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Using Ultraviolet Technique for Well Water Disinfection

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Abstract. Ultraviolet rays are widely used to disinfect microbial water. Disinfection is a treatment process for drinking water. UV disinfection is one of the physical methods used to kill bacteria and destroy cells. In most cases, the physical process immediately purifies drinking water without the formation of toxic substances. Therefore, there are no bacteria in the water, so that it can be cleaned constantly. This research aims to obtain environmentally sustainable drinking water in conditions where clean water is scarce, such as water shortage. The pilot plant was established to evaluate a ceramic filter's effectiveness in reducing turbidity, plankton, and anything else that could alter drinking water properties. As a result, some water purification stages, such as those used in water treatment plants, are reduced. To see how effective UV sterilization is in killing bacteria, especially fecal coliform and Escherichia coli bacteria. Work was done by taking samples from the well water from Al-Zaidan area in Abu Ghraib district. Before the sterilizer is inserted, this procedure works on water that meets specific requirements. Although it is a commercial filter, the ceramic filter is excellent at removing turbidity with removal efficiency (73~89) %, the removal efficiency of dissolved solids (100) %, the removal efficiency of iron (75~83) %, and the removal efficiency of bacteria (45~53) %, which is an excellent removal efficiency. The UV sterilizer's ability to remove bacteria has reached a removal efficiency of (100) %. This process is superior because it does not produce any secondary substances and has no effect on color, taste, or smell. Because water samples are taken from Groundwater, it contains high TDS content.

Keywords: UV rays; sterilizers; total suspended solids; turbidity; iron; bacteria E-coli; and ceramic filter.

1. Introduction

UV disinfection of drinking water has recently gained prominence in North America, following the discovery that UV light could effectively inactivate Cryptosporidium oocytes based on infectivity, even at very low doses [1-4]. UV sterilizers are already identified as potentially the most cost-effective way for homeowners to eliminate a broad range of biological contaminants from their water supply by studies over the years. According to the study results, the benefits include the fact that it does not introduce toxins into the water, produces no by-products, and has no effect on the taste, pH, or other properties of the water [5]. In the water treatment industry, ultraviolet (UV) light as a disinfectant is nothing new. UV disinfection was first used in Marseille, France, in 1910 [6]. The length of the UV light energy ranges between 100 and 400 nanometers, between the X-ray part of the spectrum and the visible part. At 254 nm, cell inactivation reaches its limit. UV-C is favored because of its low cost, high efficacy, and ability to clean water easily without heat or chemical additives, leaving no residue or contaminants in the water [7].

UV treatment only involves a brief contact period, resulting in reduced space requirements, and the water delivery system is corrosion-free [8,9]. UV light interacts with the substances and particles present



in the water being handled as soon as it leaves the quartz sleeves. UV light transmission through water can be hampered by a variety of dissolved substances and wastewater particles. As a result, the amount of UV light that is successfully transmitted through the reactor is dependent on the concentrations of various dissolved compounds. The particle concentration and the distance that light would travel [10-12]. This study's main objective is to disinfect the well water by UV rays to use for drinking and other house requirements in the event of water shortage and the inability to access clean water.

2. Material and methods

2.1 Study Area Description

In this study, the well water samples were obtained from Al-Zaidan area, which is located at 33°14'32"N, 44°01'27" E in Abu Ghraib district, as shown in Figure 1.

