Assessment Of The Quality Of Water Before And After Storage In The Nyankpala Community Of The Tolon-Kumbungu District, Ghana

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ABSTRACT:-The rational for the study was to assess the quality of stored water in different storage facilities in the Nyankpala community in northern Ghana. The quality of treated water supplied by the Ghana Water Company Limited was also assessed before storage. Thirty households were selected based on the type of storage facility used in storing treated water. Storage facilities considered were earthen pots (EP), metallic containers (MC) and polyethylene barrel containers (PC). During the study period, a total of 120 stored water samples and four (4) tap water samples were collected and analysed over a period of four months. Generally the quality of treated water was well within the World Health Organizations (WHO) recommended guidelines for potability. Generally the physico-chemical quality of stored water was good since parameters measured well with WHO recommended limits. However, colour (2.5-30.0 Hz, 15.4±1.5), turbidity (2.0-15.0 NTU, 7.6±1.1) and total iron levels (<0.003-0.93 mg/L, 0.34±0.1) recorded in stored water in metallic containers (MC) were higher than WHO guidelines for potability. Though tap water recorded no coliform bacteria during the study period, stored water analysed from all storage facilities recorded coliform bacteria. The presence of coliform bacteria in stored water probably resulted from unhygienic water-handling practices. Water stored in earthen pots recorded the lowest level of colifom bacteria (total coliform 0-315 CFU/100 mL, 19.2 CFU/100 ml; Faecal coliform 0-78 CFU/100 mL, 19.2 CFU/100 mL). Water stored in PC recorded the highest levels of coliform bacteria (TC 0-714 CFU/100 mL, 231 CFU/100 mL; FC 0-250 CFU/100 mL, 65.2 CFU/100 mL) during the study period. EP storage facilities recorded lower coliform levels because they have narrow nozzles which make access to water more difficult compared to that of PC and MC which has wide openings at the top.

Keywords: - stored water, water quality, Nyankpala, coliform bacteria, earthen pot, metallic containers, polyethylene barrel containers.

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INTRODUCTION

Water has always been an important and life-sustaining resource to humans and is essential to the survival of all organisms. It is vital in metabolic processes and serves as a solvent for many bodily solutes. Although water forms a major part of the earth surface, much of it is not available to humans in a form that can readily be used, as a source of drinking water or for other purposes. The human body is made up of over 70% of water. Where piped water supply to the household operates intermittently, storage facilities are commonly used to ensure that there is sufficient water for the family needs throughout the day. In Nyankpala, the discontinuity of water supply, in addition to the low water pressure in the distribution system, which hinders the delivery of water to upper floors, creates a need to use storage tanks. Water that is stored un-hygienically may be re-contaminated, and so represents a public health hazard [15].

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About 2,500 people die each day in the world due to diarrhoeal diseases associated with faecally contaminated water [16]. Other water related diseases such as cholera, malaria, filariasis, dracunculiasis (guinea worm), typhoid and onchocerciasis (river blindness), still represent the single largest cause of human mortality and morbidity [7]. The main reason for these mortality rates is the limited access to safe water, inadequate treatment of water for drinking by households and lack of proper storage practices for drinking before consumption [17], which leaves rural communities with no other choice than to manage. In addition, the water-storage containers used in these rural households are often not cleaned and are exposed to faecal contamination due to children who put their hands into the water, unhygienic handling of the water-storage containers, the use of dirty utensils to withdraw water, dust, animals, birds and various types of insects [8], [11], [3], [16]. There is a great deal of concern regarding in-house microbial contamination during handling and storage of water in developing countries. The prevalence of water-related infectious diseases has been reported to be high among people in Ghana especially the northern sector. Generally, water for drinking is stored in containers by households with or without treatment after collection from a variety of sources [7].

MATERIALS AND METHODS

Study area

The study area is located in the Northern Region of Ghana within the Guinea Savannah Agro-ecological zone. Nyankpala is 16 km from Tamale, the capital of the region. The area is located on latitude 09˚ 25' north and longitude 00˚ 55' west and has an altitude of 183 m above sea level [12]. Nyankpala experiences a unimodal pattern of rainfall, with annual rainfall beginning in May and ending in October. Mean annual rainfall is about 104.3 mm with mean day time relative humidity of 54%. Temperatures generally fluctuate between 15˚C to 45˚C with an annual mean temperature of 28˚C. Vegetation is characterized by large areas of grassland interspersed with few economic trees such as Shea (*Vitellaria paradoxa*) and Dawadawa (*Parkia biglobosa*).

