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Comparative Analysis between Water Purification Systems †

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Abstract: The global crisis regarding inadequate safe drinking water affects millions due to factors like poor infrastructure, environmental degradation, and natural disasters. To address this, water purification technologies, including filters that eliminate bacteria, viruses, and heavy metals, are crucial. The thesis focuses on analyzing five water purification methods, considering their effectiveness and competence. It examines various water sources in Bangladesh, highlighting issues like excessive microorganisms and contaminants in tap water. The study aims to promote affordable, sustainable purification systems, acknowledging the drawbacks of certain technologies. Findings reveal issues with tap and boiled water while other methods effectively remove contaminants.

Keywords: hazardous pollutant; purification system; drinking-water; safe water

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1. Introduction

The 2021 Report from UNICEF/WHO expressed that 61.7 M people in Bangladesh lack essential hygiene facilities. Billions of people worldwide will not have access to safely managed drinking water, sanitation, and hygiene services by 2030, as reported by WHO. The findings of international investigations show that, while the availability of safe water substantially decreases the possibility of diarrheal disorders and, consequently, death, the lack of sanitation significantly decrease this beneficial effect [1]. Existing research studies deal with the capacity of water purifiers to kill germs, but this research deals with the capacity of filters to retain electrolytes. Through its multi-stage series of filters, the alkaline water system provides the maximum level of filtration in the gravity filter, also known as the candle filter, producing clean, mineralized alkaline water. The pureit water filter uses a multi-stage purification process involving a pre-sediment filter, an activated carbon filter, a post-carbon sediment filter and a germkill chamber.

Though DWASA has plans to set up 300 units of water ATMs which are also known as water vending machines, its initial goal was to install 100 water ATMs for low-income people [2]. When using the ATM, one has to deposit a refundable amount of BDT 200 to the water booth's operator and collect a card from them. When the card is inserted, water starts flowing and when the card is polled out, the water flow stops. Reverse osmosis is a type of membrane-enabled system that can segregate clean water from dissolved solids of feed stream and generate, permeate as well as reject a stream [3]. Straining, interception, inertial forces, particle setting, diffusion and fluid dynamics forces are the transportation mechanism of the candle filter, commonly known as the gravity filter [4]. Pureit was originally produced by Hindustani Unilever. Based on Ultraviolet and a reverse osmosis mechanism, it did not require electricity to operate [5]. For biotoxicity assessment, more sophisticated processes have to be applied to ensure the quality of treated water. A frequently used technique for treating recalcitrant pollutants is an advanced oxidation process [6]. Though binary results show the highest adsorption capacity for toluene, the differential adsorption capacity of benzene and toluene can be used to design purification processes to target specific contaminants in groundwater [7].

Fenton's reagent, a solution of hydrogen peroxide and an iron catalyst, can produce hydroxyl radicals, which are very reactive and can break down humic acid into smaller molecules [8]. Humic acid can affect color, taste and odor of water and can react with chlorine and other disinfectants. The use of iron oxide magnetic nanocatalyst can be introduced as an improved treatment process, including reduced mass transfer limitations, lower energy consumption, and enhanced catalyst selectivity [9].

The existing research deals with the cost and competence required to purify water from pollutants and the availability of water treatment technology like boiling, candle filter, reverse osmosis, vending machine and pureit filter (germkill technology). In this paper, we will try to demonstrate the efficiency of the treatment systems with regard to removing heavy metals and retaining electrolytes.

2. Methodology

The overall approach of this research was decided based on the analysis of collected data. The research was basically experimental. The parameters were tested at the Environmental Engineering Laboratory of Civil engineering Department, BUET. The conclusion was derived from a single sample test. The phases of this research are shown in Figure 1.

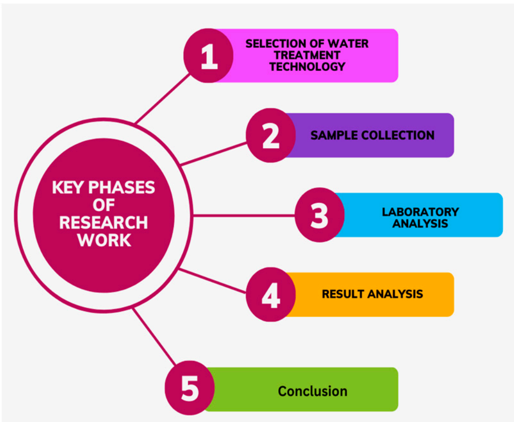

Figure 1. Steps of research.

2.1. Location of Sampling Point

Study area selection is the primary and most significant phase of conducting research. WASA ground water, water for boiling purpose, water sample from WASA water vending machine and water samples after filtering through RO, candle and pureit filter, all were collected from Dhaka WASA mod zone 3.