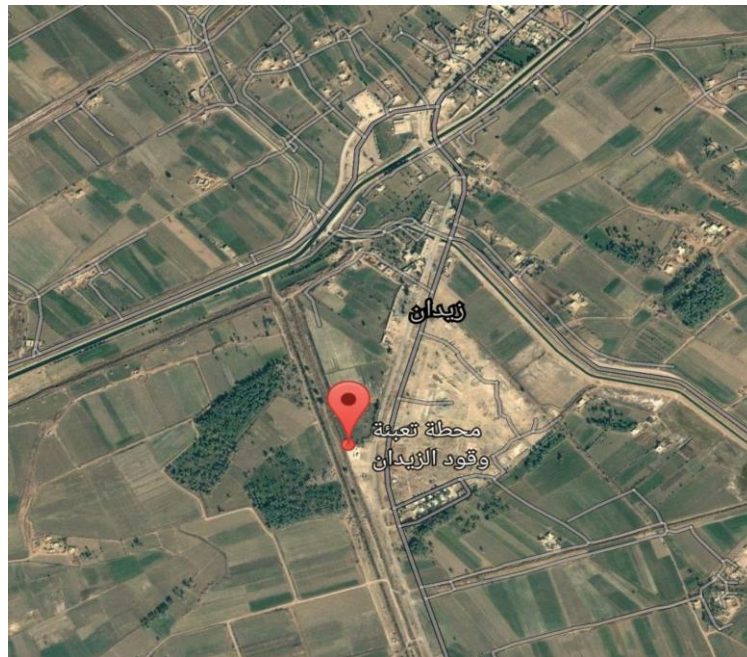


Figure 1. Al-Zaidan area- Abu Ghraib district (Google Earth).

2.2 Water Sampling and Analysis

Samples were taken from a well from Al-Zaidan area in Abu Ghraib district. The tests and study of the physical, chemical and biological properties of the samples collected were carried out in the Sanitary Laboratory - Civil Engineering, University of Baghdad and (Directorate of Environment and Water) "Ministry of Science and Technology". Table 1 shows the results. During the study period, the properties of all water samples.

Table 1. The range of data for each parameter over the study period.

No.	Parameter	Unit	Range
1	pH	-	7.28 - 7.65
2	Temperature of Air	C°	46 - 20
3	Temperature of Water	C°	25 - 30
4	Turbidity	NTU	3 - 5
5	TSS	mg/l	0 - 4
6	TDS	mg/l	1360 - 1665
7	Fe	mg/l	0.03 - 0.05
8	MPN fecal coliform	Cell/100ml	30 - 50
9	MPN E-coli	Cell/100ml	30 - 50

3. Pilot plant description

The equipment that was used to complete the pilot Plant system are described below:

- 1) **The Ceramic Filter:** A commercial device made of simple materials, burnt clay, filter and purify the water from impurities, and eliminates the bacteria present. The device consists of a ceramic candle that retains clean water inside. It provides a nanotechnology mechanism that separates and isolates water microbes, impurities, odors, and natural tourmaline stone. This silicate crystal mineral is widely used in new water filters due to its ability to destroy bacteria, toxins, rust, and parasites. It interacts with minerals in the water, such as magnesium, potassium, sodium, and lithium, to make it safe to drink. On ceramic candles with tiny pores, physical removal methods such as mechanical trapping and absorption are used. Provides secure storage after using it. Filter effectiveness is often measured by production quality or primary water quality, as shown in Figure 2.
- 2) **UV ray's sterilization device:** The UV disinfection unit is a chemical-free, highly effective method of extracting microbiological contaminants from water (up to 99.9%), as shown in Figure 3. A UV system's four fundamental components:
 - The UV lamp is housed in the reactor room, made of stainless steel, and is known as either a chamber or a reactor.
 - UV lamp: UV-C rays, which are the germicidal wavelength of ultraviolet rays, are generated by the UV lamp. All UV lamps contain a small amount of mercury, around the size of a pinhead, and they can all be recycled when in service. Mercury is an essential component of a lamp's ability to generate germicidal UV-C light. UV light is produced as fine droplets of liquid mercury accumulate in the lamp's "cold spot" and reach their optimum temperature. Like regular light bulbs, UV lamps have a filament that generates an electric current that heats and evaporates the lamp's mercury. This vaporized mercury aids in forming electric arcs, which produce UV-C rays of varying intensities to disinfect the water.
 - The sleeve of quartz is a long, cylindrical tube made of quartz glass that works to transmit light from the tube to the water while protecting the UV lamp from water flow. Minerals or contaminants can corrode this tube over time, necessitating cleaning and lamp replacement. It
 - is essential for the effective operation of the UV rays.
 - The control system is a plug that can be plugged into an outlet to provide power to the reactor before it begins to operate.
- 3) **Pump:** A submersible pump with a discharge capacity of 1000 L/hr and ahead of 1.8 m to raise water from the sedimentation basin to the ceramic filter, as shown in Figure.4.
- 4) **Plastic tank:** A circular plastic tank with a different diameter from the base to the top and a water capacity of 20 liters works by removing unwanted small suspended particles (such as sand, silt, and clay) and other essential contaminants from the water using gravity. The longer the water is there, the better. Solids and spores were collected at the tank's base, as shown in Figure 5.



