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Iron Removal from Ground Water through Expanded Polystyrene Filter

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Abstract

Expanded polystyrene (EPS) filtration is a promising method for groundwater iron removal. Pilot-scale experiments have been conducted through an up-flow filter. EPS beads were used as a filtration media to evaluate the elimination of iron from water. The used EPS beads have effective size, uniformity coefficient, and density of 0.63mm, 1.43, and 30 kg/m^3, respectively. The water has been feed at different iron concentrations from 1 to 5 mg/L which resulted in turbidities from 3.5 to 12.5 NTU, respectively. Sodium dodecyl sulfate (SDS), an anionic surfactant, was used as a coagulant. The filter was tested for filtration rates of 80, 100, and 120 m^3/m^2/day. Bed washing was performed in the downflow direction. Results showed that the EPS filter was successful in removing iron and turbidity with the percentage of 97% and 95%, respectively. The influent iron concentrations and filtration rate had remarkable effects on the effluent turbidity, iron concentration, filterability index, and headloss.

Keywords: Filtration, Groundwater treatment, Iron removal, Purification, Water turbidity

1 Introduction

Water is scored as a second essential requirement for the life after oxygen. As the world population increases, there is an annual decline in the accessibility of clean and safe water (1). Groundwater has been utilized as a wellspring of drinking water since the days of yore. It represents about 97% of the freshwater resources on the earth (2). Increased water demands require in turn a continual search for better, efficient, and economical methods of groundwater treatment. The presence of some salts in high concentrations in groundwater may increase water's Turbidity. Turbidity is an indication of the quantity of suspended material in a water sample (3). Suspended particles in water have the same type of surface charge so they repel each other when they come close together. So, they will remain suspended rather than clump together and settle out of the water (4). Water that has a high level of turbidity needs to be treated with flocculation/coagulation to remove the turbidity (5). Chemical coagulants are added to water to aggregate stabilized particles having an opposite charge. Iron is found in groundwater at high fluctuating concentration levels. The continuous use of high iron water may lead to various health problems, unpleasant taste, bad odor, the red color of water, and stains on laundry and plumbing fixtures (6, 7). Iron exists in groundwater in two forms, which are soluble ferrous iron [Fe(II)] and insoluble ferric particulate iron [Fe(III)] (8). According to WHO limits, the permissible limit of iron in drinking water is 0.3 mg/l (9). Coagulation and filtration through porous media are believed to have the potential to remove undesirable iron concentrations (6). Conventional filtration is considered the most common method of filtration. In practice, there are many types of filters such as rapid sand filters, slow sand filters, under pressured sand filters, membrane filters (10). Floating bed filters offered the advantages of low headloss and energy costs for improving the operational economics of filtration (11). Floating bed filters differ from the conventional sand filters in many ways: First, the density of media particles is less than that of the water to be filtered, and a retaining grating is placed at the top of the filter to maintain the media inside the filter under submerged conditions (12). Second floating media filters are washed with down-flow water, therefore the media expands downward and the gravitational force direction of the deposited solids coincides with the direction of wash water so that the required volume of water for washing is less than for sand filters (12). Floating media filters do not require a large land area and a large quantity of filter media as required by conventional sand filters (13). More promising, the use of expanded polystyrene (EPS) as a layer of floating beads for filtration. The advantages of EPS filters are low energy costs, high resistance of polystyrene to various chemical contaminants that may be in the effluent, and operating in either top-down or bottom-up filtration flow modes (14). Coagulation should be used along with the filtration to coagulate iron particulates into aggregates and then small iron particles combine to form larger particles which can be removed

