A New Attempt to Treat Turbid Water

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The main objective of the present study is to try to find a new treatment system to treat real turbid water. The new proposed method assembles a natural aeration system that can be used at the same time to carry out the coagulation process, which is followed by static or hydraulic flocculation and sedimentation. The objectives of study achieved this by constructing a lab-scale pilot plant consisting of a stepped cascade aerator, a horizontal baffled flocculator, and sedimentation tank. It was tested five groups of experiments, each group includes six different flow rates of (0.25 m^3/hr, 0.5 m^3/hr, 0.75 m^3/hr, 1 m^3/hr, 1.25 m^3/hr, and 1.5 m^3/hr). The alum is used with different doses using a dosing pump to supply alum into a steeped cascade aerator of dosage of (10 mg/l, 15 mg/l, 20 mg/l, 25 mg/l, and 30 mg/l). The results showed that when the flow rate is 1.25 m^3/hr, the removal efficiency of turbidity reaches its maximum value of about 94%, and thus indicates that the best flow rate for achieving the maximum turbidity removal efficiency happened with alum dosage of 30 mg/l. It was found that increasing of alum dosage beyond 30 mg/l did not significantly improve the efficiency turbidity removal. The results indicated that the using of flow rates of (1–1.25) m^3/hr together with an alum dosage of 30 mg/l is the most effective combination for achieving maximum turbidity removal efficiency. Finally, the novelty of the present study is finding a new water treatment method that aims of sustainability through the use of hydraulic treatment methods that are good efficient and at the same time low in cost.

Keywords: Water Treatment, Turbidity, Stepped Cascade Aerator, Horizontal Baffled Flocculator.

1. Introduction

(Burlingame et al., 1998) indicated that the rapid growth of population, urbanization, industrial, and agricultural activities have led to a rise in water pollution, resulting in a growing demand for clean and safe water. Water treatment operations are crucial industries in countries like Iraq, and turbidity can measure the performance of individual and overall treatment processes. Common methods include coagulation, flocculation, sedimentation, and filtration to remove suspended solids and reduce turbidity.

(Pontius, 1990) defined that the Coagulation is the process of conditioning suspended solid particles to promote their agglomeration and generate bigger particles that may be more readily removed in future treatment processes. The coagulation process is complex and could involve multiple steps to achieve "destabilization," which permits particle accumulation and increases subsequent removal.

(Tchobanoglus, Burton and Stensel, 2003) stated that the flocculation process is the agglomeration of destabilized particles that allows colloids to approach each other and grow into larger and heavier settable or filterable flocs, these particles create turbidity in water.

(Hajiali & Pirumyan, 2014) stated that the turbidity can contain a variety of pollutants, including harmful organisms. Turbidity is also related to numerous pollutants of concern to human health, e.g., metals or certain synthetic organic compounds. Thus, thorough turbidity elimination is important to assure the removal of various health-related pollutants. Furthermore, effective turbidity reduction can increase the efficiency of the following water treatment processes.

(Tolkou & Zouboulis, 2014) showed on a global scale, alum and ferric chloride are widely used as chemical coagulants in water treatment facilities. The literature has documented findings on several coagulation processes.

(Gerrity et al., 2015) stated that the use of lab-scale pilot plants is important in studying water quality standards and clarifying the removal efficiency of pollutants in general. Thus, we can understand the effects of full-scale water and wastewater treatment plants. Most previous studies used lab-scale pilot plants to study their impact on specific standards based on the main treatment principles and how to achieve and develop them, which are coagulation, flocculation, sedimentation, filtration, and disinfection.

(Khalifa et al., 2011) indicated that t a laboratory-scale pilot plant to study the cascade aeration system, a low-cost technique that enhances water flow's oxygen content. This method removes unwanted gases like H2S and other dissolved gases, improves solidified substance mixing with water, and enhances coagulation efficiency. The turbulence of water particles in the presence of coagulant molecules increases efficiency in ideal water flow. The cascade aeration system, which relies on gravity, is considered an inexpensive technique due to its simplicity and low maintenance requirements.

(Ali and Al-Hashimi, 2019) studied that the treatment system for grey water to remove and reduce pollution contamination. The system consists of a stepped cascade weir and spray aerator, which includes a suspension growth unit and clarification tank.it was showed an efficiency of 51% to 53% in removing pollutants like COD and BOD5, while decreasing Fe+2, Mn+2, and Cl-. The study also found a decrease in these pollutants (11%–23%), (12%–26%), and (16%–24%), respectively.

