Performance application of ultraviolet disinfection technique for raw water

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Abstract. Microbial water disinfection with UV rays is a universal technology. Disinfection is a method used to treat drinking water. This can be accomplished using physical and/or chemical processes. Physical Methods: Heating and UV rays are two main methods - UV rays to destroy cells and kill bacteria. The physical process generally gives drinking water an instant purification without producing harmful substances. However, there is no pollution in the water to ensure continuous cleaning. This study's primary goal is to obtain environmentally safe drinking water in situations of water shortages and homes that lack clean water. Therefore, resort to appropriate home treatment. Therefore, an experimental laboratory has been established to test the ceramic filter's efficiency in removing turbidity and plankton and everything that would change the properties of drinking water. Thus, several stages in water purification are shortened, as in the case of water treatment plants. To determine the efficiency of UV sterilization in killing bacteria, especially fecal coliform bacteria and E-coli bacteria. Work has taken place by taking samples of river water near Al Wahda water treatment plant. This technique works on water according to special criteria before entering the sterilizer. A commercially available ceramic filter was used for this. The ceramic filter is excellent at reducing turbidity with removal efficiency (96 ~ 97%), suspended solids removal efficiency (99 ~ 100%), iron removal efficiency (100%), bacteria removal efficiency (45 ~ 50 %) which is good removal rate because it is a commercial filter. The efficiency of the UV sterilizer in killing bacteria reached (100%). This technique is very excellent as it does not produce secondary substances and does not change color, taste, or smell.

Key Word: Ultraviolet Rays, Sterilizers, Total Suspended Solids, Turbidity, Iron, Bacteria E-coli, Fecal Coliform, Ceramic Filter.

1. Introduction

Water is the mainstay of life and availability, is the need for the existence of life [1]. Hence, contamination is one of the key risks that threaten all beings' lives and especially human live them, so should drinking water be free of physical and chemical contaminants and biological, and water is palatable, being colourless, tasteless and smell less [2]. Via traditional pre-treatments, drinking water treatment plants minimize high numbers of contaminants, including coagulation, sedimentation, and filtration processes. Still, to inactivate bacteria and guarantee the protection of drinking water, disinfection must be used [3].
The coliform group, which belongs to the Enterobacteriaceae family, is one of the most prominent types of bacteria that indicate water contamination with fecal matter [4]. E. coli and fecal coliform bacteria are the most commonly used indicators to indicate water contamination with pathogenic bacteria in humans. Because their presence indicates the presence of pathogenic bodies to humans, and their lifespan is longer than that of other pathogenic organisms [5]. Disinfection is a method used in drinking water treatment. This can be achieved using physical and/or chemical processes. Physical methods: Heating and UV-radiation are the main methods. Heating water to the boiling point will kill some pathogenic bacteria because there is a group that is not affected by boiling. Ultraviolet radiation to destroy cells and kill bacteria. Physical process in general Gives drinking water instant purification without creating harmful materials. However, no contamination remains in the water to ensure constant cleaning. Chemical methods: illustrated by the use of chemical oxidizers Examples include ozone (O₃), chlorine dioxide (ClO₂), chlorine (Cl₂) [6]. Physical, chemical, and biological criteria characterize drinking water as having the required quality to be used safely for drinking, cooking, and other domestic applications [7].

The use of ultraviolet (UV) light as a disinfectant is certainly not new to the water treatment industry. UV disinfection was first applied in 1910 in Marseille, France, and with the advent of low-pressure mercury lamps in the 1940's, UV light was routinely applied to disinfect process water in industries such as pharmaceutics, food, and beverages [8]. The drinking water industry's recent migration towards UV disinfection has been fueled by the finding that UV light can inactivate Cryptosporidium parvum and Giardia lamblia at cost-effective doses [9] and [10]. Besides, UV treatment requires only a short contact time, resulting in limited space requirements, and the water delivery system does not cause corrosion [11, and12]. The downside is that if the delivery system is contaminated even with a small number of microbial pollutants, UV rays do not guarantee safe drinking water. The residual disinfection effect of chemical disinfectants is not given by UV irradiation [13]. As soon as it exits the quartz sleeves, UV light begins to interact with the substances and particles present in the water subjected to treatment. Several dissolved substances and wastewater particles can reduce UV light propagation through the water. Consequently, the amount of UV light that is successfully transmitted through the reactor depends on different dissolved compounds' concentration. The concentration of particles and distance the light has to move [14-16].

Ultraviolet (UV) sterilizers have been described by studies over the years as potentially the most cost-effective and effective alternative technology available to homeowners to remove a wide variety of biological pollutants from their water source. According to study findings, the advantages lie in that it does not add contaminants into the water, does not generate by-products, and does not affect the taste, pH, or other water properties [17].