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through the filter. Salts of aluminum are the most commonly used chemicals in the water treatment coagulation process (15). Alzheimer's disease has been related to the residual aluminum ions in the treated waters (16). Among the methods used for iron coagulation and flocculation, some authors investigated the addition of small quantities of a negatively charged surfactant to a solution of positively-charged particulates, the particulates are partially coagulated into aggregates, which is clearly shown by an increase in the optical density (turbidity) of the solution. Sodium dodecyl sulfate (SDS), an anionic surfactant, is commonly used in the pharmaceutical industry, biological and biomedical research. It is also used as an emulsifier in the preparation of dried egg whites and a whipping agent in the preparation of marshmallows (17). SDS is used as a surfactant in Fumaric acid-acidulated fruit juice drinks whereby the additive does not exceed 25 ppm of the finished fruit juice drink (17). SDS is added to food products and listed on the U.S. Food and Drug Administration (FDA) list of multipurpose additives allowed to be directly and indirectly added to food (18). Recently, expanded polystyrene was used for water and wastewater treatment. Expanded polystyrene backfill was used for clarifying, discoloration, and deferrization (19). Schöntag et al. (20) constructed a study to compare descending rapid filter utilizing polystyrene granules 1046 kg/m^3 to sand and anthracite descending rapid filter. Filters were tested to remove turbidity, color, total dissolved solids, and cyanobacterium (Cylindrospermopsis raci-borski). The water quality of the polystyrene filter had a similar quality to the sand and anthracite. Kwon et al (21) performed experiments to compare the expanded polystyrene bead filter with sand filtration. The filters were tested for algae and turbidity removal. Experimental concluded that algae removal is more affected by the depth of expanded polystyrene bead than that of sand filtration. Schöntag et al.(22) Conducted that using Polystyrene (PS) beads as a filter element provides washing water savings because they require low velocities for expansion during backwash. El-Etriby and Menlibai (12) studied the filtration rate up to 15.8 m/hr, the filtrate quality improved as a filtration run progressed. The wash water volume required was around 1.0% of filtrated water. Orlov et al (23) compared the heavy sand filter with the proposed polystyrene foam filter. The results showed that the proposed filter saves 40–50% in capital investment, 30–40% in the operation costs, 7–9% in the cost of electricity, 8–36% of buildings and structures cost. Also, many studies have been examined EPS as a filter media, but the effectiveness of EPS filter to remove the iron is still needed. This study examines the use of expanded polystyrene foam as a floating filter media to improve the efficiency of water iron removal. Up-flow filtration experiments were conducted at different filtration rates and various iron concentrations using SDS as a coagulant. SDS was proposed by some authors to be used as a coagulant to overcome the disadvantages of other coagulants. This study tests SDS efficiency for iron removal. The quantity of added SDS was selected based on previous researches, where the iron was removed by using SDS and floatation (24). The present study also covers the impact of influent iron concentrations and filtration rate on the effluent turbidity, iron concentration, filterability index, headloss, and filter performance.

2 Materials and methods

2.1 Filtration system

The pilot plan was a filter of the circular column made of clear Perspex of 5.0 mm thickness. The filter had an inner diameter and height of 15 cm and 240 cm, respectively. The transparency of the column allowed a clear vision during the filtration process. The Perspex column has six piezometric openings connected to a manometric board to measure the head losses through the filter. A screen was fixed at a height of 1.90 m from ground level to prevent the escaping of the media. During the filtration process, the media was fully submerged. The filtration column was supported on a steel box of base dimensions 25 by 25 cm and 15 cm in height. The steel sheet of the box is 5 mm thick. The schematic diagram of the experimental setup is shown in Figure 1.

The used media in the filter was the expanded polystyrene foam (EPS), shown in photo 1. The selection of EPS size involves a balance between filtration efficiency (smaller media capture particles better) and headloss (larger media minimize headloss). Thus, a rule of thumb relationship was considered; the ratio of depth to effective size (L/De ratio) should be between 1000 and 2000 (25). One meter of the media depth in the filtration column was taken as a suitable depth for this pilot plant, and the EPS size was between 0.6-1.2 mm. The material characteristics of EPS were summarized in Table 1.

Photo.1: Expanded polystyrene foam.

Table 1: Characteristics of Expanded polystyrene beads (EPS).

