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Effect of storage containers on water quality

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Abstract
This work studied the effect of storage containers on water quality. The objective was to know the best container for storage of water since water quality is subject to changes due to storage over time. Water samples were stored in five different containers, glass, plastic, clay pot, ceramic, and stainless steel for 28 days and was subjected to various tests using standard methods as in SMEWW (1992). Results showed that while the quality of water for pH, total dissolved solids (TDS), total solids (TS), electrical conductivity (EC), turbidity, total hardness, alkalinity, sulphate and nitrate deteriorated with time, there was an improvement in water quality for phosphate, chloride and Coliform count (MPN). It was also observed that no particular container is the best for water storage, but depends on the parameter of interest. For instance, clay pot is the best storage container if emphasis is on pH, TDS, TS, turbidity, alkalinity, and sulphate. Plastic is best in electrical conductivity while stainless steel is best in total hardness and Coliform count. Ceramic is best in nitrate and phosphate, while glass is the best storage container if chloride is emphasized. Coefficient of variation show that total hardness is more conservative and inert with the least value of variability of 0.003 while turbidity was most affected with value of 0.22 variability. Results also indicated that chemical parameters of stored water are more conservative than the physical parameters, and quality of water in all the storage containers were found to still fall within the WHO permissible limits/standards.

Keywords: Effect, Storage, Container, Water, Quality

1. Introduction
Water is an important supply of drinking water for population around the world, principally in rural areas and it must be judiciously managed and protected (Jackson *et al*., 2001; Guergazi and Achour, 2005). Safe drinking water must have an acceptable quality that obeys physical, chemical and bacteriological parameters (Sobsey *et al*., 2008). These parameters have been used to determine the general quality of drinking water worldwide.

Water quality degradation between sources and point-of-use may be due to several reasons such as the hygienic condition of storage (Trevett *et al*., 2004; Cronin *et al*., 2006; Singh *et al*., 2006). Significant deterioration of the water quality has been detected during its storage at homes in rural and urban areas throughout Africa, Asia, and Latin America (Trevett *et al*., 2004; Hoque *et al*., 2006; McGarvey *et al*., 2008; Kausar *et al*., 2012). In fact, water storage for days may cause water quality deterioration and become unsuitable for drinking (Trevett *et al*., 2004).

While some researchers hold the view that storage of water can give rise to deterioration, other researchers have contrary views. However, studies have shown that storage does improve the quality of water (Agbede and Morinkayo, 1995; Agbede 1991). Upon storage, big suspended flocculated particles and other impurities with specific gravity bigger than the water molecules settle down at the bottom of the reservoir thus ensuring its physical clarification. Bacterial quality also improves (Oluwande, 2003; Twort *et al*., 1999), which is partly due to settling and partly the destruction of bacteria by ultraviolet radiation from sunlight near the water surface (Twort *et al*., 1999). There was increase in microbial contamination in waters stored in steel, plastic and clay containers over a period of one month. However, this was attributed to poor hygiene of the household users rather than the type of storage container (Andrew, 2004). Bacterial contamination increased in water stored for six months in household and public galvanized steel tanks (Hammad, 2008). If clean water is stored under hygienic conditions, there should be improvement in quality in terms of reduction in total suspended solids, as the particles within the stored water settle at the bottom of the storage container (Russell and Hugo, 2000).

Therefore, this research took cognizance of the fact that water quality deteriorate in storage containers when stored for a given period of time and as a result, water quality in five different containers were studied to enable determine which container is most suitable for water storage in order to preserve it from deterioration.

2. Materials and method

2.1 Samples and sampling techniques

Water sample was collected from Ezigbo stream at Abatete town in Idemili North Local Government Area of Anambra state, Nigeria. This stream is the boundary between Abatete and Alor towns respectively. A 12-litre sample was collected in sterilized polypropylene containers with leak-proof lids. Because of the most probable number of Coliform (MPN) test, and bacterial growth being time-dependent, another 2-litres water sample was collected in polypropylene container and stored in an icebox at temperature between 1-4 ^{0}C in order to keep the organisms in a state of dormancy during transportation to the laboratory. Some samples was tested in triplicate to determine the initial properties of the parameters such as pH, total dissolved solids (TDS), total solids (TS), electrical conductivity (EC), turbidity, total hardness, alkalinity, sulphate, nitrate, phosphate, chloride and most probable number of Coliform (MPN) which served as control or baseline as the case may be. 2 litres samples each were stored in the different containers such as glass, plastic, clay pot, ceramic and stainless steel. Some of the samples were collected and tests repeated in triplicates after 28 days, the tests were carried out using standard methods and procedures outlined in the (SMEWW, 1992).