This study's primary objective is to obtain safe and environmentally safe drinking water in the event of water shortage and the inability of homes to access clean water. Therefore, resort to appropriate home treatment or resort to the use of well water when necessary. Therefore, a home system has been established to test the ceramic filter's efficiency in removing turbidity and plankton, and everything else will change the characteristics of drinking water while determining the efficiency of ultraviolet rays' sterilization.

2. Material and Methods

2.1. Study Area Description

In this study, Tigris River from Al Wahda water treatment plant, 33°17'35"N, 44°26'41" E on eastern bank of the Tigris River, was chosen to collect samples as shown in (Figure 1).
2.2. Raw water Sampling and Analysis.

Samples were collected from the Tigris River from Al Wahda water treatment plant during the study period. The selected physical, chemical and biological properties of the samples collected were analyzed in (Directorate of Environment and Water) "Ministry of Science and Technology" as well as in the Laboratory of Health - Civil Engineering, University of Baghdad. As shown in Table 1, the characteristics of all water samples during the study period. Below is a description of the basic steps for the operation of the system in addition to a description of the devices that were used, as well as the steps that were followed to conduct practical tests for the study period from September to December, and the collection of samples was the beginning and middle of each month.

Table 1: The range for each Parameters during the study period

| NO | Parameter                  | Unit    | Range      |
|----|---------------------------|---------|------------|
| 1  | pH                        | -       | 7.91 – 7.84|
| 2  | Temperature of Air        | °C      | 46 - 20    |
| 3  | Temperature of Water      | °C      | 31 - 18    |
| 4  | Turbidity                 | NTU     | 47 - 27    |
| 5  | TSS                       | mg/L    | 92 - 22    |
| 6  | Fe                        | mg/L    | 0.06 - 0.03|
| 7  | MPN fecal coliform        | Cell/100ml | 60 - 30   |
| 8  | MPN E-coli                | Cell/100ml | 60 - 30   |
2.2.1. The pilot plant description

The pilot plant was constructed on three units as follows:

- The first unit is sedimentation: the sample is placed in a sedimentation basin for a whole day (Confinement). By the act of gravity, suspended materials settle at the bottom to remove the largest possible amount of suspended matter, turbidity, and materials that would cause water pollution. This is called the separation of impurities from the water by the force of nature, as shown in (Figure 2).

- The second unit is ceramic filter: using the porous structure of the filter, the largest possible amount of turbidity, suspended solids, and iron is removed, and it is also able to remove a good percentage of bacteria because it is a commercial filter. As shown in (Figure 4), thus obtaining water by certain standards and preparing it to enter the sterilizer.

- The third unit is sterilization: In this stage, the water is sterilized with ultraviolet rays, and all bacteria in it are killed, and thus drinking water is obtained as shown in (Figure 5).

The following is a description of all the devices that were used in order to complete the pilot Plant system:

1. Plastic tank: It is a circular plastic basin with a different diameter from the bottom to the top and a water capacity of 20 liters, it works under gravity's influence to remove unwanted small suspended particles (such as sand, silt, and clay) and other essential pollutants from the water. The longer the water remains. Solids and spores were deposited at the bottom of the tank.

2. pump: A submersible pump to raise the raw water from the sedimentation basin to the ceramic filter with a drainage capacity of 1000 L / hr and ahead of 1.8 m. as shown in (Figure 3).

3. Ceramic Candle Filters: A device made commercially (made in China) with simple clay components (fired clay) to filter water and purify it from impurities and bacteria in it, and it has its own small faucet. It is characterized by a nanotechnology mechanism that separates and isolates water microbes, impurities and bad smell, and also contains natural tourmaline stone, which is a crystal mineral of silicate, and due to its ability to kill bacteria, toxins, rust and parasites, it is commonly used in new water filters. To make it safe to drink, it reacts with minerals in the water, such as magnesium, potassium, sodium, and lithium. Physical methods such as mechanical trapping and absorption are used on ceramic candles with small pores for removal. Once used, it provides safe storage. The effectiveness of the filter also depends on the quality of the output, the initial water quality, and the handling practices of the users.