Characteristics	EPS beads
Chemical composition	C8H8
Shape	Spherical
Minimum size	0.6mm
Maximum size	1.2mm
Effective size	0.63mm
Uniformity coefficient (UC)	1.43
Porosity (26)	0.3492
Density	30 Kg/m^3

The filtration rate of the operation was varied as 80, 100, and 120 m^3/m^2/d. The flow rate through the filter was controlled by a gate valve fitted on the outlet pipe of the constant head tank which discharges freely to the inlet of the filter. This saves a constant flow rate under the variable head during the filtration run. Each experiment was repeated three times to ensure the experimental results.

2.2 Raw water quality

The used synthetic water in all the experimental runs was prepared by adding ferric chloride [$FeCl_3$] to 2.5 m3 of tap water after leaving it for a day to eliminate the residual chlorine (27). Sodium dodecyl sulfate (SDS) which is anionic surfactant with formula $[CH_3(CH_2)_{10}CH_2OSO^3]^- Na^+$ (From Alpha Chemicals, see physical properties Table 2, (28), was added to the synthetic water to obtain the iron in the suspended state. The water was mixed for 20 minutes in the mixing tank. The speed of the mixing tank was 60 rpm. After mixing the water was directed up-flow through the filter. Jar-tests were conducted to confirm the optimum dose of SDS. The amounts of SDS in the solution are given in Table 3. Linear relationship was found between iron and necessary SDS concentration which follow the equation:

$$SDS = 0.6\ Feo \qquad \text{Eq. (2)}$$

Table 2: Physical Properties of SDS (29)

Property	Value
Molecular weight	288.38
Melting point	204-207°C
Form	Cream-colored crystals
Solubility	10 g/100 mL water
pH (aqueous)	7.3-8.5
Density (powder)	0.396

Table 3: The amounts of SDS

Iron concentration (mg/l)	SDS concentration (mg/l)
1	0.6
2	1.2
3	1.8
5	3

2.3 Filtrated water quality

Samples of the filtered water were collected every hour throughout the run, water samples for measuring the turbidity and the iron concentration were extracted throughout the filter column at a constant depth of 100 cm. The filter run was terminated after 10 hours. Piezometers were installed along with the filter as shown in Figure 1. These piezometers served to measure the head loss at different heights of the filter, and thus the determination of the depth action. Three filter runs were performed for each iron concentration, for which the average values and standard deviation of the quality parameters were analyzed. The turbidity was measured in NTU using HACH 2100Q turbidimeter, the iron concentration was measured using PerkinElmer Atomic Absorption Spectrometry (AAnalyst 400) and the HANNA pH meter was used to measure the pH values for the inflow and filtrated water samples, which were between 7.5 to 8.5.

2.4 Filterability Index

To evaluate and compare the filter runs Filterability Index (FI) proposed by Ives (30) has been used. Ives' FI is defined as follows:

$$\text{FI} = \frac{Q}{Qo} \times \frac{H}{V \times t} \qquad \text{Eq. (1)}$$

where Q is the average effluent quality, Q_o inlet water quality, H head loss (m), V filtration rate (m/h), t is the duration of filtration run (h). This index has been used by several researchers to investigate the effectiveness of filtration (22, 31-34). This index gives a better explanation to the filter performance as it considers the head loss H and the duration of filtration run t. The duration of filtration run here is the maximum possible filter run time before either turbidity or iron concentration breakthrough (an increase in filter effluent turbidity or iron concentration above the allowable limits).

2.5 Backwash of the filter

At the end of each experiment run; backwashing was conducted with downflow clean water throughout the filter. Expansion of the media permits entrapped particles to release and flush downward out of the media and the gravitational force direction of the deposited solids coincides with the direction of wash water so that the required volume of wash water is less than that for sand filters (12). Backwashing water was introduced into the top of the filter by gravity flow at the rate of 1200 m^3/m^2/day for about 10 minutes (35). These parameters for backwash achieved an expansion of 18% which seems to be adequate according to Anderson et al (36).

