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Original Research

Efficiency of Water-Purifying devices used in homes and industries

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ABSTRACT:

The use of water-purifying devices are gaining popularity, as many homes and industries are using them to treat water for dinking. However, most of the users do not know much about the performance/efficiency of these devices, hence this investigation. Efficiency of water-purifying devices were evaluated to determine their efficiencies in treating water consumed by people. Raw water samples from groundwater source, borehole (a major source of drinking water) in Owerri, Nigeria were treated using commonly used water treatment devices: resin ion-exchanger, sand-bed filter, activated carbon filter, micron filter, reverse osmosis membrane filter, ozonator, and UV-sterilizer. The resulting purified water samples were labeled, and each were subjected to physical, chemical and bacteriological analyses using APHA (2006) water analysis method. Raw water (control) sample had pH value of 6.7 while the pH values of treated water samples fell within 6.9 – 7.1. Turbidity value of control sample was 6.0 NTU with other samples recording 4.0 NTU and below. Total heterotophic bacteria count and total coliforms counts of the raw water sample were 4.0×10^2 CFU/ml and 2.2×10^2 CFU/100ml respectively, but were below 2.5×10^2 CFU/ml and 1.9×10^2 CFU/100ml respectively in some of the treated samples, and nil in others. The overall efficiency of the treatment devices were of the order: Reverse osmosis membrane filter (76.25%) > UV-sterilizer (72.24%) > micron filter (65.85%) > Ozonator (62.97%) > Activated carbon filter (51.86%) > Resin ion-exchanger (46.67%) > Sand-bed filter (43.55%). This implies that not all water treatment devices used in homes and indutries are efficient enough to yield qualitative drinking water for unsuspecting users.

Keywords:

Efficiency, Water-purifying, Potable water, Devices, Homes.

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INTRODUCTION

Environmental pollution which encompasses the pollution of the terrestrial, aeriel and aquatic environments, has no doubt necessitated devicing means of remedying the polluted environments. The aquatic environment which man depends upon for the supply of his daily water needs is under serious pollution threats. The industrial, agricultural and other anthropogenic activities have been the major sources of water pollution. Generally, water pollution involves the intrduction of waste into water bodies directly or indirectly of substances or energy which can lead to rendering it unacceptable for the best usage, when their concentrations exceed the permissible limit (Achalu and Achalu, 2007). Pollution of available water resources in Nigeria have been reported in literatures (Okereke *et al*., 2006; Obasi *et al*., 2006; Agwung *et al*., 2006; Okereke and Nnoli, 2010; Obiekezie, 2006). Cassava processing mill around boreholes for example, affects ground water quality (Okechi *et al*., 2013).

Inorder to achieve the purpose for which water is meant, it requires treatment/purification. The process which involves the removal of unwanted biological, chemical, and physical contaminants, including suspended solids and gases from contaminated water, is refered to as water purification. When water is purified, it can serve for human consumption, and for pharmaceutical, chemical, medical and industrial applicatons. Physical, biological and chemical methods are the general methods adopted in water purification. The physical method involves processes such as filtration, sedimentation and distillation; chemical method involves flocculation and chlorination, while biological method involves the use of sand filters or biologically active carbon. For any public water supplies, purification of water is carried out for aesthetic reasons (i.e removal of taste, odour, colour and turbidity), elimination of water-borne pathogens, and for economic reasons. This gives rise to potable water. Water is said to be potable when it is free from impurities, including pathogenic organisms and is aesthetically appealing and safe as well as acceptable for drinking (Obionu, 2001). This may be achieved through the use of water purifiers.