(Khudhair & Hadi, 2019) explained that the baffled horizontal flocculator, of the static flocculator type, is another essential component of the pilot plant that helps achieve the flocculation process. The baffle flocculator has shown promising results in removing suspended particles and improving water clarity. This innovative technology utilizes a series of baffles to enhance flocculation and sedimentation processes, resulting in more efficient water treatment. The baffle flocculator has been proven to be effective in various water treatment applications, making it a viable option for improving water quality in both industrial and municipal settings. Furthermore, using this technology can lead to cost savings and reduced environmental impact compared to traditional treatment methods.

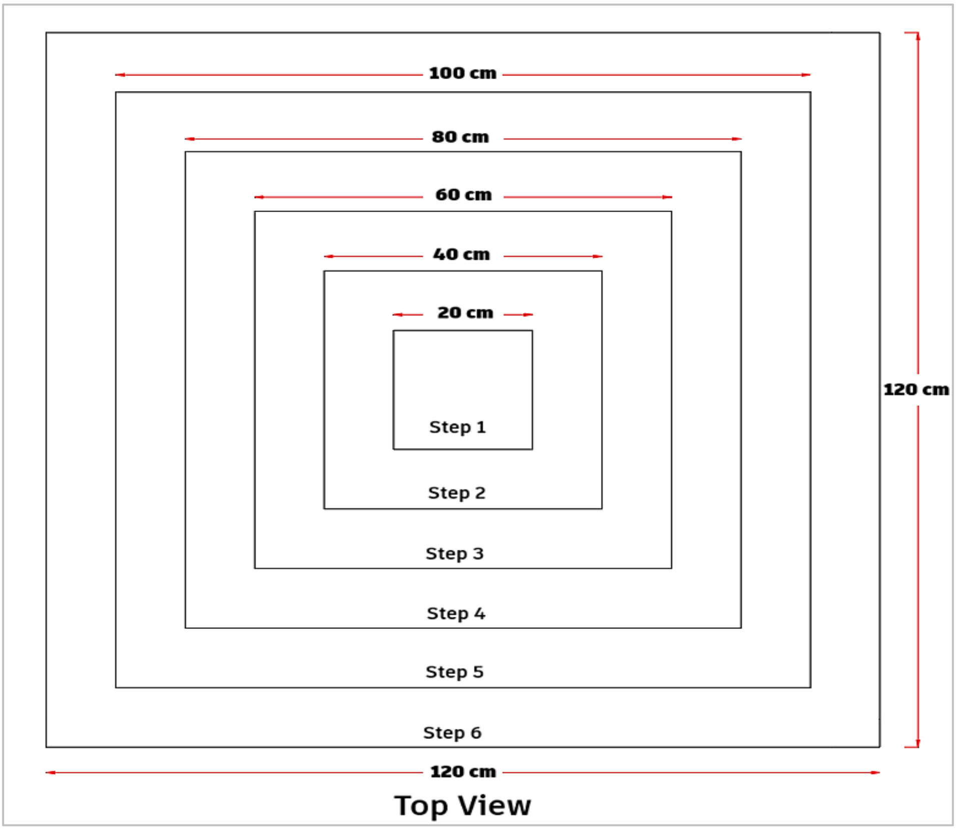
The most important contribution of the present study is to find a new and different method to treat drinking water in a natural way that is easy to operate and has acceptable efficiency, in addition to cheap cost.

2. Martial and methods

2-1 Stepped Cascade Aerator

To design a cascade aerator, it needs to calculate the area required for the design, the number of cascades, the height of the aerator, the rise of each step, and the velocity of the inlet pipe (Mukherjee, 2020).

The cascade aerator was designed in a square shape according to the design standards, based on the main factor, which is the maximum flow rate, and it was chosen based on design criteria. As a result, a pump with a flow rate of 40 l/hr was used in the pilot plant. After that, it was concluded the appropriate design for the cascade aerator with a number of steps of 6 a tread of each step of 10 cm and a rise of each step of 20 cm, the total height of cascade aerator is 120 cm and the inlet pipe is of 2.5 cm. All dimensions are shown in Figure 1. After designing the cascade aerator, it was implemented in the laboratory using transparent plastic sheets with the same dimensions as shown in Figure 2.