3 Results and discussions

3.1 Effect of influent iron concentration (Fei) on influent turbidity (Ti):

It can be observed that there was a direct correlation between inlet iron concentration and turbidity as shown in Figure 2. This returns to the ability of suspended particles to increase the water turbidity. Turbidity of the water can normally originate from the presence of the suspended iron particles ($[CH_3(CH_2)_{10}CH_2oSo_3]_3^- Fe^+$). As a result of adding small quantities of a negatively charged surfactant to a solution of positively charged particulates, the particulates are partially coagulated into aggregates, which are clearly shown by an increase in the turbidity of the solution. This may return to the addition of SDS to the solution, which interacts with Fe(III) ions in the water. Fe(III) ions were attached to dodecyl sulfate. This increases the turbidity and enhances the filter's ability to remove Fe(III) ions. Figure 3 shows the chemical structure of SDS surfactant, the formation of Fe(III) ions, and the Fe(III)/SDS interaction in the solution.

3.2 Influence of influent iron concentration (Fe_i) on effluent turbidity (Te) at different filtration rate

Figure 4(a-d) shows the effluent turbidity (Te) at different influent iron concentrations (1-5 mg\l) under different filtration rate R (80 to 120 m3/m2/day). During the filter running time, the effect of influent iron concentrations (Fei) on effluent turbidities (Te) over time can be seen under a constant filtration rate. For instance, under varied Fei, at the same filtration rate (R) of 80 m^3/m^2/day, the effluent turbidities were plotted with square points, see Figure 4(a-d). For the filtration rate (R) (80 m^3/m^2/day), the filter was able to produce filtrated water with minimum turbidity of 0.35 NTU. The maximum influent turbidity was 12.5 NTU, and the corresponding Te was less than 1 NTU for 10 hours continuously, with no shutdown for the filter cleaning. The effluent turbidities were within the recommended limit, set by World Health Organization (WHO) for drinking water, which is 1.0 NTU (37).