Water sampling and laboratory analysis

Stored water samples were collected for analysis from November, 2010 to February, 2011. During sampling efforts were made to avoid the contamination of water samples by adhering to the fundamental principles underlying the general procedures for sampling [1]. One hundred and twenty (120) samples were collected from three major storage facilities used in the community. The water storage facilities sampled from are earthen-pots (EP), metallic containers (MC) and polyethylene barrel containers (PC) (Plates 1, 2 and 3).

Plate 1:An earthen pot (EP) storage facility Plate 2: A polyethylene barrel container(PC)

Plate 3: A metallic container (MC)

Four samples were collected from the only communal tap in the community which residents fetch for storage during the study period. Onsite measurements of pH and electrical conductivity of tap water and stored water samples were done using an Eijkelkamp water quality kit. Samples for other physico-chemical analysis were collected into 1L polyethylene bottles. Samples for bacteriological analysis were collected into sterilized 250 mL screw-capped glass bottles. Samples for trace metal analyses were collected into 50 mL polyethylene bottles and acidified with 1 mL concentrated nitric acid. Samples were stored in an ice cooler at about 4°C and transported to the water quality laboratory of CSIR Water Research Institute, Tamale, for analysis. Samples for physico-chemical (including trace metals) analyses were kept in a refrigerator until completion of analyses. Coliform bacteria analyses were done immediately on arrival at the laboratory. Procedures for analyses were based on Standard Methods for the Examination of Water and Wastewater[1]. A visual comparator and turbidimeter were used to determine colour and turbidity respectively. Orthophosphate, nitrate-nitrogen and sulphate contents of tap and stored water were analysed using the stannous chloride, hydrazine reduction and turbidimetric methods respectively. A flame photometer (Jenway model PFP 7) was used to determine sodium and potassium whiles EDTA titration was employed for the determination of calcium and total hardness. Chloride contents were determined by argentometric titration and total alkalinity by strong acid titration. Calcium and magnesium hardness, on the other hand, were determined by calculation. Total iron and manganese were determined using a Shimadzu model AA 6300 flame atomic absorption spectrophotometer (AAS). Total and faecal coliform bacteria were determined by the membrane filtration technique using M-Endo Agar-Les (Difco) at 37°C and on MFC Agar at 44°C respectively. Statistical analyses of data was done using SPSS version 17.0 for Windows. One half of the value of the respective limit of detection was substituted for values below the limit of detection and used in statistical analysis. The Pearson's rank correlation was used to examine correlation between parameters. All tests were two-tailed, a probability value of $p<0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

The result of the quality of treated and stored water in various storage facilities are presented in Tables 1-5 below:

Table 1: Water quality results of tap water in the Nyankpala community.

N=4	Cl	COL (Hz)	TUB (NTU)	pH (pH unit)	TDS	NO_3-N	PO_4	F	EC (µS/cm)	Mn	TH	FC (CFU)	TC (CFU)	Fe
Min.	4.00	2.50	2.00	7.47	59.80	0.55	0.00	0.05	99.70	0.00	36.00	0.00	0.00	0.00
Max.	9.90	7.50	4.00	7.81	67.80	2.20	0.00	0.30	114.00	0.13	44.00	0.00	0.00	0.09
Mean	7.60	4.17	3.00	7.61	63.7	1.42	0.001	0.18	1.07	0.05	40.00	0.00	0.00	0.04
SD	3.16	2.89	1.00	0.18	4.01	0.83	0.00	0.13	7.17	0.07	4.00	0.00	0.00	0.05
WHO	**250**	**15.0**	**5.00**	**6.5-8.5**	**1000**	**10.00**	**-**	**1.50**	**-**	**0.500**	**500**	**0**	**0**	**0.30**

Concentrations are in mg/L unless otherwise stated.

Table 2: Water quality analysis results of water stored in polyethylene containers (PC).