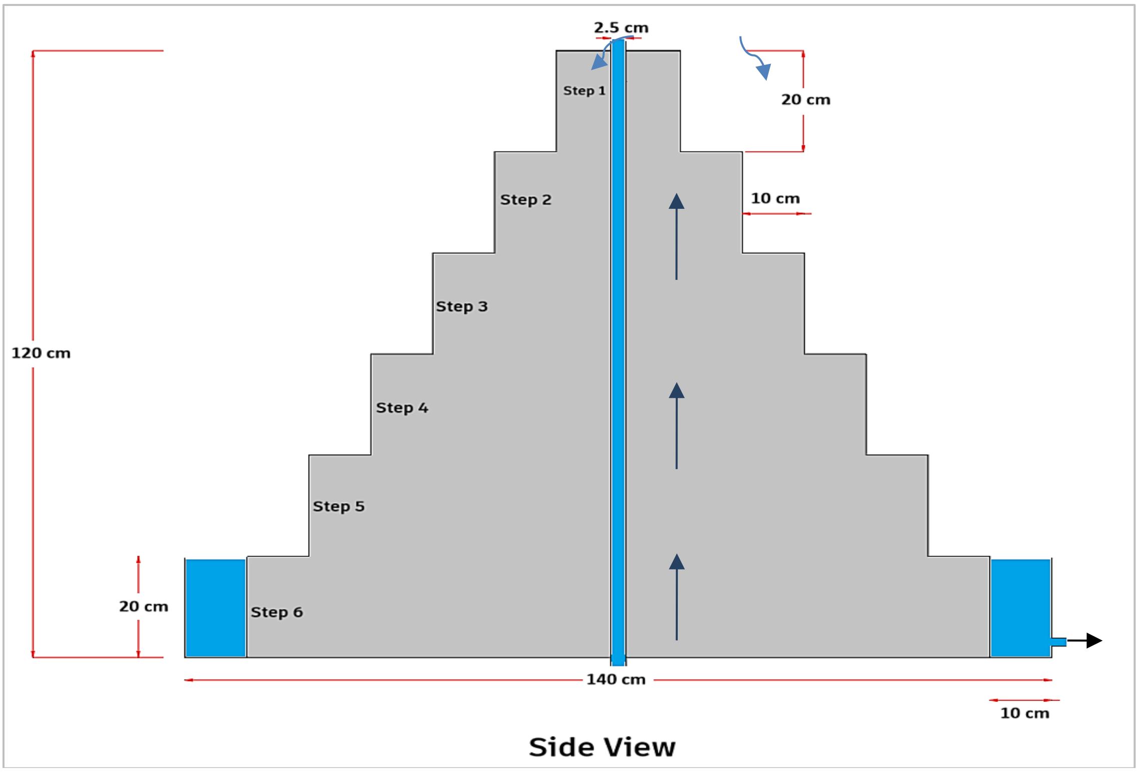


Figure 1. Design of Stepped Cascade Aerator (Top and Side View all Dimensions are in cm)

Figure 2. Photos of Stepped Cascade Aerator

2-2 Horizontal Baffled Flocculator

The baffle flocculator was designed in accordance with the flow rate to be studied; laboratory tests were done, and its effect on water treatment processes and turbidity was noticed, particularly in the present study. The baffle flocculator, the second important unit is connected to the cascade aerator via a pipe of 1.9 cm in its diameter. The design had dimensions of length 100 cm and width 96 cm. A distance of 3 cm between the baffles and a depth of 10 cm of each baffle. This flocculator was also made in a laboratory from transparent plastic sheets. This material was chosen because it is available, easy to work with, and suitable for the lab experimental work. The dimensions of the horizontal baffled flocculator are shown in Figure 3.