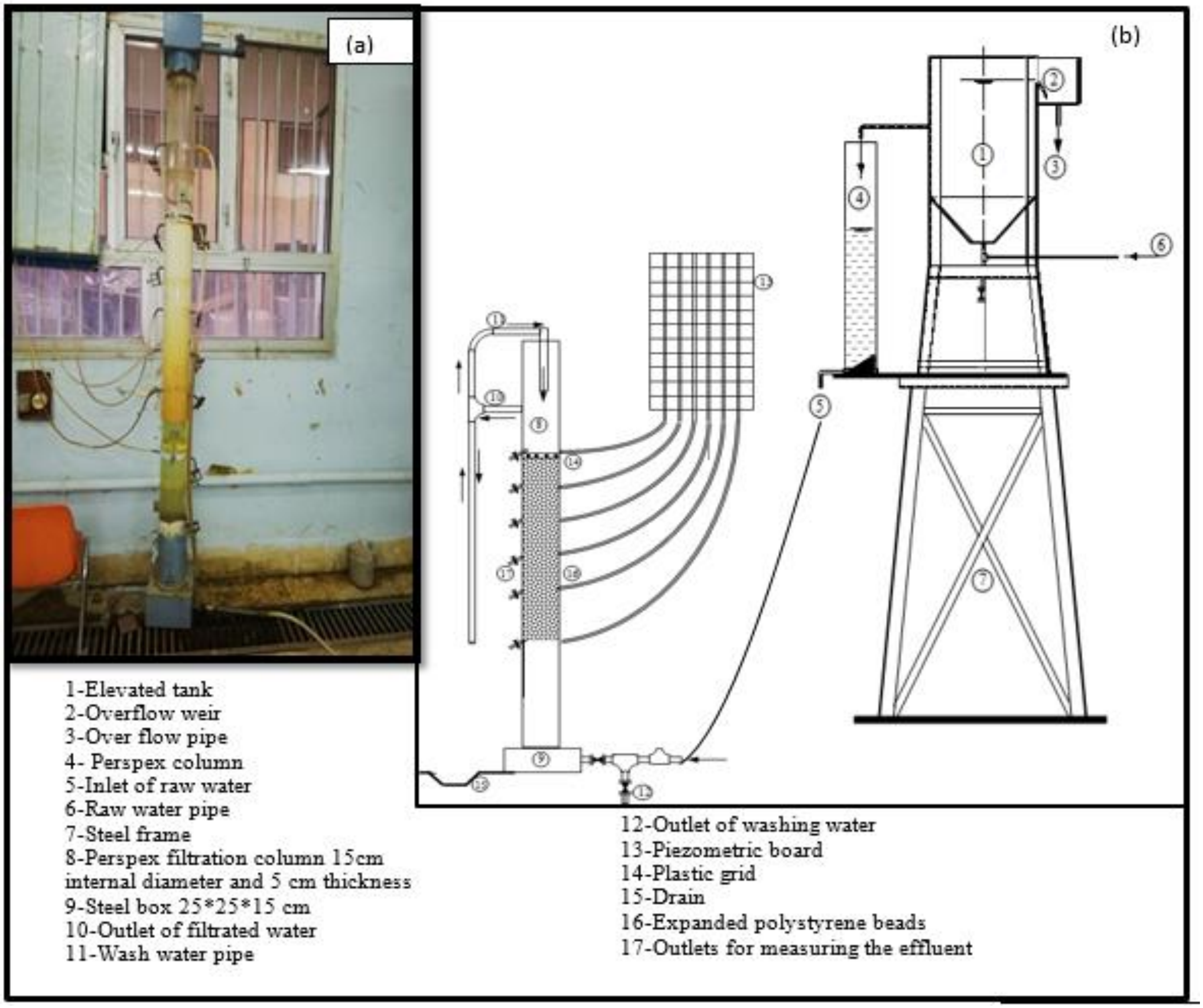


Figure 1: Schematic diagram of (a) Real photo and (b) the experimental setup

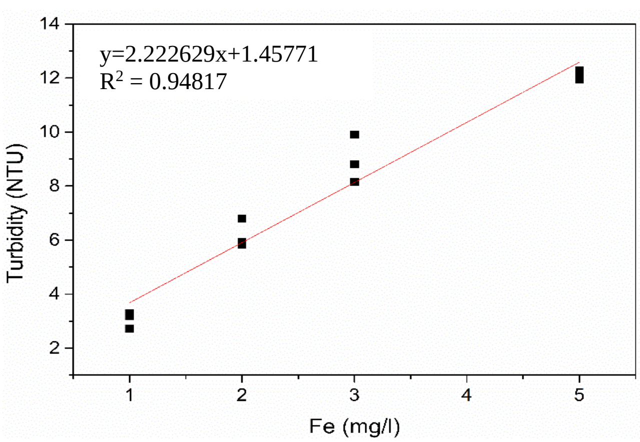


Figure 2: The correlation between inlet Fe concentration and inlet turbidity

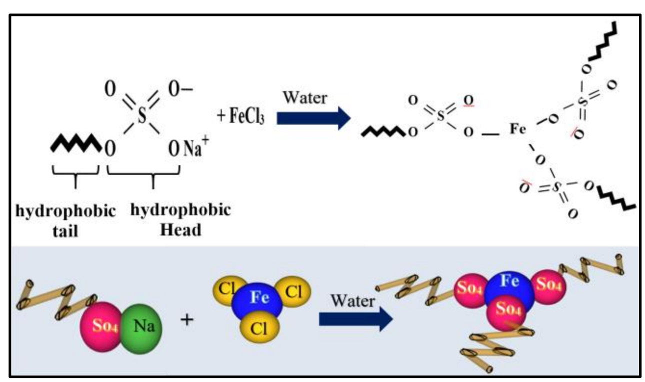


Figure 3: The chemical structure of SDS surfactant, the formation of Fe(III) ions, and the Fe(III)/SDS interaction in the solution