N=40	Cl	COL (Hz)	TUB (NTU)	pH (pH unit)	TDS	NO_3-N	PO_4	F	EC (µS/cm)	Mn	TH	FC (CFU)	TC (CFU)	Fe
Min.	4.00	2.50	1.00	7.27	55.70	0.05	0.00	0.10	92.20	0.00	32.00	0.00	0.00	0.00
Max.	9.90	62.50	24.00	7.85	95.30	14.33	0.09	0.30	114.00	0.15	44.00	250.00	714.00	0.80
Mean	7.28	10.21	4.83	7.59	66.8	3.95	0.01	0.15	102	0.07	38.2	65.2	2.31	0.19
SD	2.10	16.9	6.42	0.21	12.21	3.84	0.03	0.07	6.72	0.054	4.30	82.1	2.50	0.32
WHO	**250**	**15.0**	**5.00**	**6.5-8.5**	**1000**	**10.00**	**-**	**1.50**	**-**	**0.500**	**500**	**0**	**0**	**0.30**

Concentrations are in mg/L unless otherwise stated.

Table 3: Water quality analysis results of water stored in metallic containers (MC).

N=40	Cl	COL (Hz)	TUB (NTU)	pH (pH unit)	TDS	NO_3-N	PO_4	F	EC (µS/cm)	Mn	TH	FC (CFU)	TC (CFU)	Fe
Min.	5.00	2.50	2.00	7.35	56.30	0.01	0.00	0.05	93.70	0.00	34.00	0.00	0.00	0.00
Max.	19.40	30.00	15.00	7.88	90.70	3.54	0.21	0.40	152.00	0.20	42.00	227.00	834.00	0.93
Mean	7.83	15.42	7.58	7.60	65.1	1.30	0.05	0.16	109	0.07	38.7	49.2	2.18	0.34
SD	4.15	1.5	1.1	0.17	8.64	1.24	0.07	0.10	14.6	0.07	3.34	83.1	2.71	0.1
WHO	**250**	**15.0**	**5.00**	**6.5-8.5**	**1000**	**10.00**	**-**	**1.50**	**-**	**0.500**	**500**	**0**	**0**	**0.30**

Concentrations are in mg/L unless otherwise stated.

Table 4: Water quality analysis results of water stored in earthen pots (EP).

N=40	Cl	COL (Hz)	TUB (NTU)	pH (pH unit)	TDS	NO_3-N	PO_4	F	EC (µS/cm)	Mn	TH	FC (CFU)	TC (CFU)	Fe
Min.	4.00	2.50	1.00	7.27	58.40	0.05	0.00	0.05	98.10	0.00	32.00	0.00	0.00	0.00
Max.	7.00	25.00	11.00	7.86	67.60	8.82	0.01	0.40	113.00	0.17	40.00	78.00	315.00	0.80
Mean	6.00	6.67	3.61	7.60	63.6	3.43	0.002	0.16	106	0.04	37.2	19.2	102	0.20
SD	0.95	6.43	2.66	0.19	3.12	2.95	0.002	0.11	5.28	0.06	2.89	26.3	1.13	0.27
WHO	**250**	**15.0**	**5.00**	**6.5-8.5**	**1000**	**10.00**	**-**	**1.50**	**-**	**0.500**	**500**	**0**	**0**	**0.30**

Concentrations are in mg/L unless otherwise stated.