2.2. Sample Collection

Six samples were collected for the study. The date and location of the sample collection were carefully recorded.

Samples which were selected for experiment:

1. Boiled Water.
2. WASA Tap Water.
3. Candle Filter.
4. Reverse Osmosis.
5. Water Vending Machine.
6. Pureit Filter (Germkill Technology).

2.3. Boiled Water

Water was boiled in the vessel by heating on a stove with the temperature increased to around 100 degrees Celsius. It was kept in the vessel so that the heavier suspended solids may be sedimented overnight.

2.4. WASA Supply Water

WASA ground water was collected from household taps for testing purposes on 21 August 2022.

2.5. WASA Water Booth

The water sample was collected from the WASA vending machine on 1 December 2022. The source of the sample was Prominent Housing WASA water booth as shown in Figure 2.

Figure 2. Water ATM booth prominent housing.

2.6. Candle Filter

The water sample from the Candle filter (gravity filter) as shown in Figure 3 was collected from the home of an inhabitant of Mohammadpur, Dhaka, which falls into DWASA mod zone 3, on 3 December 2022. The name of the company from which the Candle filter was purchased was Eva Water filter.

Figure 3. Homebased Candle Filter.

2.7. Reverse Osmosis

Water sample from reverse osmosis filter was collected from the home of an inhabitant of DWASA mods zone 3 on 21 August 2022. The filter was produced by the company Aqua Shine.

2.8. Pureit Filter

A water sample was collected for testing purpose from the pureit filter produced by Unilever Bangladesh. It was collected on 3 December 2022. The pureit water filter uses ultraviolet technology as one of its purification methods. Ozone-based advanced oxidation technologies provide an efficient process through which to degrade micropollutants from the aquatic environment, emphasizing the potential application of these techniques in water treatment and purification processes [10].

2.9. Physicochemical Testing

Testing of heavy metals such as lead, chromium, cadmium and some essential elements, namely calcium, magnesium, sodium, and potassium, were carried out at the Environmental Engineering Laboratory of Civil Engineering Department at BUET. Their expert knowledge of DWASA drinking water characteristics was used to choose these criteria. The parameters, testing method, equipment and operating condition of heavy metal test and electrolyte test are listed in the Table 1.

Table 1. Tested parameters, testing methods and equipment.

Heavy Metal Test				Electrolyte Test			
Parameters	Testing Method	Equipment	Operating condition	Parameters	Testing Method	Equipment	Operating Condition
Lead	USEPA 206.2 Rev 2.2 SM 3113 B	Shimadzu AA-6800 FLAAS	Lead hollow cathode lamp	Sodium	USEPA 206.2; SM 3113B	Shimadzu AA-6800 FLAAS	Sodium Hollow Cathode Lamp
Cr	USEPA 206.2;SM 3113B	Shimadzu AA-6800 FLAAS	Chromium hollow cathode lamp	Potassim	USEPA 206.2; SM 3113 B	Shimadzu AA-6800 FLAAS	Potassium Hollow Cathode Lamp
Cd	USEPA 206.2; SM 3113 B	Shimadzu AA-6800 FLAAS	Cadmium hollow cathode lamp	Calcium	USEPA 206.2; SM 3113 B	Shimadzu AA-6800 FLAAS	Calcium Hollow Cathode Lamp
				Magnesium	USEPA 206.9; SM 3113 B	Shimadzu AA-6800 FLAAS	Magnesium Hollow Cathode Lamp

3. Results and Discussion

The Bangladesh Standard Testing Institution (BSTI) created and published the Bangladesh Standard Specification for Drinking Water (BDS 1240:1989) to regulate the quality of drinking water. Figures 4–8 show the lead, sodium, calcium, potassium and magnesium respectively concentration in milligrams per liter unit of each sample in compliance with Environmental Conservation Rules (ECR,23) and WHO drinking water criteria.

3.1. Presence of Heavy Metals after Filtering

3.1.1. Lead

According to ECR'23 and WHO standards, the lead concentration limit for safe drinking water is 0.05mg/L. The lead concentration was tested in the environment laboratory using the equipment Shimadzu AA-6800 FLAAS, which had a minimum detection level of 0.001 mg/L. As we can see from Figure 4, only WASA tap water exceeded the lead concentration limit set by ECR'97 and the WHO standard. Figure 9 shows the lead removing efficiency of each water purification technology.