Figure 2. The Ceramic filter.



Figure 3. UV ray's sterilization device.



Figure 4. Submersible pump with capacity to discharge of 1000 L/hr.



Figure 5. Plastic tank.

4. The procedure for collect sampling

During the study phase, the following practical measures will be clarified:

- Taking a sample for the well water from Al-Zaidan area- Abu Ghraib district through a plastic tank.
- For all laboratory analyses, took (0.5) liter in a glass jar and proceeded as follows: (turbidity, pH, TSS, TDS, Fe, bacteria, air, and water temperature).
- The sample of well water is put in a plastic tank and allowed to settle for an entire day.
- The water is transferred to the ceramic filter through the submersible pump, which is connected to a constant current point.
- Before entering the UV sterilization method, a portion of the water coming out of the ceramic filter, around (0.5) liter, is taken for laboratory examination (turbidity (2100 p/HACH), pH (WTW), TDS(WTW), TSS (Lovibond/ Photometer MultiDirection), iron (Lovibond/ Photometer MultiDirection), bacteria, and temp Air and water) to understand the filter output and water characteristics better.
- In the final step, the sterilizer is connected to a constant current source and switched on. The water is pumped into a UV sterilizer.
- After the sterilizer has ejected water, to evaluate the device's efficiency in particular and the experimental method in general, a sample is taken, and the necessary analysis (bacteriological analysis) is carried out. Throughout the study period, this phase is replicated at various work months. The pilot plant system is shown in Figure 6.



Figure 6. The pilot plant.

5. Results and discussion

The following are running water samples through the pilot plant, including the sedimentation tank's effects, the ceramic filter, and the UV sterilizer.

5.1 Effect of the Sedimentation Tank

After the water sample has been in the basin for a day, there is a clear impact in reducing the percentage of turbidity and suspended solids. The temperature of the aquarium water has gained to that of the surrounding air. The majority of the parameters were unchanged. Owing to the influence of gravity, the aquarium process was physical, and no chemicals were used. For the well water samples, the removed efficiency of turbidity and TSS were (25~33) % and (25~33) %, respectively.

5.2 Effect of the Ceramic Filter

The following measurements can evaluate the effect of ceramic filter:

1. **Air and water temperature.** The highest value for air temperature during the study period and statistical analysis of the parameters was (46°C). Where the highest value for the water samples (30°C). The air temperature was at its lowest value (20°C). At the same time, the well water samples' lowest temperature was (25°C). The ceramic filter did not affect the water samples temperature as the samples acquired the air temperature.
2. **pH.** The statistical analysis results revealed that the highest pH of the well water taken from Al-Zaidan area during the study period was (7.65), and the lowest pH was (7.28). Whereas the highest pH value was (7.61) for water from the ceramic filter taken from the well water, and the lowest pH value was (7.10). We conclude that all outcomes decreased by a small percentage, as was observed in [13]. The results indicate that it was within the World Health Organization drinking water criteria (6.5-8.5) [14]. The ceramic filter performed admirably in terms of keeping the pH level within reasonable limits. Generally, In the summer, as CO₂ levels drop due to absorption into the atmosphere or photosynthesis by algae or water plants, the pH increases [16]. We conclude that it was within the World Health Organization drinking water specifications within the permissible limits and did not exceed the limits [14]. It was not classified within the standards that cause water quality deterioration.
3. **Turbidity.** By describing the statistical analysis, the results of the present study showed that the highest value of turbidity was observed in well water (3.5 NTU), and the lowest value was (1.4 NTU) after staying in the sedimentation basin. On the other hand, the highest value of turbidity was (0.62 NTU) from well water samples outside the filter, and the lowest value was (0.32 NTU) as shown in Figure 7. Well water samples outside the filter within the WHO drinking water standards [14], and the water samples complied with the standards specified for the ultraviolet sterilizer (5 NTU), the filter removal efficiency was good and ranges between (73~89) %, as shown in Figure 13. It affects the amount of browning produced by organic matter, silt and clay by affecting both the size of the substance and the particles' concentration. Turbidity is less attractive than clear lake water. It is also unfitting for human consumption. Turbidity is a good measure of water quality [15].
4. **TSS Concentration.** The current study's findings indicated through the descriptive statistical analysis that the highest value of TSS was contained in the well water after it had spent time in the sedimentation basin (3 mg/l). On the other hand, the lowest value for TSS was (zero). As for the water outside the filter, the TSS value was (1 mg/l), as shown in Figure 8. The removal efficiency was (100) % through the filter as shown in Figure 14. The samples after the filter were within the standards of drinking water of the World Health Organization [14]. Value (TSS <10 mg/L) [17].
5. **Iron Concentration.** The results obtained for the well water showed that the highest value of iron (0.05 mg/l) during the study period by describing the statistical analysis, and the lowest value was (0.03 mg/l). While the water is coming out from the filter, the Fe concentration value was (under range) where the device's reading for the Fe concentration ranged between (0.02-1 mg/l), as shown in Figure 9. The ceramic filter is characterized by the good removal ability of iron concentration in a well water sample. Because the iron concentration in samples during the study period is relatively low, the removal efficiency ranges from (75~83) %, as shown in Figure 15. The resulting water complied with the water standard for UV sterilization, which specifies a value for (Fe <0.3 mg/l) [17]. Also, within the WHO drinking water standards [14]

6. **TDS Concentration.** The current study results showed that the highest value of dissolved solids in well water was (1665 mg/l), while the lowest value for dissolved solids was (1360 mg/l). The ceramic filter did not affect the TDS. The values were outside the World Health Organization permissible limits for drinking water [14].
7. **Bacteria E-coli and fecal coliform.** The results of the current study indicated through statistical analysis, the highest concentration of bacteria E-coli and fecal coliform in well water was (50 MPN /100ml), and the lowest concentration of bacteria E-coli and fecal coliform was (30 MPN /100 ml). While the highest concentration of bacteria E-coli and fecal coliform in the water outside the filter was (27 MPN /100 ml), and the lowest concentration of bacteria E-coli and fecal coliform was (14 MPN/100 ml), as shown in Figures 10 and 11. The performance of the ceramic filter in reducing the bacteria concentration was average. It ranged from (45~53) %, as shown in Figures 16 and 17.

5.3 Effect of the ultraviolet sterilizer (UV)

E-coli and fecal coliform bacteria' highest concentration was from the well water samples outside the filter (27 MPN/100 ml). In contrast, the lowest concentration for both the E-coli and fecal coliform bacteria were (14 MPN/100 ml). After the water passed through the UV sterilizer, the E-coli bacteria and fecal coliform concentration were (zero), as shown in Figure 12. The UV sterilizer efficiency was excellent in removing bacteria as it reached (100) %, as shown in Figure 18. This is one of the features of drinking water according to WHO standards [14]. It involves using the ultraviolet component of the electromagnetic spectrum to inactivate some microorganisms. Pathogens such as bacteria, viruses, and parasites can kill many diseases by UV rays. As the only disinfection process for drinking water, UV rays are widely used in Europe [18].