The study found that generally physico-chemical parameters of stored water measured were well within the WHO recommended limits, though they were higher than that of tap water. However, the physico-chemical parameters of stored water exhibited variations, but chemically, the water was potable for consumption, except in some cases where turbidity, colour and total iron levels were higher than WHO recommended values. Water from PBC and MC recorded higher levels of colour and turbidity (fig. 1 and 2). Increased colour and turbidity levels have undesirable effect on the aesthetic quality of the water. Turbidity measurements give an indication of the concentration of suspended clay, silt, organic matter, inorganic matter, plankton and other microscopic organisms in a water source [5]. High turbidity values are associated with the survival of microorganisms due to association of the microorganisms with particulate matter in the water [5]. High levels of colour in these facilities could be a result of rust deposits inside storage facility. Turbidity and iron present in higher amounts can also cause a rise in colour level (Fig. 2 and 3). These can be dislodged if there is a change of water at storage. Though water from the main tap recorded no coliform bacteria growth, almost all of household storage water samples analyzed contained coliform bacteria (fig.4 and 5). The presence of coliform bacteria in stored water most probably originated from unhygienic water-handling practices (i.e. unsanitary use of utensils and hands touching the water). This is in agreement with earlier studies conducted by Patel and Isaacson [9], Sutton and Mubiana [14] and Sobsey[13] who indicated that the geometric design of household water-storage containers played an important role in ensuring that the stored drinking water does not become contaminated by external factors such as dirty hands and utensils. This result also agrees with other studies carried out by Pinfold [10] who found that the most common route of contamination of stored water or the presence of coliform bacteria in stored water is through water handling such as dipping. So when water samples are taken by this process, the water might be disturbed and the settled materials suspend and get into the sampled water. Usually contamination occurs when water is regularly obtained by using a 'dipper' (often a plastic/metal bowl or gourd). Hands are in regular contact with the local surroundings and acts as a potential conduit for transferring microorganisms from contaminated sites within the home (and compound) to the stored water, either via the 'dipper' or through direct contact with the water. In addition, the transportation of water from the main source to household water storage tanks after fetching resulted in the presence of coliform bacteria. The presence of coliform bacteria in stored water for domestic use has health implications, since consumption of unwholesome water affect human health in many ways [8]. Other possible cause for the presence of coliform bacteria observed in the different storage tank types may have resulted from water temperature inside the storage tanks. Though temperature was not measured in this study but several studies have shown that temperature plays an important role in the survival of microorganisms and the effectiveness of a disinfectant. Cynthia [4] stated that an increase in water temperatures can result in higher rates of inactivation of microorganisms in water samples. A research conducted by Cynthia [4], showed that, the temperatures found in three different storage tank types indicate the potential for increased bacterial growth which is a health concern because even low levels of bacterial growth have the potential to cause illness in users [18]. Storage tank use factors such as cleaning frequency also appear to impact the microbial water quality of the stored water. Tank material also impact on the quality of water stored inside household storage tanks i.e. water storage tanks, that are in direct contact with water can contribute contaminants from either the material used in the tanks or from internal coatings used to protect the materials from contact with the water. Disease-causing microorganisms from human or animal faeces (bacteria, viruses, parasites) can be present in stored water. In addition, several studies carried out in developing communities on the microbiological quality of stored household drinking water, have reported on the presence of dust, animals, birds and various types of insects can result in coliform bacteria in storage tanks. Comparatively, the treated and stored water in various storage facilities exhibited variations in mean values as to the World Health Organization (WHO) guidelines (Table 5). Among the storage facilities, the degree of contamination of water stored in metal tank was greater than that stored in polyethylene tank and pot. Earthen pot showed less degree of contamination compared with polyethylene and metal tanks and this may be due to the fact that there was lower water temperature in the earthen pot than the others and also cleaning frequency was regular. Contamination levels of stored water are generally low where containers are well protected from water handling, such as with the tap and also the presence of a lid may offer some additional protection [6], [2].