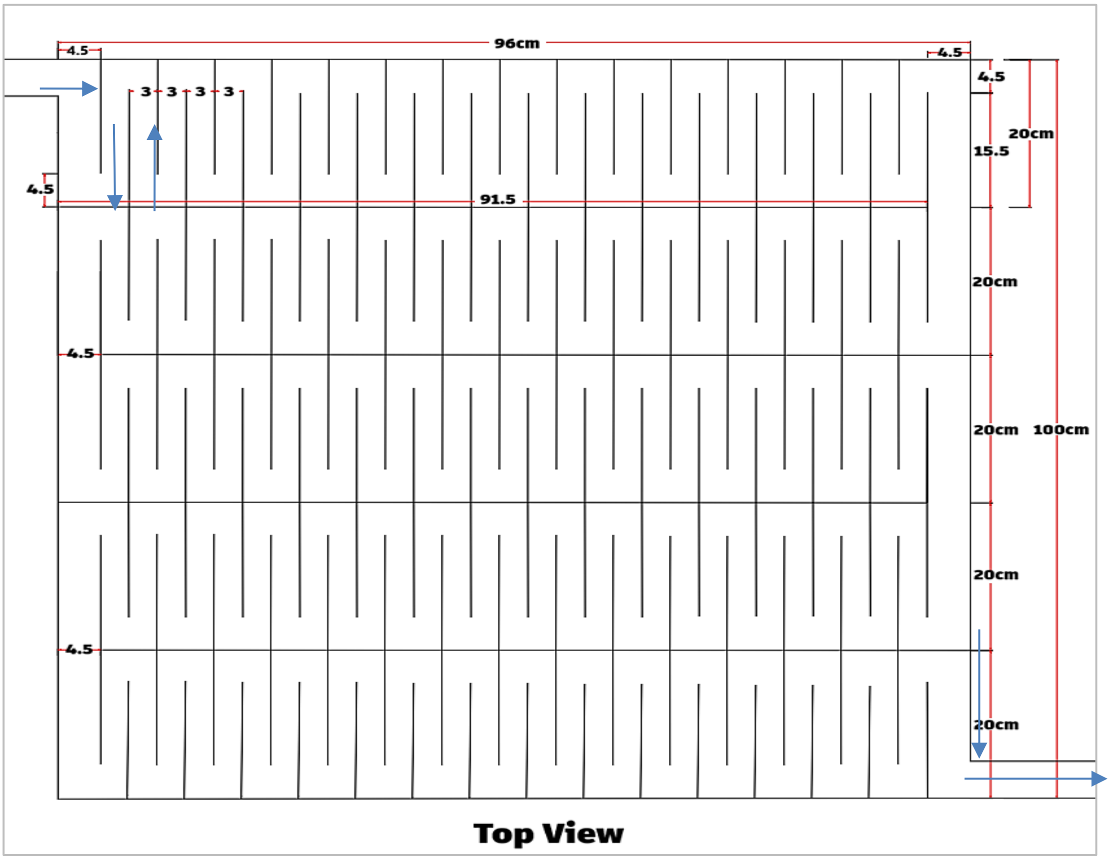


Figure 3. Design of Horizontal Baffled Flocculator (Top View all Dimensions are in cm)

Figure 4. Photos of Horizontal Baffled Flocculator

3. Experimental Work

The pilot plant established in the present study consists of: (1) an inlet tank with a capacity of 500 liters, (2) a flow meter of 36 L\min, (3) a pump of 40 L\min, (4) a stepped cascade aerator, (5) a horizontal baffled flocculator, (6) pipes of diameter 3\4", (7) a dosing pump of 25 L\hr, (8) valves of diameter 1", and (9) an outlet tank with a capacity of 40 liters for taking samples and conducting laboratory testing for turbidity measurements. The layout of pilot plant is shown in figure 5 and figure 6. It was used turbid water which was taken from Tigris River in Baghdad city with a turbidity of 15 NTU, and a pH of 8. The inlet tank was filled, and the pump was used to pump water into the cascade aerator. Following the pump, there is a flow meter that controls the flow rate coming from the inlet tank. A dosing pump is attached to the top of the cascade aerator, and it pumps alum, which was the coagulant used in the present study, to achieve the coagulation process. The mixing of turbid water with alum solution cascade aerator was caused by moving water flow through steps of aerator with accompanying of turbulence eddies on each step of aerator. The present study is unique because it also examines the coagulation of pollutants in water. Aluminum sulfate (alum) was used as a main coagulant in the present study. The alum has the chemical formula of ($Al2(SO4)3.14H2O$) which was always used in water treatment plants. To achieve the coagulation process, the alum was dissolved in a 20-liter water tank at different concentrations and then pumped into the stepped cascade aerator using a dosing pump. The turbid water then flows into the baffled flocculator, which is connected to the cascade aerator via a pipe of 1.9 cm diameter to initiate the flocculation process, and finally to the outlet tank for samples collection. The samples were tested in Baghdad's Ministry of Science and Technology laboratory as shown in figure 7.