4. UV Reactor: The UV disinfection device is a chemical-free, highly efficient method of eliminating the possibility of microbiological pollutants from the water (up to 99.9 percent). The four main components of a UV system. The reactor chamber, also known as just a chamber or a reactor, where the UV lamp is located and is made of stainless steel. The UV lamp: It produces UV-C rays, which is the wavelength of ultraviolet rays that are considered germicidal All UV lamps generally contain a grain of mercury about the size of a pinhead, and all lamps can be recycled while the lamp is running; the mercury is completely contained within the body Lamp, and with proper recycling, these bulbs are harmless and pose no threat to the environment. Mercury is a vital part of a lamp's ability to produce the wavelength of germicidal UV-C light. Fine droplets of liquid mercury collect in the "cold spot" of the lamp, and once they reach the peak temperature, UV light is emitted. Like a normal light bulb, all UV lamps have a filament to create an electric current that heats and evaporates the lamp's mercury. This evaporated mercury helps form electric arcs that generate UV-C rays at different intensities to disinfect the water. The quartz sleeve It is a long, cylindrical tube made of quartz glass specially designed to protect the UV lamp from the flow of water, and it works to transfer the light from the tube to the water. Minerals or pollutants can damage this tube over time; it must be cleaned and changing the lamp.
It is essential for the effective operation of the UV rays. The controller unit is a plug that can be connected to electricity and deliver power to the reactor until it starts working.
2.2.2. Experimental work steps

The practical steps will be clarified during the study period:

1- Taking a sample of raw water from the Tigris River from Al-Wahda water treatment through a plastic tank.

2- Draw about (0.5) liter in a glass container for all analyzes, and the laboratory analyzes are conducted as follows (turbidity, pH, TSS, iron, bacteria, temperature Air and water).

3- The raw water sample is placed in a plastic tank and left to settle for a full day.

4- The submersible pump is connected to a constant current point, and the water is transferred to the ceramic filter.

5- An amount of water coming out of the ceramic filter, about (0.5) liter, is taken to perform laboratory analysis (turbidity (2100p/HACH), pH (WTW), TSS (Lovibond/Photometer MultiDirection), iron (Lovibond/Photometer MultiDirection), bacteria and temperature Air and water) before entering the UV sterilization system, to understand the filter performance and water characteristics.

6- The system is operated in the last stage by connecting it to a constant current site. The water is transferred to the UV sterilizer.

7- Water coming out of the sterilizer. A sample is taken and the required analysis (bacteriological analysis) is performed to determine the efficiency of the device in particular and the experimental system in general. This process is repeated at different periods of the work months during the study period. (Figure 6) shows the pilot plant arrangement.
3. Results and Discussion

Through the results obtained from passing the water sample through the pilot plant, which includes the effect of the ceramic filter and the ultraviolet sterilizer, it was as follows:

3.1. Effect of the ceramic filter:

3.1.1. Air and water temperature (Temp.)

The results indicated that during the study period and the statistical analysis of the parameters, the highest value for air temperature was (46 c°), and raw water samples taken from the Tigris River were the highest value (31 c°). The lowest value for air temperature was (20 c°). At the same time, the lowest temperature for raw water samples was (18 c°). The ceramic filter did not affect the samples' temperature as they passed through it.

3.1.2. PH

Through the statistical analysis, the results showed that during the study period, the highest value for the pH of raw water taken from the Tigris River was (7.91), the lowest value of pH was (7.87). Whereas The highest pH value for water from the filter (drinking water) taken from river water was recorded (7.88), and the lowest for the pH value (7.84), as shown in (Figure 7) We conclude that all outcomes decreased by a small percentage, as was noted in [18]. We infer from the findings that it was within the acceptable limits of the World Health Organization's drinking water (2011) requirements (6.5-8.5) [19]. The efficiency of the ceramic filter was excellent in maintaining the pH value within the permissible limits. We conclude that all results decreased by a small percentage, as was observed in [20].

3.1.3. Turbidity (Turb.)

By explaining the statistical analysis, the results of the current study showed that the highest value of turbidity was recorded in river water (38 NTU) after the sample was deposited, and the lowest value for turbidity was (22. NTU) after remaining in the sedimentation basin. On the other hand, the highest value for turbidity (1.44 NTU) was recorded for drinking water taken from river water samples outside the filter, and the lowest value for turbidity (0.8 NTU) was recorded, as shown in (Figure 8) for each of the WHO drinking water standards (2011) [19], these values were obtained within the permissible limits. Outside. The efficiency of the ceramic filter in removing turbidity was high, as the removal percentage ranged from (96 – 97) %, and the resulting water was compatible with the water quality of the (5 NTU) ultraviolet disinfectant, as shown in (Figure 13). Turbidity is the optical property of water from the scattering, diffusion and absorption of light by suspended materials. It affects both the volume of matter and the concentration of particles that affect the amount of browning, such as organic matter, silt and clay. Turbid water is not only aesthetically less attractive than clear lake water, but it is also not suitable for home use. Turbidity serves as a useful water quality indicator for water. The turbidity values for formazine turbidity units vary from zero in visible waters to 100 or more in highly turbid waters in natural lake waters [21].