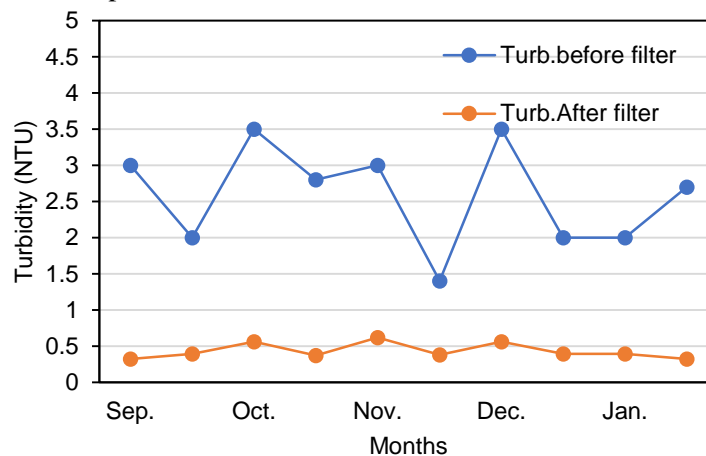


Figure 7. Turbidity before and after the ceramic filter.

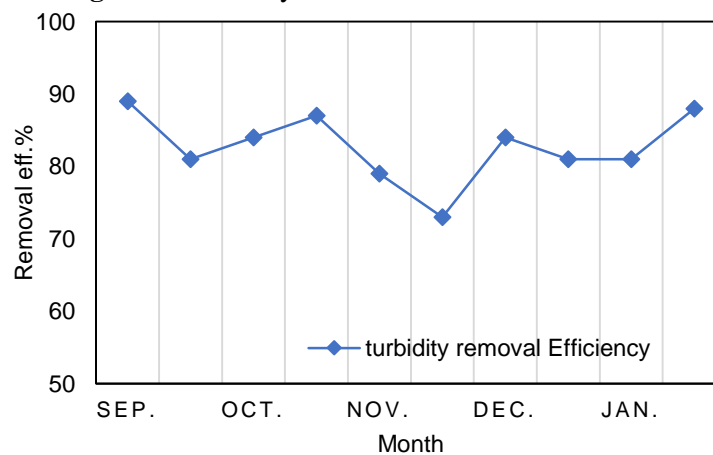


Figure 8. Turbidity removal efficiency of the ceramic filter.

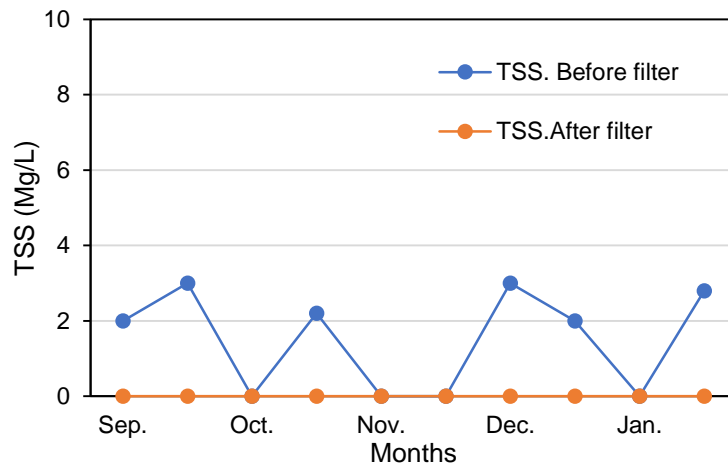


Figure 9. TSS Concentration before and after the ceramic filter.

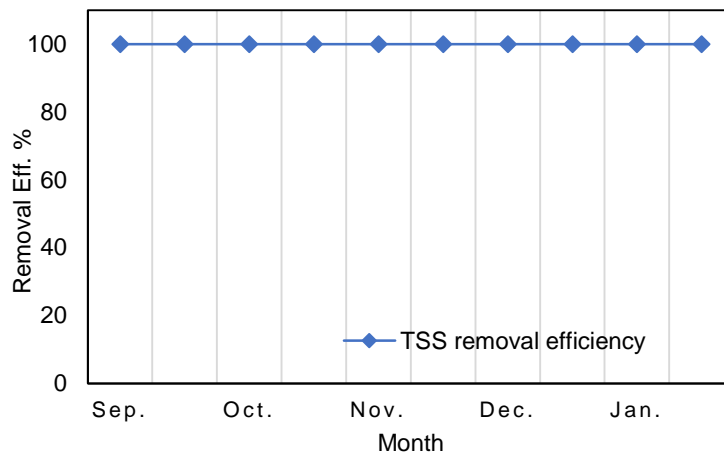


Figure 10. TSS concentration removal efficiency of the ceramic filter.