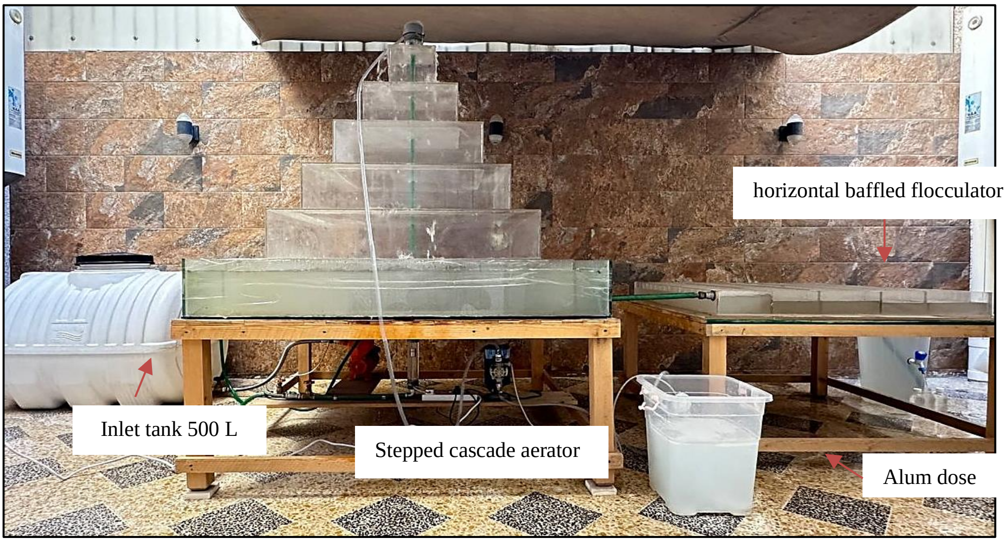


Figure 5. pilot plant

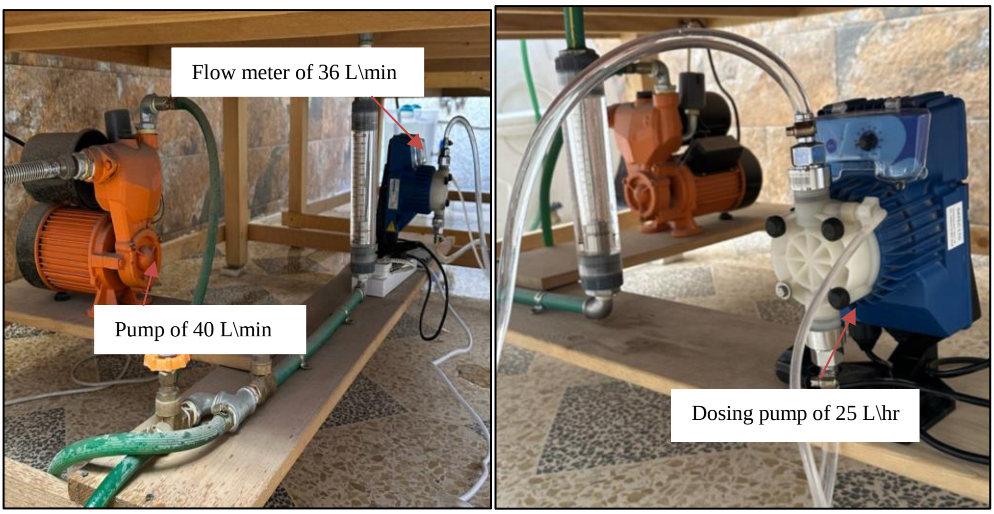


Figure 6. side view of pilot plant

Figure 7. Turbidimeter

4. Results and Discussions

The experimental work aims to remove turbidity from the raw water of the Tigris River, which was of 15 NTU and is considered real turbid water, it was tested five groups, each group includes six different flow rates of (0.25 m^3/hr, 0.5 m^3/hr, 0.75 m^3/hr, 1 m^3/hr, 1.25 m^3/hr, and 1.5 m3/hr). The alum is used alum in different doses using dosing pump into a steeped cascade aerator of (10 mg/l, 15 mg/l, 20 mg/l, 25 mg/l, 30 mg/l). The experimental work started with a dose of alum of 10 mg/l for the six different flow rates as mentioned above to evaluate the efficiency of removing turbidity of raw water. Then alum dosage increased to 15 mg/l, as well as to use other alum doses as mentioned above, the process was repeated. Aeration has recently been shown to be significant in boosting the level of oxygen in the water, which is essential for developing the growth of good bacteria capable of breaking down organic contaminants. The cascading air design effectively causes turbulence and agitation in the water, increasing the interaction between air and water and resulting in good aeration. It is considered a low-cost technology because it is based on gravity.

In general, the data in Figure 9 shows that as the flow rate increases, the turbidity removal efficiency also increases. The highest efficiency was achieved at a flow rate of 1 m^3/hr, with an efficiency of 83.33%. However, it is interesting to note that there was a slight decrease in efficiency at a flow rate of 1.25 m^3/hr, which then leveled off at around 81% for higher flow rates. This suggests that there may be an optimal flow rate for achieving the highest turbidity removal efficiency with an alum dose of 10 mg/l of real turbid water.