These results confirm the ability of the filter to efficiently remove the turbidity under these operating conditions. The effluent turbidities (Te) were plotted with circle points at the filtration rate (R) of 100 m3/m2/day, see Figure 4(a-d). At this filtration rate, the Figure shows that the filter was able to produce filtrated water with minimum turbidity of 0.45 NTU. Te was less than 1 NTU for 10 hours of continuous working of the filter for all Fei runs, except the run of influent turbidity (Ti) of 12.5 NTU. This run provided turbidity of less than 1.0 NTU for 8 hours only. After that, the effluent turbidity was more than 1 NTU. This means that the filter should be washed after 8 hours of continuous running at 100 m^3/m^2/day. The effluent turbidities (Te) were plotted with triangular points at the filtration rate of 120 m^3/m^2/day, see Figure 4**Error! Reference source not found.**(a-d). From the Figure, the filter was able to provide turbidity of less than 1 NTU for 8 hours of operation for all influent turbidities, However, the run of influent turbidity of 3.5 NTU (iron concentration of 1 mg/l) continued to provide turbidity less than 1.0 NTU for 10 hours. For the same filtration rate, the increments of Fei, lead to the increments of Te. This may return to the expanding of Ti with expanding of Fei, as mentioned in section 4.1. The expansion of Ti leads to increasing in Te. Also, it can be observed that after a certain time (depending on the initial influent iron concentration), the effluent turbidities started to increase. The reason could be that the accumulation of deposited iron particles within the EPS filter initially increases over the filtration time. Over time, the accumulated iron particles on the Expanded polystyrene (EPS) minimize the attachment of the incoming iron particles. The variation of filtrated water turbidity at different filtration rates is shown in Figure 4(a-d). The figure demonstrates that the filtration rate influences the effluent turbidity. As the filtration rate increases, the effluent turbidity increases. Many previous studies reported that good removal in the filters was achieved at a low filtration rate (4). The higher flow rate forces the particle to permeate deep into the filter. Since the filtration velocity is higher, the shear forces experienced by attached particles are greater. So, particle detachment is much more likely, leading to an early increase in the effluent turbidity. It was visually observed that as increasing the filtration rate from 80 to 120 m3/m2/day, particles penetrated deeper into the filter. This results in increasing effluent turbidity. This visual observation can be fully supported by the results shown in Figure 4(a-d), where the overall effluent turbidity for all initial turbidity values was better for a lower filtration rate. One possible reason for the increase in the filtrate turbidity is the shorter retention time corresponding to a higher filtration rate. In addition, the higher filtration rate results in greater fluid shear forces at the media surfaces. The increased shear force would likely result in a decrease in the iron attachment efficiency, because of the greater fluid drag on iron near the EPS media surface.

3.3 Influence of influent iron concentration (Fe_i) on effluent Iron Concentration (Fe_e) at different filtration rate

Figure 5(a-d) displays the effluent iron concentration (Fee) at different influent iron concentrations (Fei) (1-5 mg\l) under different filtration rate (80 to 120 m3/m2/day). For Fei=1 mg/l at different filtration rates, the variations of effluent iron concentrations over time were plotted in Figure 5a. The Figure shows that the effluent iron concentrations were decreased throughout the overall time of the run (10 hours). The reason could be that the accumulation of deposited iron particles within the EPS filter reduces the output iron concentration. The figure also represents that the filter was able to produce filtrate with a minimum iron concentration of 0.034 mg/l. furthermore, all effluent iron concentrations were less than that recommended by WHO for drinking water (0.3 mg/l) (9, 37). This may return to the low concentration of the Fei (1 mg/l), which facilitates the filter job to keep the effluent iron within the WHO standards.

