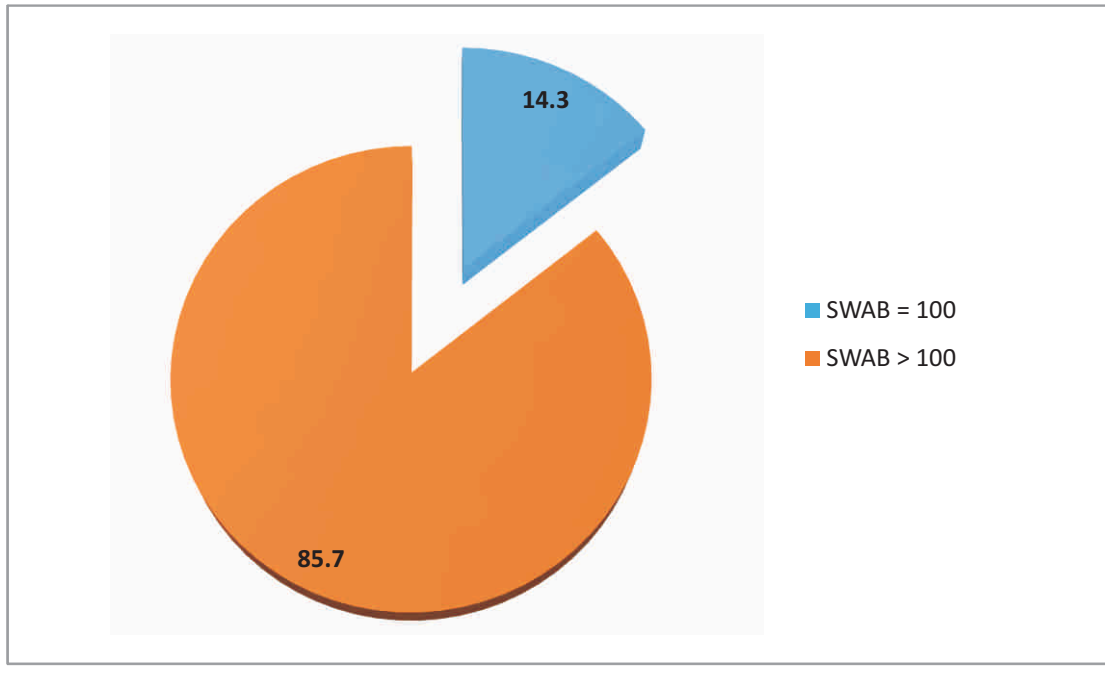

Figure 1: Heterotrophic plate count (Total viable bacteria count) of swaps

Table 3 presents the results of correlation between the microbial load of water samples and interior component of the dispenser machines. It was revealed that a positive correlation existed between the TVB count of water dispensed ($r = 0.581$, $p<0.05$) and TVB of dispensing machines before cleaning. This indicates that dispensing machines with higher TVB contained water with higher TVB (cfu/ml) before cleaning. Also, the TC count of water dispensed before cleaning the machines was positively correlated with TVB count of dispensing machines before cleaning ($r=0.442$, $p<0.05$). Furthermore, there was a positive correlation between total coliform count and TVB count of water dispensed before cleaning the

Table 3: Correlation Matrix Between Microbial Load of Water Samples and Interior Component of the Dispenser Machines

	TVB_{wb}	Total $coliform_{wb}$	TVB_{w2w}	TVB_{mb}
TVB_{wb}	1			
Total $coliform_{wb}$	0.363*	1		
TVB_{w2w}	0.141		1	
TVB_{mb}	0.581*	0.442*	0.197	1

*. Correlation is significant at the 0.05 level (2-tailed)

Note: TVB_{wb}= TVB count of water dispensed before cleaning the dispensing machines

Total $coliform_{wb}$ = Total coliform count of water dispensed before cleaning the dispensing machines

TVB_{w2w}=TVB count of water dispensed two weeks after cleaning the dispensing machines

TVB_{mb}= TVB count of dispensing machines before cleaning

dispensing machine (r=0.363, p<0.05). On the other hand, there were no significant correlations between TVB count of water dispensed two weeks after cleaning the dispensing machines and TVB count of dispensing machines before cleaning. This suggests that TVB counts of water dispensed two weeks after cleaning the dispensing machine may not be associated with the total viable counts of dispensing machine before cleaning.