As shown in Figure 10, the turbidity removal efficiency appears to increase as the flow rate increases, its maximum of 85.47% with a flow rate of 1.25 m^3/hr before slightly decreasing of flow rate to 1.5 m^3/hr with an alum dose of 15 mg/l of real turbid water.

Figure 11, the present results of flow rate of 1 m^3/hr that achieves the highest turbidity removal efficiency of 90.06% with an alum dose of 20 mg/l.

Figure 12, reveals that as the flow rate increases, the turbidity removal efficiency also increases. At a flow rate of 1 m^3/hr, the alum dose of 25 mg/l achieved a turbidity removal efficiency of 91.67%.

Finally, in Figure 13, when the flow rate is 1.25 m^3/hr, the turbidity removal efficiency reaches its maximum of 94.26%. This indicates that the optimal flow rate for achieving the highest turbidity removal efficiency with alum dosage of 30 mg/l is within the range of 1–1.25 m^3/hr.

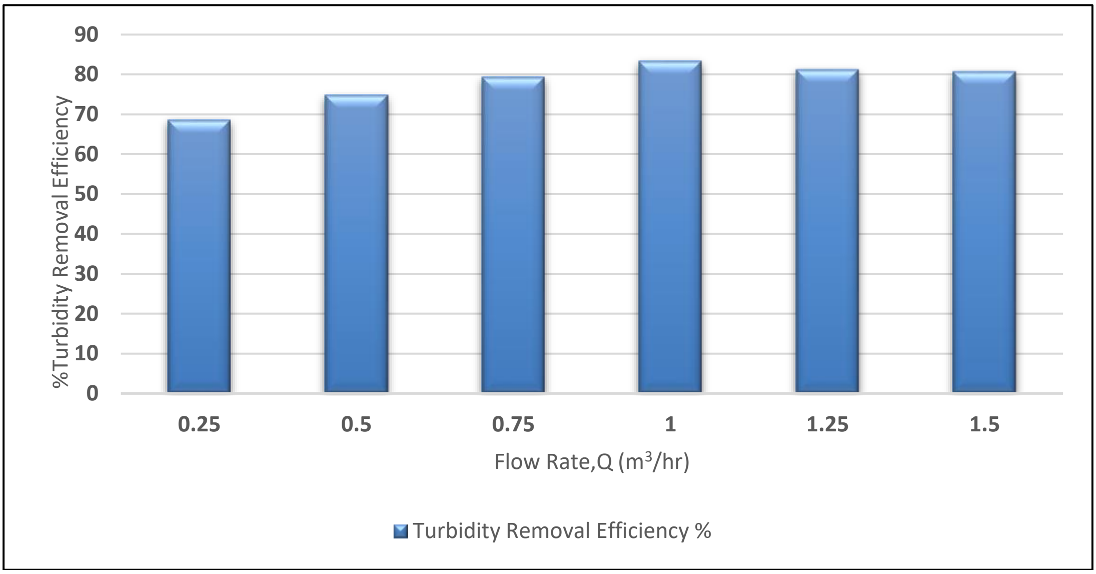


Figure 9. The Relationship Between Flow Rates and Turbidity Removal Efficiency of Alum Dosage of 10 mg/l