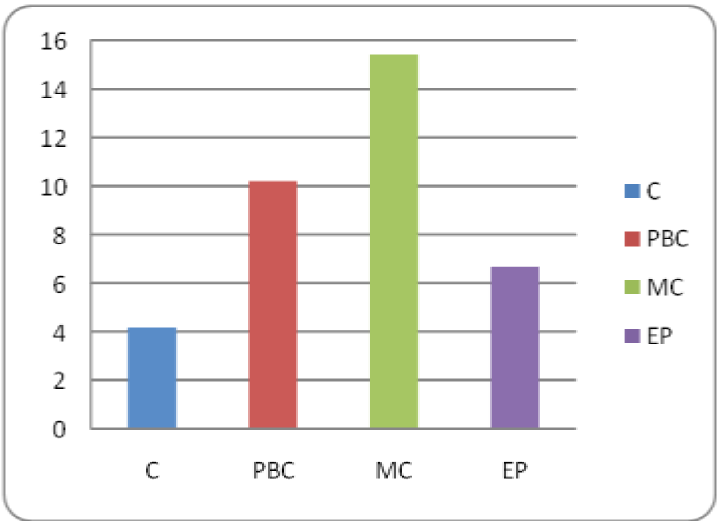

Fig.1. Mean Colour (COL) in main tap and storage facilities

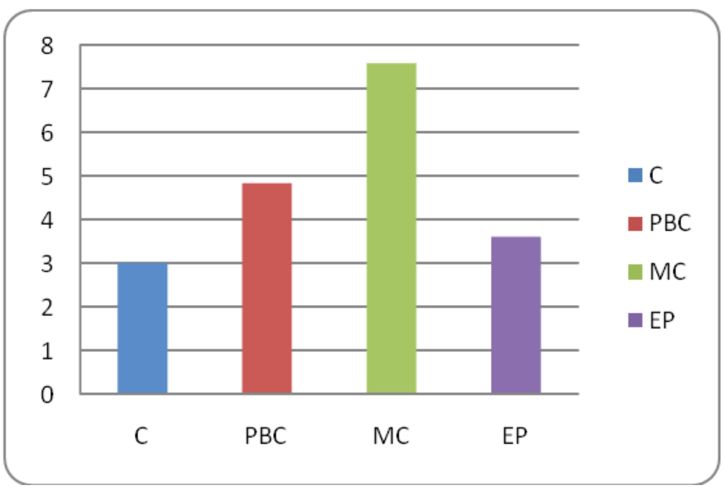

Fig.2. Mean Turbidity (TUB) in main tap and storage facilities

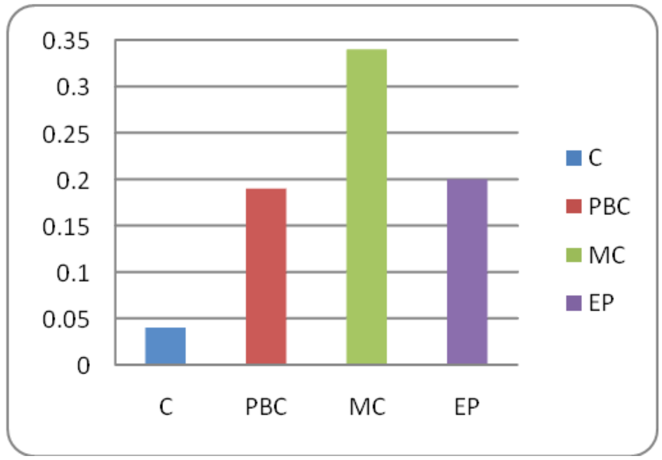

Fig.3. Mean Total iron (Fe) in main tap and storage facilities

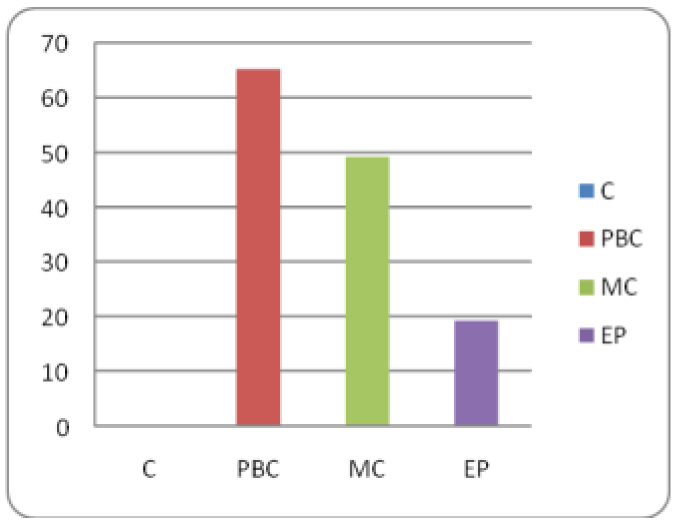

Fig.4. Mean faecal coliforms (FC) in main tap and storage facilities

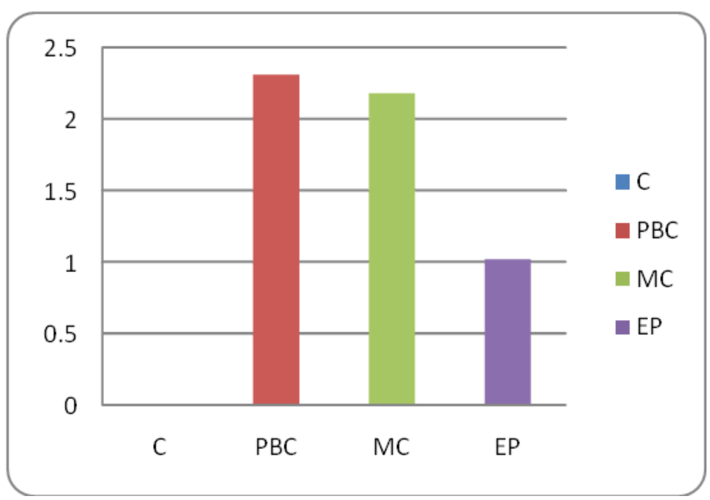

Fig.5. Mean total coliforms (TC) in main tap and storage facilities

CORRELATION MATRIX

Correlation analyses show that there were significant differences in quality of water measured between the main tap and storage facilities; and equally significant differences among the facilities which suggests strongly positive relationships between parameters such as Turbidity and Colour, Total and faecal coliforms (Table 5 and 6). In the main tap and facilities, turbidity strongly correlated with colour (r = 0.977, p < 0.01) and total coliform also correlated with faecal coliform (r = 0.903, p < 0.01). Among the facilities, turbidity again correlates strongly with colour (r = 0.977, p < 0.01) as total coliform also exhibited positive correlations with faecal coliform (r = 0.900, p < 0.01).

Table 5: Correlation analyses showing the quality of water measured between the main tap and storage facilities.

	Cl	COL	TUB	PH	TDS	NO3-N	PO4	F	EC	Mn	TDN	FC	TC	Fe
Cl														
COL	.048													
TUB	.095	**.977****												
PH	-.055	.226	.274											
TDS	-.160	.354*	.342*	.085										
NO3	.092	-.169	-.181	-.112	-.043									
PO4	-.075	.558**	.485**	.033	.205	-.277								
F	.007	-.124	-.092	.070	-.166	.072	.142							
EC	-.064	-.203	-.148	-.139	.434**	-.050	.020	-.048						
Mn	-.187	-.193	-.242	-.166	-.127	.137	-.130	-.040	-.248					
TDN	.014	.024	.037	.105	.339*	-.297	-.129	-.327*	.082	.173				