Water purifiers used in homes and industries are micron filters (in catridge form), carbon filters (in catridges, cylinders or vessels), rapid sand filters (in cylinders or vessels), UV water purifiers (usually in tubes), reverse osmosis membrane filters, ozonators and resin ion-exchangers. Activated carbon also refered to activated charcoal is used to reduce chlorine, herbicides, toxic chemicals as well as taste and odour (Aizpuru *et al*., 2003). Activated carbon filters do not actually serve as primary purification techniques. They however play complimentary roles to other purification techniques as secondary treatment devices. They do not remove bacteria, but can become breeding grounds for them including pathogenic ones (Hall and Dietrich, 2000). With small pores sizes (in microns) associated with micron water filters and relative efficiency, they are perfect choice for both industrial and domestic uses (WHO, 2007). The rapid sand filters are used in the first stage in filtration process in water treatment and most commonly used in water purification. They mildly reduce odour, taste and dissolved impurities in drinking water. UV water purifier is very effective at inactivating cysts in low turbid water as its efficiency decreases with increased turbidity, hence it is sometimes necessary to add residual disinfectant after it is used (Campbell and Wallis, 2002). Reverse osmosis membrane filter is commonly used to purify drinking water from sea. It does this by removing salt and other substances from the water molecules. Ozonator is a machine that produces Ozone. In Europe, Ozone which is a very strong and broad spectrum disinfectant, is widely used. It is an effective method to inactivate harmful protozoa and works well against pathogens. To use Ozone as a disinfectant, it must be created on-site and added to the water by bubble contact (Brian, 2010). Resin ion-exchanger is mainly used in softening water that has undergone filtration processes. Resin ion-exchanger can remove carbonate, bicarbonate and sulphate ions in water (Muraviev *et al*., 2002).

A wide variety of water-purifying technologies are in use globally depending on the raw water source, contaminants present, standard to be met, and avialable finances (Water Resource, 2004). In Nigeria, the use of water-purifying devices in homes (domestic use) and industries (for commercial purposes) is gaining popularity. Individuals now purchase simple water purifiers to treat water for consumption, while industries, particularly water bottling companies, use both simple and integrated purifying devices in processing raw water from either surface or ground sources which are sold to the public. This work was aimed at ascertaining the effectiveness of some of these devices that have flooded Nigerian markets, and used in homes and industries.

METHODOLOGY

Sample collection and purification

Water samples for this study were collected from borehole (groundwater source) in Owerri, Nigeria. A total of eight (8) water samples were collected from the same source and subjected to purification processes using different purifying devices under investigation. They were resin ion-exchanger, Ozonator, sand-bed filter, activated carbon filter, micron filter, reverse osmosis membrane filter and UV-sterilizer. The samples were labeled as follows:

Sample 1 – Raw water from borehole

Sample 2 – Borehole water treated by resin ion-exchanger

Sample 3 – Borehole water treated by sand-bed filter

Sample 4 – Borehole water treated by activated carbon filter

Sample 5 – Borehole water treated by micron filter

Sample 6 – Borehole water treated by reverse osmosis membrane filter

Sample 7 – Borehole water treated by Ozonator

Sample 8 – borehole water treated by UV-sterilizer.

Laboratory investigations

Water samples were subjected to physico-chemical and bacteriological analyses using APHA (2006) standard methods for the examination of water. The physical parameters analyzed were pH, total disssolved solids (TDS), conductivity and turbidity. Chemical parameters analyzed were iron, calcium hardness, magnesium hardness, total hardness, nitrate; while bacteriological analyses considered total heterotrophic bacteria counts and total coliform counts. In total heterotrophic count, 0.1ml of each water sample was inoculated on sterile solid medium using spread plate method. Total coliforms in each water sample was determined using membrane filtration technique which involved the filtration of 100ml of water sample through sterile filter membranes which were later placed on EMB media and incubated at 37ºC for 24 hours. The colonies were later counted using Stuarts colony counter (model SC5).

RESULTS

In Table 1, the pH value of raw water which served as control sample was 6.7, while the pH values of water samples treated by different treatment devices ranged between 6.9 and 7.1. The total dissolved solids of control sample was 66.0mg/l while values of treated samples ranged from 48.0mg/l to 64.0mg/l. Conductivity values were 110.0µS/cm (for control sample), 105.0µS/cm (sample treated by resin ion-exchanger), 96.0 µS/cm (sample treated by UV-sterilizer), and 82.5 µS/cm (sample treated by micron filter). The values of turbidity varied from 0.0NTU to 4.0NTU, for all the treated samples, while the control sample had the value of 6.0NTU. The values of Iron in all the samples were either 0.03mg/l or 0.02mg/l. The control sample and sample treated by sand-bed filter, recorded total hardness of 10.0mg/l each. Others had lower values between 8.0mg/l and 4.6mg/l. The values of nitrate in water

