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PHYSICO-CHEMICAL CHANGES AND BACTERIOLOGICAL DETERIORATION OF POTABLE WATER DURING LONG TERM STORAGE

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ABSTRACT

Potable water samples obtained from near the treatment plant were analysed for some physical and chemical parameters as well as changes in microbial population during storage. Although values obtained for pH, total acidity, total alkalinity, and total hardness of water samples decreased with duration of storage, recorded values were still within FAO recommended standards for drinking water. Suspended particles became noticeable and the smell of water samples became unpleasant after 12 weeks of storage. *Escherichia coli, Enterobacter aerogenes, Staphylococcus aureus, Pseudomonas aeroginosa, Klebsiella pneumoniae Proteus sp. Streptococcus faecalis* and *Micrococcus sp* were the bacteria species encountered in stored water samples. *E. coli* was the most frequently encountered. The presence of these bacterial species has significant health implications. Total viable counts in water samples increased from 3.8 x 10^5 cfu/ml on day 0 to 42.0 x 10^5 cfu/ml by the 16th week of storage, while coliforms increased drastically from week two to week six of storage after which the population began to drop. Differences between control and stored water samples were significant ($p<0.05$) in all cases considered. That treated water samples entering the distribution system samples contained coliforms cast a doubt over the potability status of water supplied to the communities in the area under study.

Keywords: drinking water, water quality, storage, microbial load, coliforms.

INTRODUCTION

The importance of potable water supply in the socio-economic life of communities cannot be overemphasized. Often, source and potability of water supply reflects on the health conditions of communities as microbiological contamination of water is the primary cause of disease outbreaks in many communities particularly in many developing countries. The transmission of disease through drinking water is, therefore, one of the primary concerns for safe water supply (Ahmed *et al.,* 2004). In many developing countries, availability of potable water becomes a problem when supply is interrupted frequently and shortages become the order of the day. In most Nigerian communities, treated water supply from municipal distribution system is the most popular source of water supply because of the belief that it has passed through an efficient water purification system. Water from this source is also believed to have met the recommended standards for potable water supply and, therefore, considered to be the safest in terms of quality control and prevention of water communicable diseases.

As such, government-managed water treatment plants constitute the main source of such treated water supply to both urban and rural settlements. Unfortunately, for some reasons the supply of potable water through public water from the main municipal distribution network is very unstable and unpredictable as supplies are often erratic. In other situations, the authorities saddled with responsibility of water supply are unable to meet up with the demand. Interruptions in water supply could be for a short period or even last for months during which period people opt for alternative sources of water from unconventional sources particularly streams and rivers (Ukhun *et al.*, 2005) to meet their immediate needs. This trend makes people resort to storing treated water from the water treatment plants. Elsewhere, situations such as earthquake, flooding and related natural disasters result in interruptions in water supply which often lead to domestic water storage (Georgia, 1999).

Water supply from the mains that is presumed safe is often stored in plastic tanks and other plastic containers for several months without considerations for the possible implications of storage on the quality of stored water. Studies have shown that water may become contaminated at any point between collection, storage and usage (Tambekar *et al.*, 2006a; 2006b). Also, storing water in containers and handling procedures of water at home, hotels or restaurants cause water quality deterioration to such extent that the water becomes potential risk of infection to consumers (Jagals *et al.*, 1999). This study investigates the effect of long-term storage on the physico-chemical and bacteriological quality of potable water supplied to a Nigerian community.

MATERIALS AND METHODS

Sample Collection

The drinking water samples used in this investigation were obtained from near the main water treatment plants that supply water to Abeokuta metropolis (south western Nigeria) and a few rural settlements on the outskirts of the town. Volumes of 250 ml of treated water samples were collected into pre-sterilised screw-capped plastic containers. Collection was done from a public tap less than 50 meters from the main water treatment plant. The containers were covered and sealed after collection. Collection near the water treatment plant was done to rule out possible effects of changes in water quality along distribution line. Samples collected were taken to the laboratory and analysed within 4 h. The samples analysed soon after collection gives the status of the water samples at collection, and also gives information on the state of water entering the distribution system, while sterile distilled water was analysed as control.

Water storage

Samples were stored at room temperature in screw capped plastic containers. This was to simulate storage of water as it is practised in many homes. At two weeks interval, for up to 16 weeks, samples were taken from the stored water for physico-chemical and bacteriological analyses. Three replicates of each water samples were examined.

Physico-chemical analysis

The pH of samples was determined using a pH meter (Jenway, UK), temperature was checked with the aid of a centigrade calibrated thermometer (Digitron thermometer, model 275K) and colour of the samples in a clear glass container was noted. Other physical tests (particularly taste and odour) were carried out using the human sense organs. Titratable acidity, and total acidity, total alkalinity and total hardness were determined using standard procedures as described by FAO (1990).