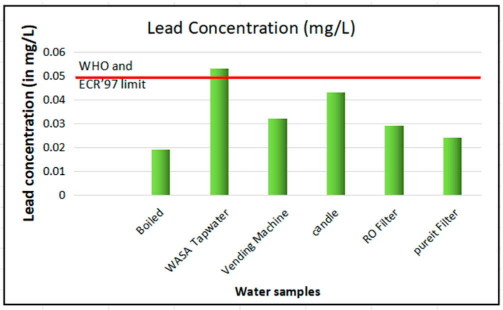

Figure 4. Lead concentration of the samples.

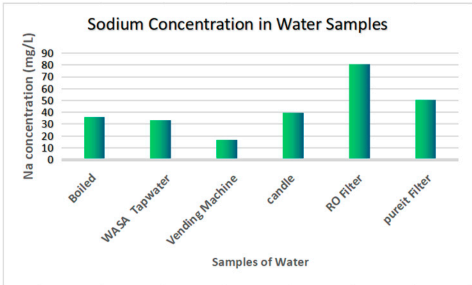

Figure 5. Sodium Concentration In the Samples.

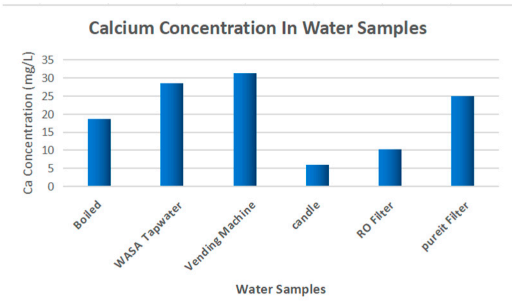

Figure 6. Calcium concentration in water samples.

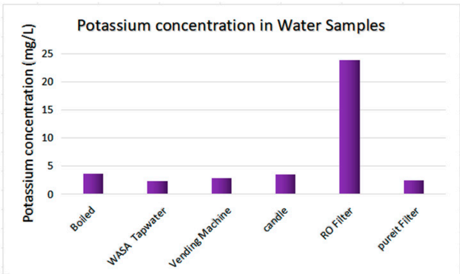

Figure 7. Potassium concentration in water samples.

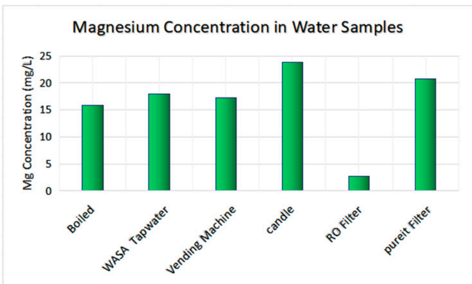

Figure 8. Magnesium concentration in samples.

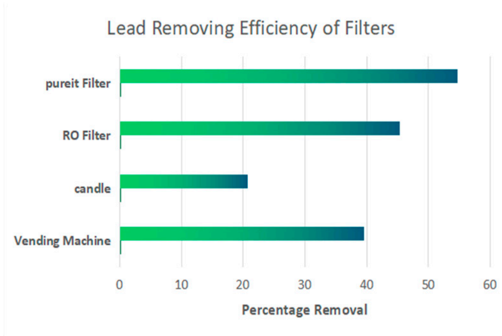

Figure 9. Lead-removing efficiency of filters.

3.1.2. Chromium

The ECR'23 and WHO guideline value for chromium in drinking water is a maximum of 0.05 mg/L. Chromium was tested using the equipment Shimadzu AA-6800 FLAAS, which had a minimum detection level 0.001 mg/L. From Table 2, we can see that none of the samples have exceeded the limit of chromium concentration set by ECR'23 or WHO.

Table 2. Chromium concentration of the samples.

Parameters	Concentration (mg/L)
Boiled	0.008
Wasa Tap Water	Below MDL(0.001)
Vending Machine	0.001
Candle	Below MDL(0.001)
RO Filter	Below MDL(0.001)
Pureit Filter	Below MDL(0.001)

3.1.3. Cadmium

According to ECR'23, the maximum allowable limit of cadmium is 0.005 mg/L and according to WHO, it is 0.003 mg/L. The equipment used for the cadmium test was Shimadzu AA-6800 FLAAS, which had a minimum detection level for cadmium of 0.1 mg/L. As we can see from Table 3, all the samples which were tested had a cadmium concentration below the minimum detection level.

Table 3. Cadmium concentration in the samples.

Parameters	Concentration (mg/L)
Boiled	Below MDL(0.1)
Wasa Tap Water	Below MDL(0.1)
Vending Machine	Below MDL(0.1)
Candle	Below MDL(0.1)
RO Filter	Below MDL(0.1)
Pureit Filter	Below MDL(0.1)

3.2. *Efficiency of Retaining Electrolytes*

3.2.1. Calcium

According to WHO guidelines, the minimum desired level for Ca concentration is 75 mg/L to a maximum permissible level of 200 mg/L. From Figure 10, we observe that none of the water samples had Ca concentration close to the desired concentration. So the water which is purified using the candle, RO or pureit filter might not fulfill the calcium requirement expected from water.