3. Results and discussion

Table 1 show the physical and chemical properties of the stream water stored in five different containers for 28 days and the containers are glass, plastic, clay pot, ceramic and stainless steel respectively. From the results, there were significant variations in the physicochemical properties of the stored water. After storage, the pH of the water recorded slight but significant increase with values ranging from 6.83 to 7.33 as against initial value of 6.50 before storage. The water stored in clay pot had a pH of 7.33 while the one in glass recorded 6.83, this trend is an indication that pH values of water stored in containers increase with increase in time and tends from slightly acidic condition to slightly alkaline condition.

For total dissolved solids (TDS), glass and stainless steel recorded similar results with very slight variation with values of 177.13 mg/l for glass and 177.27 mg/l for stainless steel. Likewise, the difference between plastic and ceramic is insignificant since the values are 175.47 mg/l and 174.60 mg/l for plastic and ceramic respectively. However, the waters in ceramic and stainless steel did not show any variations in their pH values. There was no significant variations in the total dissolved solids, of the water before and after storage in the different containers except the one in the clay pot which recorded significantly higher dissolved solids of 186.93 mg/l. These results are against the baseline of 193.83 mg/l before start of experiment. The results showed increase in concentration of dissolved solids in the storage containers an indication that under quiescent conditions, dissolved solids in suspension settle to the bottom of storage containers.

Results of TS show that difference in concentrations for glass, plastic, ceramic and stainless steel are negligible and the values are 294.77 mg/l, 297.00 mg/l, 294.73 mg/l and 296.93 mg/l respectively. Only clay pot had a different concentration value of 302.60 mg/l significantly different from other storage containers when compared with the baseline value of 394.07.

Initial value of electrical conductivity was 50.57 $\mu s/cm$ but a reasonable difference occurred among the storage containers. It was highest in clay pot with value of 47.67 and least in glass with value of 33.57 $\mu s/cm$. There were more significant variations in the electrical conductivity especially in the water stored in plastic, clay pot and stainless steel containers, all of which recorded significantly different values of 48.89 $\mu s/cm$, 47.67 $\mu s/cm$ and 47.90 $\mu s/cm$ respectively as against 50.57 $\mu s/cm$ before storage.

Baseline for turbidity was 9.23 NTU and there was improvement in the quality of water in the containers because turbidity values decreased. Turbidity removal was highest in ceramic and glass containers with the same value 5.53 NTU and least in clay pot with value 6.33 NTU, so that turbidity of water showed slight but significant variation after storage. This is an indication of improved water quality since the turbidity value decreased in all the storage containers.

Chemical properties of the water recorded some changes during storage in which the alkalinity concentration of the stored water increased slightly. Baseline value was 93.00 mg/l but the highest value of 94.47 mg/l was recorded in clay pot. The recorded increases appear to confirm (or corroborate) the equally slight increases in the pH of water during storage.

Table 1 show that storage does not have noticeable effect on chemical properties of water such as the concentrations of sulphate, nitrate and phosphate. The range in sulphate concentration in water fall between 23.88 mg/l baseline and 24.70 mg/l for clay pot an indication of slight increase from baseline value.

Concentrations of nitrate decreased in all containers, it was 10.11 mg/l in the baseline study and least clay with value 9.74 mg/l, an indication that clay pot is the best storage container for removal of nitrate from water since the concentration is least, because the higher the concentration, the greater the risk as a result of blue-baby syndrome disease it causes in infants.

Clay pot has the least concentration in phosphate and seems to be the best storage container if phosphate is emphasized. The concentration was 0.63 mg/l against baseline value of 0.87 mg/l and these show that there is no sharp contrast between this range and therefore no significant change. But chloride content reduced being in the range of 14.36 mg/l and 15.46 mg/l against 17.12 mg/l before storage.

Generally, phosphate, sulphate and nitrate content of the water did not show any significant variation during the storage period but rather had slight changes. There were more varied levels of variation in the physicochemical composition of the water before and after storage in the different test containers. The physical properties altered more significantly than the chemical properties. Comparatively, more changes in the physicochemical properties were recorded in the water stored in clay pot.