3.1.4. Iron Concentration (Fe)

The statistical analysis showed through the results of the current study that the highest value of iron was recorded in the river water (0.06mg/L), The lowest value was (0.03mg/L). On the other hand, the highest value of Iron (zero) was recorded for drinking water taken from river water samples outside
the filter, and the lowest value for Iron (zero) was recorded as shown in (Figure 9). These values are obtained within the permissible limits for both WHO drinking water quality (2011) [19]. In river water samples, the ceramic filter has amazing removal ability, as shown in (Figure 14) The resulting water was compatible with the UV disinfectant water standard, which specifies a value of (Fe <0.3 mg/L) and also within the limits defined by the World Health Organization.

3.1.5. **Total Suspends Solids (TSS)**

The results of the current study showed through the description statistical analysis that the highest value of TSS was recorded in river water after its residence in the sedimentation basin (78 mg / l). In contrast, the lowest value for TSS was (19 mg / L). As for drinking water obtained from river water samples, the highest value of TSS (1 mg / L) was recorded, and the lowest value of TSS (zero), as shown in (Figure 10) The water produced from the ceramic filter was high. Removed from suspended solids and conformed to the water standard for UV sterilization, which indicates a TSS value (TSS <10 mg / L) (Figure 15). The TSS values increased seasonally in winter and autumn and decreased in summer, which may increase the amount of water, soil erosion, and wind speed of rainfall, dust storms, and suspended organic materials [22] and [23].

3.1.6. **Bacteria**

The results of the current study indicated through statistical analysis, the highest concentration of bacteria E-coli and fecal coliform in raw water taken from the Tigris River was (60 MPN /100ml), and the lowest concentration of bacteria E-coli and fecal coliform was (33 MPN /100ml). While the highest concentration of bacteria E-coli and fecal coliform was recorded in the water outside the filter, it was followed by samples of river water (33 MPN /100ml), and the lowest concentration of bacteria E-coli and fecal coliform was (17 MPN /100ml), as shown in (Figure 11) In the river water samples, the performance of the ceramic filter in reducing the bacteria concentration was average and ranged from (45 ~ 50) percent, as shown in (Figure 16).

3.2. **Effect of the ultraviolet sterilizer (UV)**

The highest concentration of bacteria E-coli and fecal coliform from river water outside the filter was (33 MPN /100ml), while the lowest concentration of bacteria E-coli and fecal coliform was (17 MPN /100ml). After the water passed through the UV sterilizer, the concentration of bacteria E-coli and fecal coliform was (zero), as shown in (Figure 12). The efficiency of the UV sterilizer was excellent in removing bacteria, as shown in (Figure 16). this is one of the features of drinking water according to WHO standards [19]. It includes using the electromagnetic spectrum’s ultraviolet component to inactivate certain microorganisms. Pathogens such as bacteria, viruses and parasites that can cause a number of diseases can be killed by UV rays. As the only disinfection process for the processing of drinking water, UV rays are widely used in Europe [24-26].
Figure 7. PH before and after passing through the ceramic filter.

Figure 8. Turbidity before and after passing through the ceramic filter.

Figure 9. Fe before and after passing through the ceramic filter.

Figure 10. TSS before and after passing through the ceramic filter.
Figure 11. Bacteria E-coli and fecal coliform before and after passing through the ceramic filter.

Figure 12. Bacteria E-coli and fecal coliform before and after passing through the UV.

Figure 13. Turbidity Removal Efficiency

Figure 14. Fe Removal Efficiency
4. Conclusions
Through this study, the efficiency of the experimental system was measured at the home level through the use of commercially available devices, and through the results that were reached, it was found that it could be used as an alternative to large stations in the event of water scarcity or the inability to access potable water to homes. His conclusion is as follows:

1. When the water remained in the sedimentation basin at the start of the system, the turbidity decreased greatly with removal efficiency (15 ~ 20%) and TSS (12 ~ 15%). At the same time, iron does not change, and pH. The water temperature changes as the air temperature are acquired.

2. After the water passes through the ceramic filter, we find that it contributes to reducing turbidity by a high percentage (96~97) % and reduces TSS by (100~99) %, iron removal efficiency by (100) %, and affects very little on the pH and does not affect the temperature.

3. It was evident from the pilot plant work that the UV unit was efficient (100) %, as the bacteria were removed by (100) %.

4. We conclude that the pilot plant can be used in its straightforward and simple form to serve the individual or family when water is scarce and drinking water does not reach the homes.

Acknowledgment
The authors are grateful to the University of Baghdad's Sanitary Engineering Laboratory and Civil Engineering Department / College of Engineering for their valuable help in completing this work.

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