Table 1: Physico-chemical and Bacteriological properties of raw and treated water samples

Parameter	Water Sample							
	1	2	3	4	5	6	7	8
pH @ 25ºC	6.70	7.10	7.00	7.00	7.00	7.00	6.90	6.90
TDS (mg/l)	66.00	63.00	60.00	64.00	50.00	48.00	58.40	58.60
Conductivity (µS/cm)	110.00	105.00	100.00	108.00	82.50	79.40	95.80	96.00
96.0Turbidity (NTU)	6.00	4.00	0.00	1.00	0.50	0.00	1.00	0.00
Total Iron (mg/l)	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02
Calcium (mg/l)	6.00	3.00	6.00	4.00	3.00	3.00	5.00	3.00
3.0Magnesium (mg/l)	4.00	2.00	4.00	2.00	2.20	1.60	3.00	2.00
Total hardness (mg/l)	10.00	5.00	10.00	6.00	5.20	4.60	8.00	5.00
Nitrate (mg/l)	0.35	0.23	0.22	0.13	0.23	0.22	0.22	0.22
THC (CFU/ml)	400.00	200.00	20.00	250.00	nill	nill	nill	nill
TCC (CFU/100ml)	220.00	10.00	190.00	10.00	nill	nill	nill	nill

Key:
Sample 1 – Raw water from borehole; Sample 2 – Borehole water treated by resin ion-exchanger
Sample 3 – Borehole water treated by sand-bed filter; Sample 4 – Borehole water treated by activated carbon filter
Sample 5 – Borehole water treated by micron filter
Sample 6 – Borehole water treated by reverse osmosis membrane filter
Sample 7 – Borehole water treated by Ozonator; Sample 8 – borehole water treated by UV-sterilizer
THC – Total Heterotrophic Counts; TCC – Total Coliforms Counts
TDS – Total Dissolved Solid.

samples purified with activated carbon filter was 0.13mg/l; water samples from sand-bed filter and micron filter was 0.23mg/l each, and 0.22mg/l nitrate value for water samples from other treatment devices. The nitrate value in control water sample was 0.35mg/l.

The total heterotrophic bacteria and total coliforms in the control sample were 4.0 x 10^2CFU/ml and 2.2 x 10^2CFU/100ml respectively. Water samples from sand-bed filter, resin ion-exchanger and activated carbon filter, recorded 20CFU/ml, 2.0 x 10^2CFU/ml and 2.5 x 10^2CFU/ml (for total heterotrophic bacterial counts), and 1.9 x 10^2CFU/100ml, 10CFU/100ml and 10CFU/100ml (for total coliforms counts) respectively. Other samples however, did not record any of these bacteria.

Considering the average percentage reduction of some water properties by different water treatment devices which invariably account for their efficiency in water treatment, reverse osmosis membrane filter recorded greater efficiency (76.25%) while sand-bed filter recorded the lowest (43.55%) (Table 2). Summarily, the order of efficiency of the investigated water treatment devices was: reverse osmosis membrane filter > UV-sterilizer > micron filter > ozonator > activated carbon filter > resin ion-exchanger > sand-bed filter.

DISCUSSION

Water quality affects human health either at short or long run, and needs to be given serious attention. The use of water treatment devices has gone a long way

Table 2: Percentage Reduction of Some Water Samples Properties Treated by Different Water Treatment Devices

Water Property	Percentage Reduction (%)						
	RIE	SBF	ACF	MIF	RMF	OZR	UVS
TDS	4.55	9.09	3.03	24.24	27.27	11.52	11.21
Turbidity	33.33	100.00	83.33	91.67	100.00	83.33	100.00
Total hardness	50.00	0.00	40.00	13.33	54.00	20.00	50.00
THC	50.00	95.00	37.50	100.00	100.00	100.00	100.00
TCC	95.45	13.64	95.45	100.00	100.00	100.00	100.00
Average % Reduction (Efficiency)	46.67	43.53	51.86	65.85	76.25	62.92	72.24