Bacteriological analysis

Pour plate method was employed in determining heterotrophic plate count noting the colony forming units per ml (cfu / ml) of the water samples on MacConkey agar. Total Coliform was assessed by the Most Probable Number (MPN) technique. Confirmatory tests were then carried out on positive MPN tubes to confirm the presence of *E. coli*. Pure cultures of isolates obtained by repeated streaking on agar plates were subjected to various tests for characterisation, including, Gram staining, catalase, coagulation, ability to utilise citrate, sugar utilisation, indole production and other tests as specified by McDaniel *et al*. (1985).

RESULTS AND DISCUSSION

The results of this investigation have revealed that the stored water samples did not show physical signs of pollution until after 12 weeks of storage. The development of taste, odour and suspended particles was most likely due to the growth of slimy moulds and activities of other microorganisms whose populations have started building up after few days of storage (Table 1). The pH, total acidity, total alkalinity and total hardness of stored water decreased significantly ($p<0.05$) after 16 weeks of storage. This could be as a result of build up of metabolites of microorganisms that were increasing in population. However, the observed pH, alkalinity and total hardness were within the WHO (1995) recommended levels for potable water.

The bacterial species isolated from the water samples include *Staphylococcus aureus*, *Bacillus substilis, Escherichia coli, Enterobacter aerogenes, Pseudomonas aeroginsa* and *Micrococcus* sp. Other bacterial species encountered in the stored water were *Klebsiella pneumoniae, Proteus sp.* and *Streptococcus faecalis* (Table 2). Values of total viable counts recorded for control water samples and water samples stored for 16 weeks were significantly different ($p < 0.05$).

Most of these bacteria have been isolated from community drinking water supplies in Nigeria (Inyang and Aderemi, 2001; Edema *et al*. 2001) and have been implicated in outbreaks of water transmissible diseases in various parts of the country (Antai and Anozie, 1987; Onuh and Gonchi, 1998). The population of these microorganisms in stored water increased progressively with storage until after the 12^{th} week when their population began to decline. *E. coli*, *Staphylococcus aureus* and *Enterobacter* species were bacteria that were frequently encountered particularly within the first twelve weeks of storage. *E. coli* was constantly encountered at all stages of storage.

The occurrence of *E. coli* and *Enterobacter* sp. in freshly collected water samples is indicative of faecal contamination. This implies that water entering the distribution system was not entirely devoid of coliforms. The United States Environmental Protection Agency (US EPA, 2005) recommends zero contamination level of coliforms in drinking water.

The implication of this observation is that even though water entering the distribution system may look clean and have no undesirable odour or taste, it may contain harmful microorganisms which are ordinarily invisible to the naked eye. In essence, water supplied to communities from the water treatment plant cannot be certified as potable. This observation requires urgent attention from the appropriate authorities particularly with the reports of sporadic outbreak of cholera and other related water transmissible diseases in the area covered by this study.

Several factors could be responsible for this observation. The occurrence of coliforms in freshly treated water may be due to unhygienic conditions of the treatment plants and the personnel operating the plant. Clark *et al.* (1982) reported that coliforms could be found in both chlorinated and unchlorinated water as the complete elimination of coliforms in water requires knowledge of their population in such water to determine the quantity of chlorine that would be required for complete elimination. The observed count on freshly treated water samples, therefore, put to question the effectiveness of the water treatment procedures for water supplied to communities in the area under study. Many treatment plants designed and installed in many third world countries have inherent operational problems (Ogedengbe, 1982). Some are very old and are never frequently maintained. The implication of this is that treated water obtained from taps and distribution points within the treatment plant premises are not potable as they are not entirely devoid of coliforms.

Results of the investigation as shown by MPN of organisms indicate that the population of coliforms decreased with storage time, while the total number of bacteria in the stored water samples increased (Table 3).

This may be attributed to the fact that as storage progresses and metabolic wastes accumulate some coliforms were eliminated from the environment which was becoming competitive. The modified growth environment for the microorganisms encouraged a kind of succession as some species were eliminated while growth of others was encouraged. The general effect of these activities is invariably reflected on the physical attributes of the water samples particularly on parameters such as the taste, colour and odour. These physical factors which are related may limit the usefulness of water.

Although, the effect of the type of material used for making storage tanks are commonly made of in the area under study was not investigated, reports have shown that the type of material (plastic, concrete or galvanised steel) domestic storage tanks are made of have some effect on the quality of drinking water (Jawas *et al.*, 1988). It is, however, important to note that storage in plastic tanks and containers have over the years replaced galvanised steel tanks for water storage in the area of study. It is believed that galvanised steel tanks are by themselves a source of contamination. Ziadat (2005) reported that galvanised tanks impact on the major cations (Na^+, K^+, Ca^+, Mg^+) and heavy metal (Pb, Fe, Cu, Zn, Mn and Ni) content of stored water.

That the quality of water stored for 2-4 weeks meets the required standard except for the presence of coliforms is an indication that water could be stored for a short time before use. Georgia (1999) postulated that water can only be stored for a short time after which it begins to deteriorate. However, for water to be stored, it is expected to meet the quality requirement of potable water. Also, such stored water should be examined periodically to determine the degree of deterioration with a view to deciding on the type of usage such water can be put to. Improving domestic water storage and handling practices have been shown to be of health benefit to consumers (Mintz *et al*., 1999).