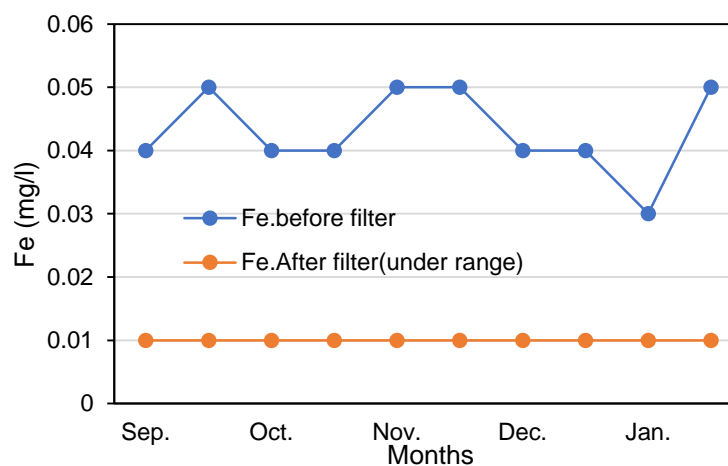


Figure 11. Fe Concentration before and after the ceramic filter.

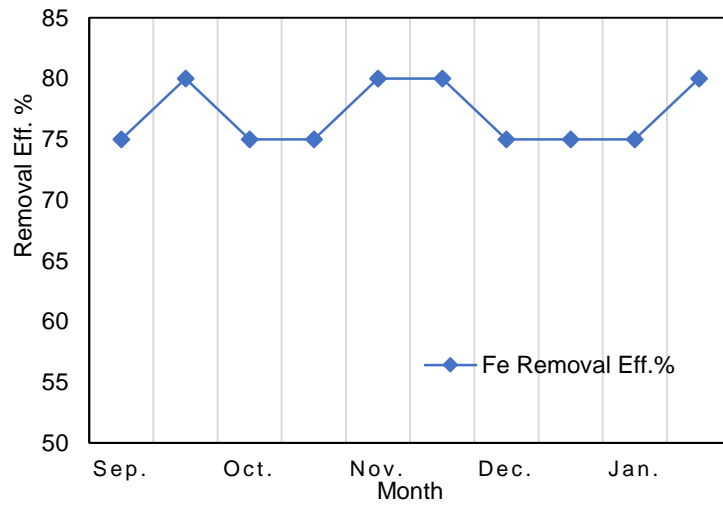


Figure 12. Fe concentration removal efficiency of the ceramic filter.

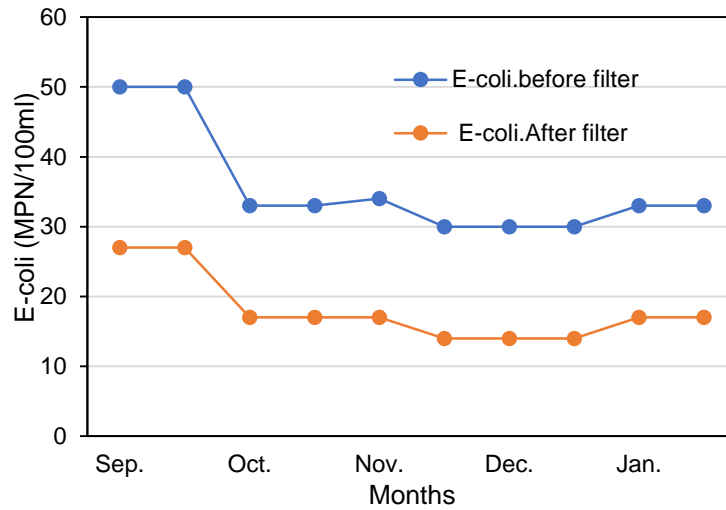


Figure 13. E-Coli Concentration before and after the ceramic filter.