Key:
THC: Total Heterotrophic Count; TCC: Total Coliforms Counts
TDS: Total Dissolved Solid; RIE: Resin ion-exchanger
SBF: Sand-bed Filter; ACF: Activated Carbon Filter
MIF: Micron Filter; RMF: Reverse Osmosis Membrane Filter
OZR: Ozonator; UVS: UV-sterilizer.

in improving quality of water used in homes and industries. The study shows that some of the treatment devices do not yield qualitative water considering the fact that some biological, chemical and physical properties of resulting water samples were below drinking water standards. However, some devices such as reverse osmosis membrane filter and UV-sterilizer, appear to have higher efficiency in improving water quality as both physical, chemical and biological properties were reduced to standard values. Reverse osmosis is most commonly known for its use in sea water purification. It is known that portable reverse osmosis (RO) water processors are purchased by individuals for personal water purification in various locations in rural and urban areas for filtration of river or ocean waters, hence RO systems are used by mariners (Malki, 2008). It should be noted however, that water produced by reverse osmosis is similar to distilled water which lacks necessary minerals needed for good health.

UV-sterilizer is quite efficient in low turbid water (Campbell and Wallis, 2002). This is synonymous with its effectiveness in reducing the total heterotrophic bacteria and total coliforms to zero levels as observed in this study. However, its effectiveness decreases as turbidity increases due to absorption and scattering caused by presence of suspended solids. Sand filter is known to have little effect on odour, taste and dissolved impurities in drinking water; it however reduces turbidity to greater levels (Frank, 2008) which conforms with what was obtained here. This implies that based on Obionu's (2001) definition of potable water, sand filter does not give qualitative water for drinking, conforming to its least comparative efficiency in this study.

Hall and Dietrich (2000) stated that no form of carbon filter removes bacteria but can become breeding grounds for them, it was contrarily observed in this study that about 95.45% of the total coliforms and 37.50% of total heterotrophic bacteria in raw water samples were respectively removed. Fresh activated carbon filter is likely to achieve this, hence the replacement of it after usage is advocated. The ozonator was quite effective. This method is known for inactivation of harmful protozoa that form cysts and is widely used in Europe as a strong and broad spectrum disinfectant (Brian, 2010).

Worthy of note about this method of water treatment is its effectiveness over a wide range of pH and its stronger germicidal properties than chlorine as well as its strong oxidizing power with short reaction time. Water treated by this method do not retain its potability, because no germicidal or disinfection residual is provided by ozonation to inhibit re-growth of microorganisms.

The micron filter was relatively able to reduce turbidity, total coliforms and total heterotrophic bacteria levels. This of course is attributable to its small pore sizes, hence they are good choice for both industrial and domestic uses, particularly because of their effeciency and relative cost of cleaning (WHO, 2007). As resin ion-exchanger has univalent hydrogen, sodium and potassium ions which exchange divalent calcium and magnesium ions in water, this is no doubt what gives it the capability of water softening and purification which reflected in the results obtained in this study.

In water treatment, certain factors determine the best method to be adopted. One of the factors is the source of raw water to be treated. The distribution and usage of available water sources differ from place to place (Okereke amd Nnoli, 2010). However, most of the available water sources in many parts of the globe including Nigeria, have been reported to be polluted (Efe *et al*., 2005; Ejechi *et al*., 2007). Groundwater such as spring water and borehole water, which are major sources of supply for domestic and industrial users of water purifiers, appear to be unsafe due to pollution from industrial and domestic activities (Okechi *et al*., 2013; Obiekezie *et al*., 2006). Consequently, the efficiency and life span of frequently used water purifiers are threatened. This implies that products of some water purifiers might not be safe for consumption as Ifeanyi *et al*., (2006) reported of poor quality of packaged satchet water, assumed to have been subjected to purification process using any of the water treatment devices.

RECOMMENDATION/CONCLUSION

No single water purifier may yield/gaurantee expected potable water. Source of water to be purified by any of these devices should be critically considered. To maintain greater efficiency of these devices, proper maintenance culture should be adopted. Manufacturers of water treament devices should spell out the efficiencies of their products as well as the maintenance procedures as to properly guide prospective users.

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