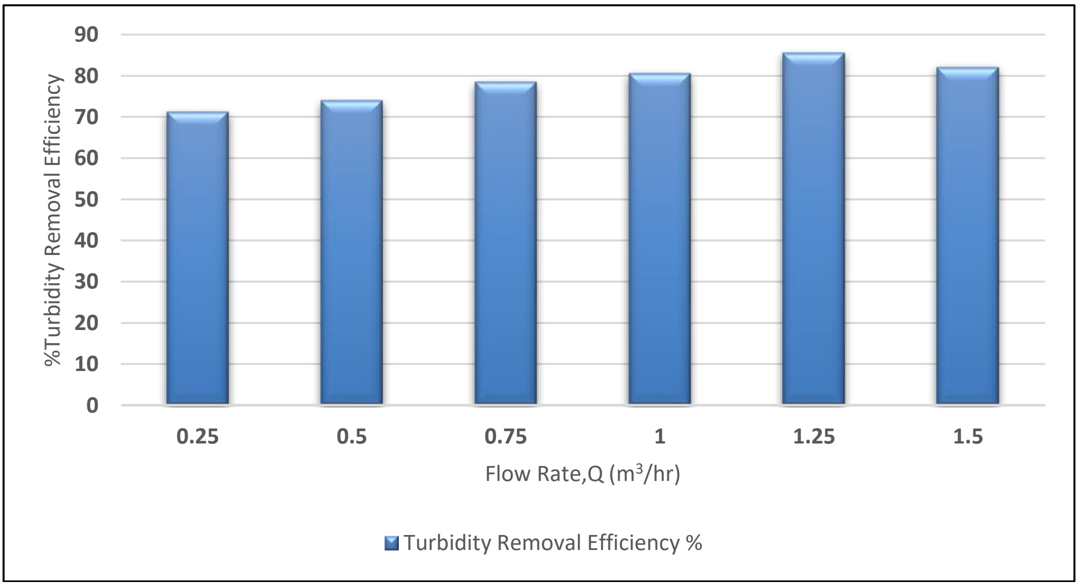


Figure 10. The Relationship Between Flow Rates and Turbidity Removal Efficiency of Alum Dosage of 15 mg/l

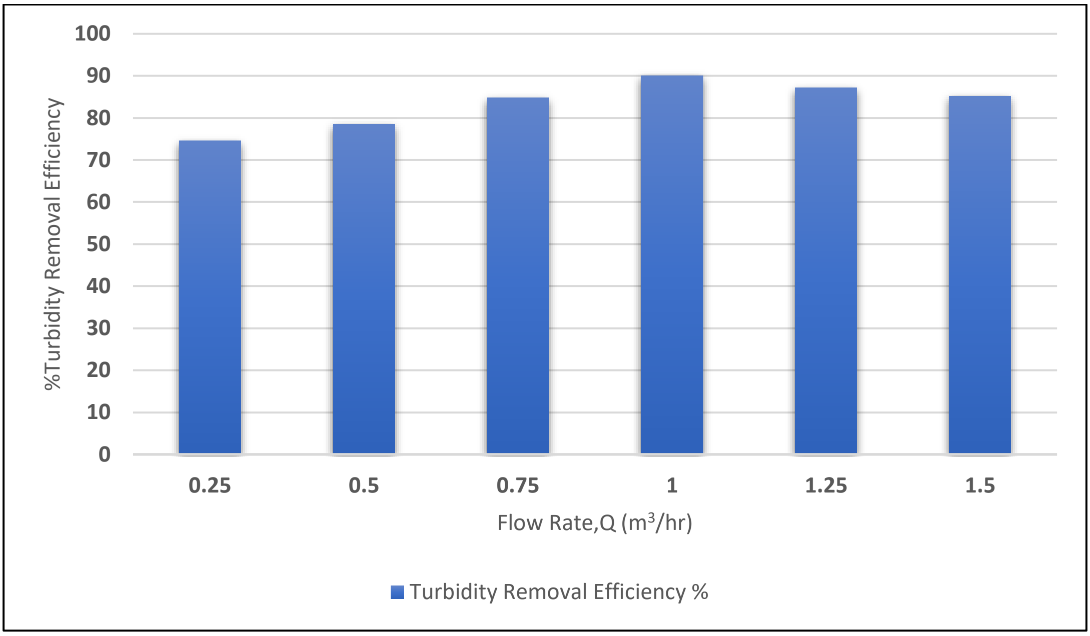


Figure 11. The Relationship Between Flow Rates and Turbidity Removal Efficiency of Alum Dosage of 20 mg/l.