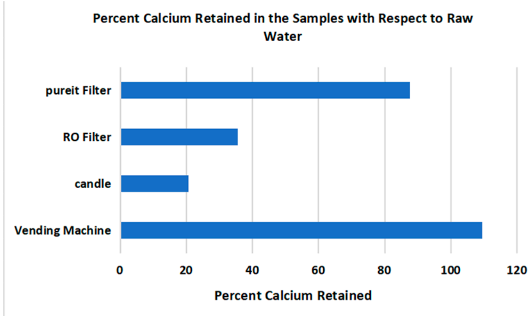

Figure 10. Percentage of calcium concentration compared to raw water.

3.2.2. Magnesium

After analyzing the data, we can observe from Figure 11, that none of the samples are even close to the limit specified for magnesium concentration by WHO, which is 50–200 mg/L.

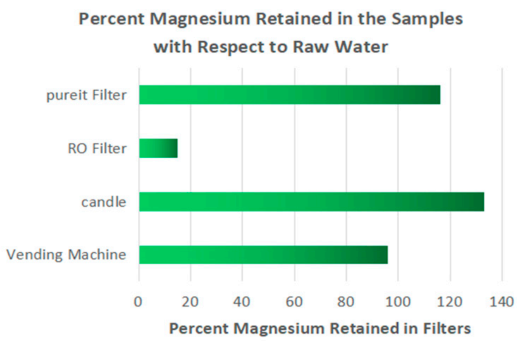

Figure 11. Percentage of magnesium contained in the sample.

3.2.3. Potassium

From Figure 12, we see that only the RO filter has a potassium concentration that exceeds the limit set by the Bangladesh standard, which is 12 mg/L. As for the rest of the samples, the potassium concentration is far below the desired level.

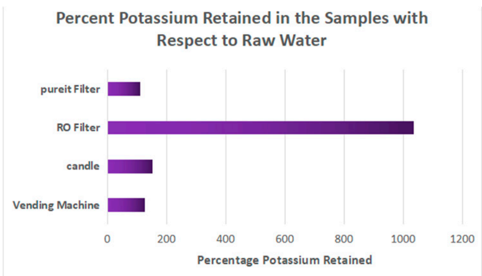

Figure 12. Percentage of potassium contained in the sample.

3.2.4. Sodium

From Figure 13, we see that none of the samples contain a sodium concentration that exceeds the limit set by ECR'23 or WHO guidelines, which is 200 mg/L.

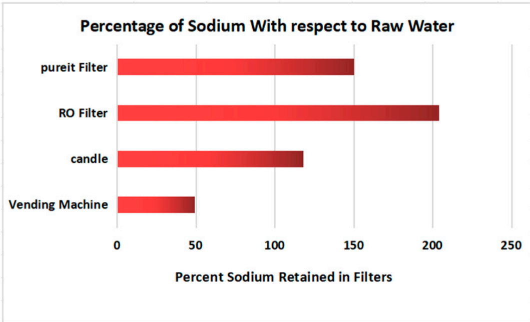

Figure 13. Percentage of sodium retained in the purified water.

4. Conclusions

From our overall analysis, we can deduce that, for retaining essential elements, specifically potassium and sodium, the water vending machine shows the least effectiveness. In addition, the vending machine has low chromium-removing efficiency compared to other filters tested. Considering the efficiency of removing cadmium, chromium and lead, the reverse osmosis filter shows the best performance. However, it also removes a significant amount of electrolytes: calcium and magnesium, to be specific. To retain the essential elements and remove the harmful metals from the water samples, the pureit filter has proved to be the most balanced. Along with high lead-removing efficiency and a moderate cadmium-removing efficiency, the pureit filter also retains high percentages of sodium and potassium. Hence, water from the pureit filter is most recommended for safe consumption. The candle filter is the least efficient at removing lead; it also removes calcium and potassium from water to a great extent. A high concentration of sodium and magnesium was found in the filtrate of the candle filter, which is important for maintaining electrolyte concentration in water. If this filtrate water is used for industrial purposes rather than for drinking, then it might prevent pipes from corroding, as these minerals might contribute to form a protective scale on the inner surface of the pipes. Again, for drinking purposes, water has to be boiled prior to filtering through the candle filter to kill micro-organisms.

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Institutional Review Board Statement: The study was conducted in accordance with the Bangladesh University of Engineering and Technology and approved by Bangladesh University of Engineering and Technology for ethical approval.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and confidentiality.

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Conflicts of Interest: The author declares no conflict of interest.

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