Figure 5b displays the variations of effluent iron concentrations overtime at Fei = 2 mg/l within different filtration rates. The effluent iron concentrations (Fee) were less than 0.30 mg\l for all filtration rates (R) over 8 hours. The Fee at a filtration rate of 80 and 100 m^3/m^2/day continued decreasing throughout the overall time of the run. However, the Fee at the filtration rate of 120 m^3/m^2/day was decreased through the first 5 hours, then it flipped over to gradually raises till the end of the run time. The interpretation could return to the tendency of a high flow rate to push out the semi-adhesive iron on the EPS or iron-coated EPS. Figure 5c offers the variations of effluent iron concentrations over time at Fei=3 mg/l within different filtration rates. The effluent iron concentrations (Fee) were less than 0.30 mg\l for all filtration rates (R) over 8 hours. The Fee at a filtration rate of 80 m3/m2/day continued decreasing throughout the overall time of the run. However, the Fee at a filtration rate of 100 and 120 m^3/m^2/day was decreased through the first 5 and 4 hours, respectively, then it flipped over to gradually raises till the end of the run time. The interpretation could return to the tendency of a high flow rate to push out the semi-adhesive iron on the EPS or iron-coated EPS. Figure 5d offers the variations of effluent iron concentrations overtime at Fei = 5 mg/l within different filtration rates. The effluent iron concentrations (Fee) were less than 0.30 mg\l for all filtration rates (R) over 5 hours. The Fee at a filtration rate of 80 m^3/m^2/day continued decreasing throughout the overall time of the run. However, the Fee at a filtration rate of 100 and 120 m^3/m^2/day was decreased through the first 4 and 2 hours, respectively, then it flipped over to gradually raises till the end of the run. The same interpretation could be used in this run. Finally, it can be concluded that the filtration rate influences the effluent iron concentration. As the filtration rate increases the effluent iron concentration increases. Also, the increments in inlet iron concentration led to the increments in outlet iron concentration. As mentioned before, this may return to the shorter retention time corresponding to a higher filtration rate. The shorter retention time decreases the ability of iron adsorption on EPS. In addition, the higher filtration rate results in greater water shear forces at the EPS surfaces. Increased shear would likely result in a decrease in iron attachment efficiency because of the greater fluid drag on iron near the EPS surface.

3.4 Removal Efficiency

The main objective of the filtration process is to efficiently remove particles from the feed water. Therefore, the filtrated water quality is considered as one of the most important parameters for characterizing the filter efficiency. In this study, filter efficiency was defined in terms of effluent turbidity and iron concentration. The efficiency was calculated based on the average values of effluent quality during the entire run time (10 hours). A comparison was made to investigate the turbidity removal efficiency for different filtration rates as plotted in Figure 6.