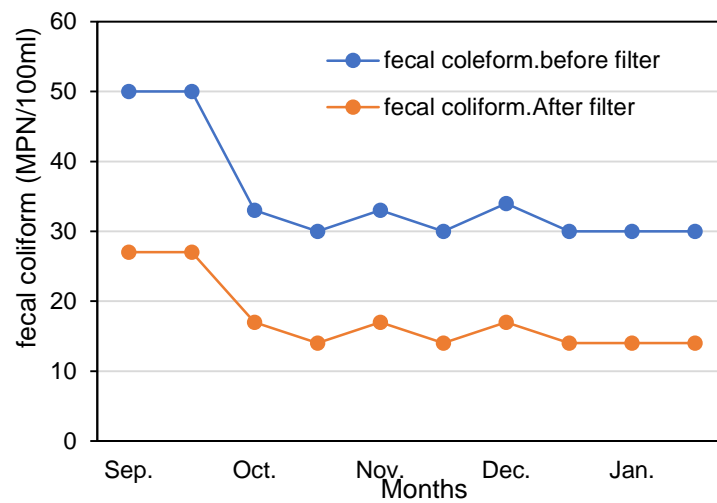


Figure 14. Fecal coliform Concentration before and after the ceramic filter.

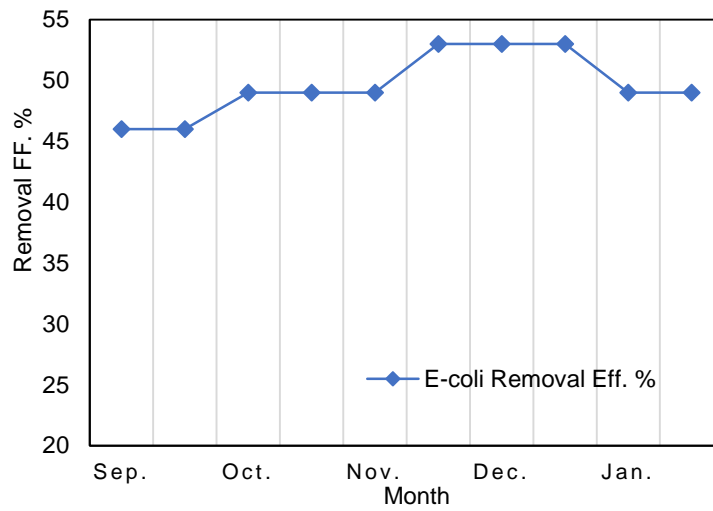


Figure 15. E-coli concentration removal efficiency of the ceramic filter.

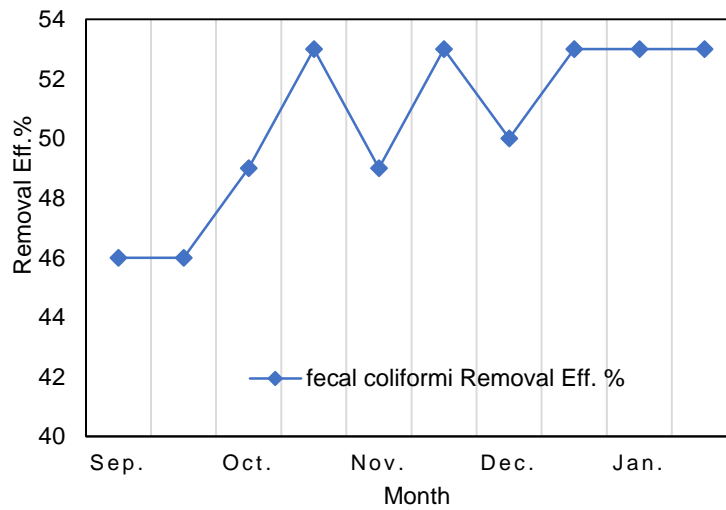


Figure 16. Fecal coliform Concentration removal efficiency of the ceramic filter.