Several bacterial species isolated from stored water samples in this study have significant health implications (WHO, 2001). The report of the occurrence of antibiotic-resistant strains of *E. coli* (Oyagade and Fasuan, 2004) in water used for domestic purposes by Nigerian communities' signals additional dangers associated with the use of water stored for a long period of time. Regrettably, *E. coli* was the most consistent bacterial species encountered in the water samples at the different stages of storage, a trend similar to observations of Hussain *et al*. (2001). This trend, if not given adequate attention, may add to the existing water and sanitation problems in the Third World. It is estimated that about 1,400 people (mostly children) die every hour due to waterborne diseases (Bauwer, 2003).

This study has shown that there is a need for an improvement in water treatment procedures in the area under study. There is also a need for awareness programmes to be put in place to educate communities on the possible health implications of drinking water which has been stored for a long time.

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Table 1: Physico-chemical properties of potable water with storage in plastic containers

Storage time (in weeks)	Colour	Odour	Taste	Presence of particles	pH (at 25°C)	Total acidity (mg/l)	Total alkalinity (mg/l)	Total hardness ($CaCO_3$/1)
0	Colourless	Odourless	Tasteless	None	6.85a	93.0ab	22.3b	45.7b
2	Colourless	Odourless	Tasteless	None	6.85a	93.1ab	22.2b	45.8b
4	Colourless	Odourless	Tasteless	None	6.81a	93.2ab	23.2a	46.8a
6	Colourless	Odourless	Tasteless	None	6.75b	94.2a	23.0a	46.8a
8	Colourless	Odourless	Tasteless	None	6.70bc	92.0b	22.0b	46.0ab
10	Colourless	Odourless	Tasteless	None	6.66c	88.0c	20.0c	44.0c
12	Colourless	Unpleasant	Tasteless	Few particles	6.56d	84.0d	18.7d	40.0d
14	Colourless	Unpleasant	Tasteless	Few particles	6.53de	80.2e	18.4de	36.1e
16	Colourless	Unpleasant	Tasteless	Suspended particles visible	6.50e	78.2f	18.0e	35.0f
Recommended standards CaCO3L for potable water (FAO, 1990)	Colourless	Unpleasant	Tasteless	No visible solid particles	6.8- 8.5	50-120mg-L	200mg-L	15 –100

† For quantitative data on the table, figures with the same superscript alphabets along columns are not significantly different ($p>0.05$)

Table 2: Bacterial species in stored water samples

Storage time (in weeks)	Bacterial species isolated
0	*Escherichia coli*
2	*Staphylococcus aureus, Bacillus subtilis, Escherichia coli*
4	*Escherichia coli, Enterobacter aerogenes, Staphylococcus aureus, Pseudomonas aeroginosa*
6	*Escherichia coli, Staphlococus aureus, Micrococcus sp. Bacillus subtilis.*
8	*Staphylococcus. aureus, Streptococcus faecalis, Micrococcus sp*
10	*Klebsiella pneumoniae, Streptococcus faecalis, Staphylococcus aureus, Escherichia coli.*
12	*Klebsiella pneumoniae, Pseudomonas aeroginosa, Proteus sp., Steptococcus faecalis, Escherichia coli*
14	*Staphylococcus aureus, Micrococcus sp. Streptococcus faecalis*
16	*Staphylococcus aureus, Bacillus substilis Escherichia coli*

Table 3: Total viable count and Most Probable Number in stored water samples

Storage time (in weeks)	*Total viable count (TVC) (cfu x 10^5 /ml)		**Most probable number (MPN) / l00ml	
	Control (Sterile distilled water)	Stored water samples	Control (Sterile distilled water)	Stored water samples
0	† 0.0^g	3.8^g	0^f	20^f
2	0.0^g	4.4^g	0^f	120^c
4	0.0^g	10.0^f	0^f	210^b
6	3.4^e	20.0^e	0^f	240^a
8	5.8^c	21.5^d	13^e	40^d
10	6.9^b	22.8^c	25^d	30^e
12	8.0^a	23.0^c	40^c	17^f
14	4.5^d	30.0^b	55^b	8^g
16	2.8^f	42.0^a	67^a	4^h

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4	0.0^g	10.0^f	0^f	210^b
6	3.4^e	20.0^e	0^f	240^a
8	5.8^c	21.5^d	13^e	40^d
10	6.9^b	22.8^c	25^d	30^e
12	8.0^a	23.0^c	40^c	17^f
14	4.5^d	30.0^b	55^b	8^g
16	2.8^f	42.0^a	67^a	4^h

* Recommended total viable count standard limit in potable water = 1.0 x 10^2 (WHO, 1971; FAO, 1997)
** Recommended MPN limit in potable water = 0 (FAO, 1997)
† Figures with the same superscript alphabets along columns are not significantly different ($p<0.05$)