Table 1: Physicochemical properties of water stored in different containers presented in mean of triplicate ± standard deviation

	pH	TDS (mg/l)	TS (mg/l)	EC (µs/cm)	Turbidity (NTU)	Total Hardness (mg/l)	Alkalinity (mg/l)	Sulphate (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Chloride (mg/l)
WHO Limits	6.5-8.5	50-150 ppm	500	400	5	0-60	20-200	150	50-100	0.10	200-600
NEAT (control)	6.50 ± 0.00	193.83 ± 7.45	394.07 ± 2 .15	50.57 ± 0.87	9.23 ± 0.57	87.13 ± 0.77	93.00 ± 0.34	23.88 ± 0.90	10.11 ± 0.22	0.87 ± 0.04	17.12 ± 0.88
Glass	6.83 ± 0.58	177.13 ± 0.76	294.77 ± 0.38	33.57 ± 0.83	5.53 ± 0.58	87.33 ± 0.11	92.90 ± 0.17	22.27 ± 0.06	9.99 ± 0.05	0.67 ± 0.01	15.46 ± 0.04
Plastic	7.00 ± 0.10	175.47 ± 0.46	297.00 ± 1.04	48.89 ± 0.51	5.67 ± 0.11	87.87 ± 0.23	93.73 ± 0.11	22.03 ± 0.11	10.00 ± 0.04	0.69 ± 0.02	15.34 ± 0.07
Clay Pot	7.33 ± 0.06	186.93 ± 1.45	302.60 ± 3.51	47.67 ± 0.92	6.33 ± 0.11	87.50 ± 0.17	94.47 ± 0.23	22.70 ± 0.17	9.74 ± 0.08	0.63 ± 0.03	14.36 ± 0.03
Ceramic	6.90 ± 0.10	174.60 ± 0.40	294.73 ± 0.11	43.27 ± 1.33	5.53 ± 0.11	87.33 ± 0.11	93.57 ± 0.55	22.63 ± 0.29	10.10 ± 0.02	0.72 ± 0.01	15.12 ± 0.12
Stainless Steel	6.90 ± 0.00	177.27 ± 0.98	296.93 ± 0.92	47.90 ± 0.86	5.83 ± 0.58	87.17 ± 0.64	93.47 ± 0.06	22.20 ± 0.10	9.95 ± 0.01	0.69 ± 0.01	14.55 ± 0.18
Coeff. of Variation	0.038	0.043	0.127	0.136	0.220	0.003	0.006	0.030	0.018	0.083	0.064

Table 2 show changes in the total Coliform count of water during the 28 days storage in different vessels. The baseline Coliform count recorded an average of 19.33 cells as the Most Probable Number (MPN) of Coliform cells in 100 ml of the water. This value is well above the maximum acceptable level of 3 cells per 100 ml (WHO, 2004; APHA, 2006). There was a general decline in the Coliform count of the water irrespective of the storage material. There were variations in the manner of reduction in Coliform counts. The water stored in clay pot, ceramic and stainless steel all retained decreasing number of Coliform cells until the third week (21 days) while the water stored in plastic and glass containers retained Coliform until the second week (14 days). At the end of the storage period (28 days), no Coliform cells were found in any of the stored water irrespective of the material. This is supportive of the fact that the Coliform lived out their existence in the water during storage. Most Coliform are enteric and do not thrive well in habitats that are quite different from that of the guts of humans. Thus, they are always incapable of existence for long time outside the intestine of mammals. This why some of them are used as markus (indicator organisms) for recent fecal contamination in water environment.

Table 2: Coliform content of water stored in different containers (MPN/100ml) presented in mean of triplicate ± standard deviation

Type of Container	Week				
	0	1	2	3	4
Control	19.33 ± 1.15	19.33 ± 1.15	19.33 ± 1.15	19.33 ± 1.15	19.33 ± 1.15
Glass	19.33 ± 1.15	3.67 ± 0.58	2.33 ± 0.58	0	0
Plastic	19.33 ± 1.15	4.33 ± 1.15	2.67 ± 0.58	0	0
Clay Pot	19.33 ± 1.15	10.67 ± 1.53	5.67 ± 0.58	1.33 ± 1.15	0
Ceramic	19.33 ± 1.15	6.67 ± 0.58	2.67 ± 0.58	1.33 ± 1.15	0
Stainless Steel	19.33 ± 1.15	8.33 ± 1.15	4.33 ± 1.15	2.00 ± 0.00	0

Table 3 summarized the results and presented them in an orderly manner as in the quality of water stored in the containers. Column 1 of the table is an indication that the water stored in the container experienced least deterioration (i.e. Exceptional quality) and a decreasing trend up to column 5 with highest deterioration (i.e. worst quality). The results in Table 3 also indicated significant increase in concentrations of total solids (TS), electrical conductivity (EC), total dissolved solids (TDS), turbidity, total hardness, alkalinity, sulphate and pH, an indication of deteriorating trend in the quality of water stored in different containers. For chloride and phosphate, the concentrations decreased indicating an improvement in water quality with time. In the MPN test, Coliform count decreased with time. It was observed that the best container for storage with respect to Coliform count was in the order glass > plastic >ceramic > Clay pot > stainless steel. This is an indication that stainless steel has the least tendency for good storage as far as Coliform organism is concerned.