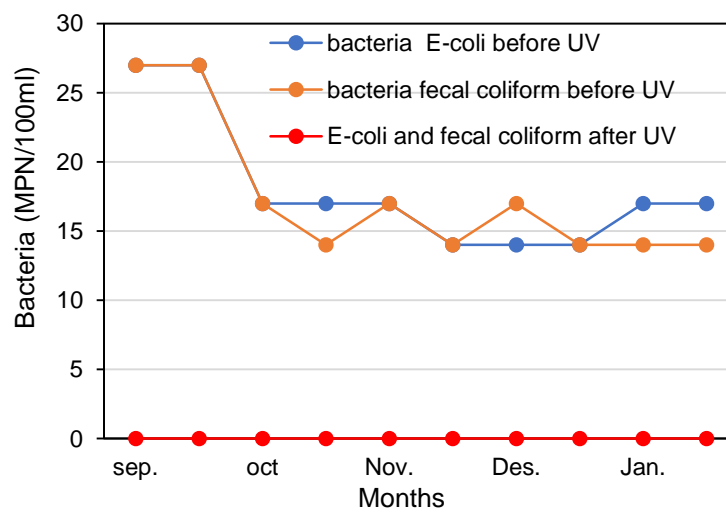


Figure 17. E-Coli and fecal coliform Concentration before and after the UV unit.

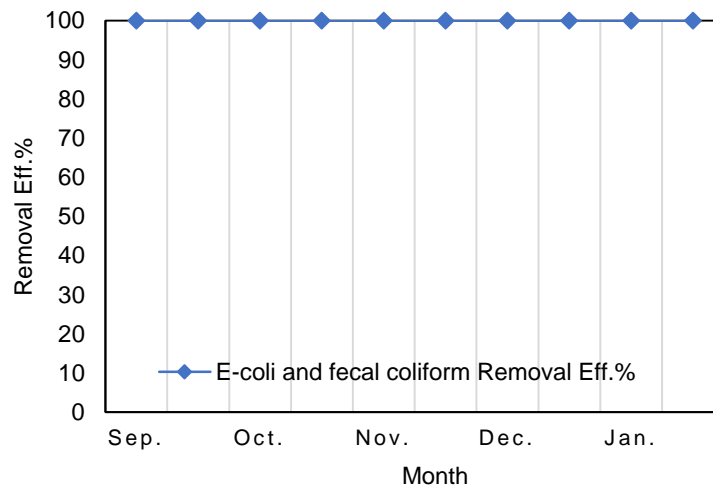


Figure 18. E-coli and fecal coliform concentration removal efficiency of UV unit.

6. Conclusions

The experimental system's performance was calculated in this study using commercially available instruments. It was discovered that the findings could be used as an alternative to large stations in cases of water shortage or inability to get potable water to homes.

- Some turbidity and TSS were eliminated while the water persisted in the sedimentation basin at the system's start. TSS and turbidity removal efficiency was both (25~33) %. The pH and iron did not change will the water temperature gain the air temperature due to the contact between them.
- The removal efficiency of TSS was (100) %, the turbidity removal efficiency of samples from well water was (73~89) %, iron removal efficiency by (75~83) %, and removal efficiency for bacteria (45~53) % during the filtration process of well water samples. At the same time, it had a minimal effect on the pH and did not affect the temperature at all.
- The UV device was effective (100%) in the pilot plant, as the bacteria were eliminated (100) %.
- We conclude that the pilot plant can be used to support a person or family when water is scarce and is not available in their houses.
- The high concentration of TDS in well water and the pilot plant did not reduce these concentrations. Therefore, this water can use for all hose purposes like dishes washing and house cleaning etc. except drinking because it needs desalinization before disinfection

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