Perception and Practices of Users towards the Water Dispenser Machines

The key informants in their discussion stated that all the water dispensers were installed at least six months before the study. The key informants narrated that some members of staff had never used a dispenser prior to working at the Federal Training Centre and most of the users made use of non-disposable cups. In most of the interview sessions, participants reported that the internal components of the dispensers do not require regular cleaning, only the external components do. During a discussion, one of the key informants reported that they wiped the exterior surface from time to time but did not think it was important to clean the interior (tank). In another interview, a participant reported that irregular cleaning of the interior of the tank was hinged on the perception that no contamination could occur inside the tank since water flows in there regularly. Quoted below are some opinions of participants from two different units:

> "…*it is water dispenser and it is clean water that comes from it so only the body is cleaned…*"

> *"...no contamination could occur inside the tank since water flows in there regularly..."*

During the interview sessions, the participants discussed some of the practices involved in maintaining good hygiene around the dispensing machines. They reported that the major users of a dispenser in an office ranged from one to three persons and that clerks were responsible for replacing the empty water bottles. However, most of the participants could not describe the routine procedure involved in the replacement of the dispenser bottles. They further stated that they had no particular routine procedure. During an interview session a participant stated that part of the routine is to leave empty bottles standing if the new bottle is not ready to be mounted, and when ready, the mouth of the new bottle will be wiped with clean napkin before it is placed on dispenser unit.

> *"...part of the routine was to leave empty bottles standing if the new bottle was not ready to be mounted and when ready, the mouth of the new bottle will be wiped with clean napkin before it is placed on dispenser unit…"*

Discussion

This study assessed the quality of water dispensed and microbial load of the interior components of dispenser machines in a federal training centre, in Nigeria. It was found that both physico-chemical and heavy metal parameters of all the water samples were within the SON and WHO permissible limits for drinking water. This implies that the water from the 14 dispensing machines were fit for drinking in terms of physico-chemical characteristics. This is similar to a study conducted by Amira (2012) on the characteristics of water dispensed from some public coolers in Cairo, Egypt, where the chemical parameters of water samples from all coolers were within the WHO's guidelines for drinking water. Total Viable Counts (cfu/ml) were found in water samples from all dispensing machines before the cleaning; only 28.6% of the water samples had TVB counts higher than the recommended limit. More than sixty percent of the dispensing machines had water samples with total coliform bacteria which were higher than the 0MPN/100ml recommended by WHO's guidelines and SON's standard (WHO, 2006; SON, 2007). This result is similar to that of the study carried out by Liguori *et al*. (2010) on microbiological quality of drinking water from dispensers in Italy. The increase in the bacterial load of water samples from all the dispensing machines could be attributed to lack of adequate maintenance of the dispenser machines as reported by some of the users; or poor hygiene practices while replacing the dispenser bottles. It could also be attributed to the low flow rates in these types of units since bacteria can attach to the internal pipework surfaces, form a biofilm and then multiply (Mena and Gerba, 2009). This assertion can also be ascribed to WHO (2003), that affirmed that "elevated HPC levels occur especially in stagnant parts of piped distribution systems, in domestic plumbing, in bottled water and in plumbed-in devices, such as softeners, carbon filters and vending machines. The principal determinants of regrowth are temperature, availability of nutrients and lack of residual disinfectant. Nutrients may derive from the water body and/or materials in contact with water".

Also, the study revealed that opportunistic pathogenic bacteria that are capable of posing threat to health of the consumers, *Staphylococcus aureus* and *Pseudomonas aeruginosa* were found in 12 (85.7%) of the 14 water dispensers before cleaning. Occurrence of opportunistic pathogens in water dispensers might be as a result of irregular cleaning of the dispensers or poor installation practices. This is in accord with a study which isolated *Pseudomonas aeruginosa* in 15 (30%) and 34 (68%) out of 50 samples of water collected from tap and water dispenser respectively in Cyprus (Elena, 2011). Similar finding was also reported by Liguori *et al*. (2010). This result may imply that unlike heterotrophic bacteria, water coolers do not promote the growth of coliforms.

Immediately after the dispenser machines were cleaned, TVB, TC & EC were not detected in any of the water samples from the dispensing machines. This may be attributed to the effectiveness of the cleaning and chlorination of the dispensing machines. This implies that cleaning was effective in the total elimination of the microorganisms immediately after cleaning and reduction of the microorganism even two weeks after the cleaning even though there was a re-growth. This is supported by a study conducted by Zanetti *et al*. (2009) which concluded that the periodic application of hydrogen peroxide (3%) to water dispensers led to a reduction in the load of *Pseudomonas aeruginosa,* thus leaving water with bacteria counts conforming to standard regulations for drinking water. This, therefore, implies that cleaning of the water dispensing machines should be as regular as possible. In this present study, it is important to note that neither *Enterococcus spp.* nor *Eschericia coli* was detected in any of the water samples as well as the internal component of the dispensing machines. This confirms that sources of contamination of the water and the dispensing machine were not from a faecal origin.