However, some of the results support the views of researchers such as (Trevett *et al*., 2004; Cronin *et al*., 2006; Singh *et al*., 2006; Hoque *et al*., 2006; McGarvey *et al*., 2008; Kausar *et al*., 2012). Because it can be seen from Table 3 that storage gave rise to deterioration of water quality for parameters like pH, total dissolved solids, total solids, electrical conductivity, turbidity, total hardness, alkalinity, sulphate and nitrate respectively. While the quality of water improved in phosphate, chloride and Coliform count (MPN) which support the claims of researchers like (Agbede and Morinkayo, 1995; Agbede, 1991). It is evident from the results that no particular container is the best in storage of water, instead it depends on the parameter of interest. For instance, in column 1 of Table 3, it can be seen that clay pot is the best storage container if emphasis is on pH, TDS, TS, turbidity, alkalinity and sulphate; plastic is best in electrical conductivity is to be minimized; stainless steel is best in total hardness and MPN count; ceramic is best in nitrate and phosphate, while glass is best in chloride. The results also varied if a look is taken at columns 2 to 5 of Table 3.

Table 3: Quality of water stored in different containers in decreasing order of magnitude

	Type of container/storage potential				
Parameter	**Exceptional**	**Excellent**	**Very Good**	**Good**	**Fair**
pH	Clay pot	Plastic	Ceramic	Stainless steel	Glass
TDS	Clay pot	Stainless steel	Glass	Plastic	Ceramic
TS	Clay pot	Plastic	Stainless steel	Glass	Ceramic
EC	Plastic	Stainless steel	Clay pot	Glass	Ceramic
Turbidity	Clay pot	Stainless steel	Plastic	Glass	Ceramic
Total hardness	Stainless steel	Clay pot	Ceramic	Plastic	Glass
Alkalinity	Clay pot	Plastic	Ceramic	Stainless steel	Glass
Sulphate	Clay pot	Ceramic	Glass	Stainless steel	Plastic
Nitrate	Ceramic	Plastic	Glass	Stainless steel	Clay pot
Phosphate	Ceramic	Plastic	Stainless steel	Glass	Clay pot
Chloride	Glass	Plastic	Ceramic	Stainless steel	Clay pot
MPN	Stainless steel	Clay pot	Ceramic	Plastic	Glass

Table 4: **Coefficient of variation of parameters in increasing order of magnitude**

Parameter	Coefficient of Variation	% Variation
Total hardness	0.003	0.30
Alkalinity	0.006	0.60
Nitrate	0.018	1.80
Sulphate	0.030	3.00
pH	0.038	3.80
TDS	0.043	4.30
Chloride	0.064	6.40
Phosphate	0.083	8.30
TS	0.127	12.70
EC	0.136	13.60
Turbidity	0.220	22.00

Table 4 show the variation of parameters in increasing order of magnitude in which three regions of insignificant variability were identified. The low region fall between 0.30 % to 4.30 % so that such parameters like total hardness, alkalinity, nitrate, sulphate, pH and total dissolved solids fall under this category. Only chloride with per cent variation of 6.40 % and phosphate with per cent variation of 8.30 % were found in the moderate region. Much variations were noticed in total solids, electrical conductivity and turbidity which recorded the highest variability in the high region. These results are indications of the fact that only electrical conductivity and spherical discrete particles are much affected when water is stored in containers. Slight variability of these parameters could be as a result of their inert characteristics while in solution. Nevertheless, the quality of water in all storage containers showed that the parameters still fall within the WHO permissible limits as shown in Table 4.

Conclusion

This study concluded that storage containers affect the quality of water stored in them. It was observed that the longer the water is stored in the containers, the more it deteriorates or improves. For instance deterioration was noticed in some of the parameters such as pH, total dissolved solids, total solids, electrical conductivity, turbidity, total hardness, alkalinity, sulphate and nitrate respectively. The quality of water improved in phosphate, chloride and Coliform count (MPN). For Coliform count, it was in the order glass > plastic > ceramic > clay pot > stainless steel, which implies that water stored in stainless steel has the least quality. For other parameters, no container could be said to be the best for storage, instead it depends on the parameter of interest. For instance, clay pot favors pH while plastic favors electrical conductivity. Coefficient of variation show that total hardness is more conservative and inert with the least value of variability of 0.003 while turbidity was most affected with value of variability of 0.22.

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