FC	-.181	-.100	-.120	.103	.149	.072	-.120	-.004	-.292	.172	.076			
TC	-.223	-.094	-.135	.092	.056	.006	-.007	.019	-.227	.183	-.045	**.903****		
Fe	.109	.228	.298	.440**	.389*	.066	-.074	-.040	.032	.110	.226	.263	.095	

** Correlation is significant at the 0.01 level (2-tailed).

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

Table 6: Correlation analyses showing the quality of water measured among the storage facilities

	Cl	COL	TUB	PH	TDS	NO3-N	PO4	F	EC	Mn	TDN	FC	TC	Fe
Cl														
COL	.050													
TUB	.095	**.977****												
PH	-.004	.243	.296											
TDS	-.140	.354*	.344*	.065										
NO3	.120	-.190	-.200	-.121	-.054									
PO4	-.071	.551**	.476**	.038	.202	-.299								
F	.027	-.103	-.077	.084	-.160	.073	.162							
EC	-.031	-.203	-.143	-.185	.426**	-.052	.024	-.035						
Mn	-.119	-.206	-.253	-.242	-.167	.119	-.146	-.050	-.308					
TDN	-.006	.036	.055	.092	.352*	-.283	-.116	-.286	.062	.201				
FC	-.181	-.130	-.147	.113	.144	.049	-.145	.011	-.295	.171	.110			
TC	-.224	-.131	-.171	.103	.047	-.025	-.036	.039	-.229	.179	-.011	**.900****		
Fe	.134	.208	.283	.457**	.386*	.041	-.099	-.027	.034	.095	.269	.239	.057	

CONCLUSION

The study found that the quality of tap water stored was generally good for consumption by WHO standards. However, coliform bacteria were detected in stored water in the study area throughout the study. Treated water from the main tap was of good quality by WHO standards. Even though stored water available in the households storage tanks could generally be considered potable, the presence of contaminants in the water were of concern especially the coliform bacteria counts. With detection of coliform bacteria in the stored water, the health of consumers might have been agreed with incidences of water related diseases and efforts must be made to improve the situation.

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