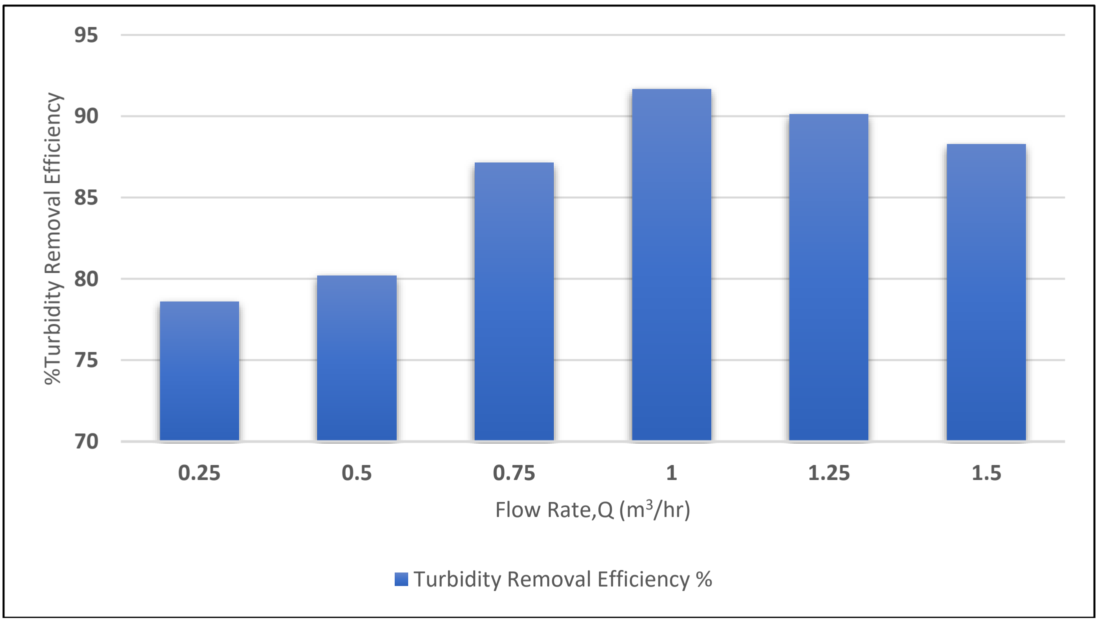


Figure 12. The Relationship Between Flow Rates and Turbidity Removal Efficiency of Alum Dosage of 25 mg/l

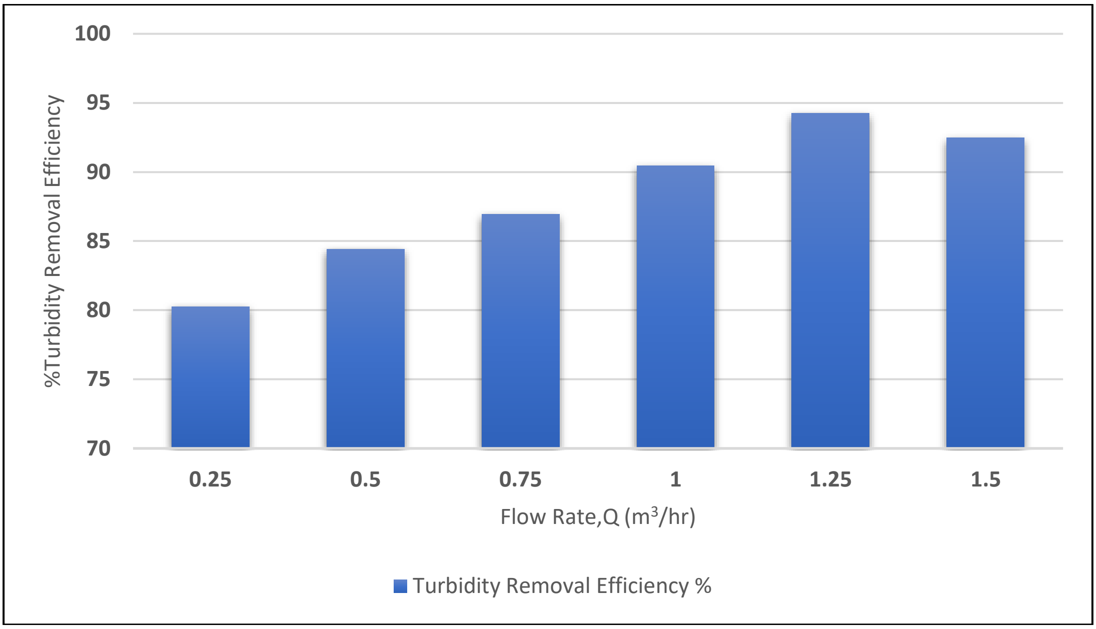


Figure 13. The Relationship Between Flow Rates and Turbidity Removal Efficiency of Alum Dosage of 30 mg/l

5. Conclusions

It is clear that maintaining a constant flow rate and balance with alum doses within the recommended range is crucial to achieving optimal turbidity removal in water treatment systems. The best value of flow rate is 1.25 m3/hr, the turbidity removal efficiency reaches its maximum of 94.26%. This indicates that the optimal flow rate for achieving the highest turbidity removal efficiency with alum dosage of 30 mg/l is within the range of 1–1.25 m3/hr., ensuring effective turbidity removal from raw water. Operators can more effectively remove turbidity from flowing water by carefully monitoring and adjusting operational parameters, leading to improved overall water quality.

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