A study by Ahammed (2012), reported a reduction in TVB count from 8,600 to 2,200 cfu/ml immediately after cleaning water coolers. Samples collected after one week showed no increase in TVB count. However, a sudden increase in TVB counts in water samples analysed

was noticed after a period of one month. This present study revealed a drastic reduction of bacterial load from water dispensed from all the 14 dispensing machines immediately after the cleaning.

Heterotrophic plate counts (HPC) or TVB count are useful in indicating the effectiveness of water treatment processes, thus as an indirect indication of pathogen removal. It also functions as a measure of the number of re-growth organisms that may or may not have sanitary significance (WHO, 2003).

Furthermore, this study documented that total viable bacteria counts of water dispensed before cleaning the dispensing machines related positively with the TVB count of dispensing machines before cleaning. This indicates that dispensing machines with higher TVB contained water with higher TVB (cfu/ml) before cleaning. Also, it might be as a result of dirt on the water cooler which creates conducive environment for heterotrophitic bacteria to growth. This finding concurs with several studies (Obiri-Danso *et al*., 2003; Onda *et al.*, 2009) which reported that bacteria adhere more readily to rough surfaces and the characteristic of the plastic bottles used in water coolers could support biofilm formation. Also, the total coliform of water dispensed before cleaning the dispensing machines was found to positively correlate with total viable count of dispensing machines before cleaning. The finding suggests that dispensing machines with high total viable count dispense water with high total coliform count before cleaning the dispenser. The study found that total viable counts of water dispensed two weeks after cleaning the dispensing machine were not influenced by the total viable count of dispensing machines before cleaning.

It was revealed that the perception and practices of dispenser users had an influence on the quality of water mounted and dispensed from the machines, as well as the dispensers. All the key informants perceived that the internal compartments of the dispenser did not require regular cleaning. Moreover, some participants believed that since water flowed regularly inside the dispensers, no microorganism could grow there. The higher bacterial load in the water samples before cleaning might be a result of inadequate cleaning and disinfection of the reusable bottles at the manufacturing or refilling facility (Falcone-Dias *et al,* 2012; Marzano and Balzaretti, 2013). Also, in a review article by Williams *et al.,* (2015), it was documented that when bottles are installed on dispensers, additional contamination of both faecal indicator bacteria and total coliform may occur. Lévesque *et al.* (1994) in a study emphasised that contamination could be due to improper maintenance of the dispenser including infrequent or ineffective cleaning. Also, most recently installed dispensers were six months before the study commenced. It was also possible that the dispensers had microbial load related to the time of dispenser installation meaning that the newly installed dispensers had less microbial load.

The study revealed that hygiene practices in the use of the dispensing machines were poor since none of the dispensing machines had ever been cleaned. Moreover, clerks were the main persons responsible for replacing the empty water bottles and cleaning if need be. In a review article, Williams *et al.* (2015) suggest that consumer education about the proper use and cleaning of dispensers and improved design may help to reduce contamination of bottles. In this study, most of the users could not describe the routine procedure involved in the replacement of the dispenser bottles. The users who were expected to be more educated on the dispenser use were not involved in the replacement/cleaning of the water dispensing machines; rather their clerks who were less concerned about the hygiene practices were mostly involved. However, not cleaning the mouths and necks of dispenser bottles before mounting them on the dispenser machines was a poor hygiene practice which might also have been a function of the high microbial load.

Conclusion

Water contamination is by all means a serious problem in developing and developed nations. Water quality can be regularly tested particularly for microbes to prevent water-borne disease transmission. This study shows that water

dispensers can cause deterioration of drinking water quality by promoting growth of heterotrophic bacteria and other opportunistic pathogens. The study also shows that adequate disinfection of water dispensers during cleaning is effective in reducing the number of heterotrophic bacteria and coliforms. This was proved by the significant reduction in microbial load in the dispenser machines (100%) immediately after cleaning (day 1) even though there was subsequent building up thereafter. The study therefore recommends regular cleaning of the dispensing machines and adoption of appropriate routine monitoring regimes to prevent regrowth of opportunistic pathogens thus reducing the chances of contamination of the drinking water source.

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