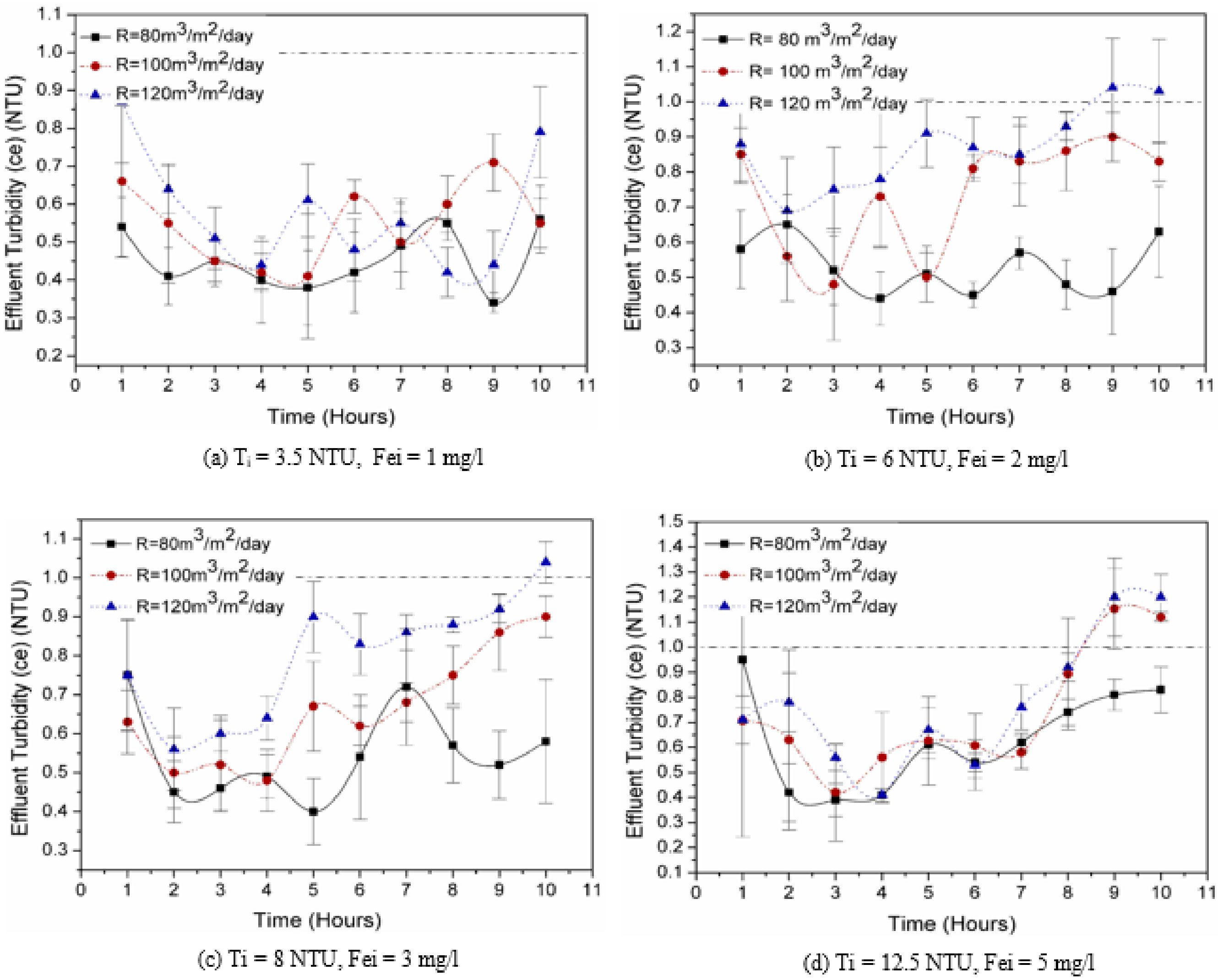


Figure 4: Effluent Turbidity versus Time at different filtration rates and influent iron concentrations

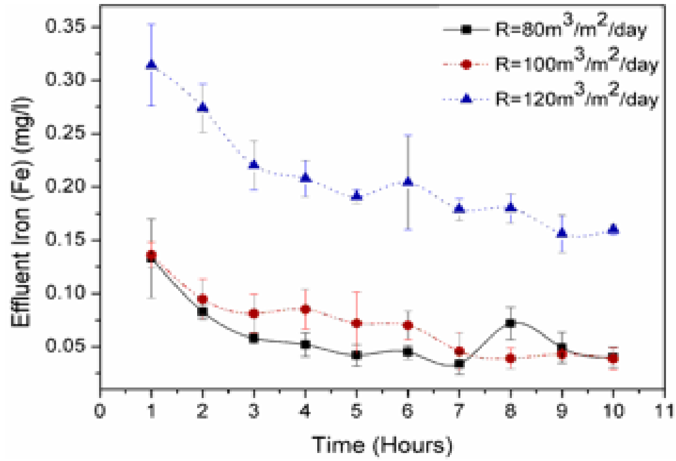
Turbidity removal efficiency can be expressed as the follows (5):

$$TRE\% = \frac{\text{Influent turbidity} - \text{Effluent turbidity}}{\text{Influent turbidity}} \qquad \text{Eq. (3)}$$

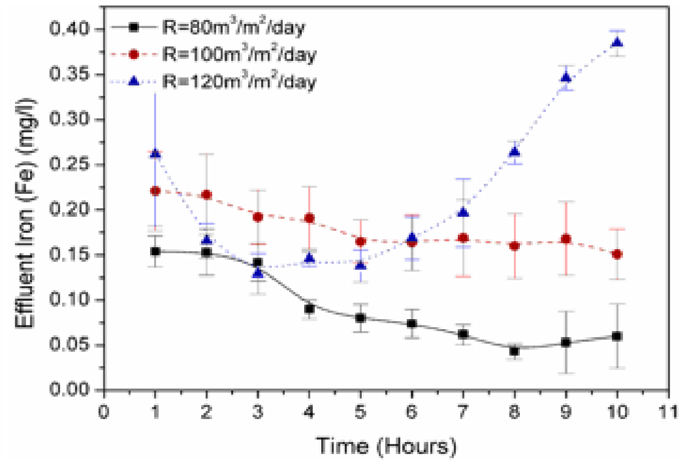
where TRE is turbidity removal efficiency in percentage. The results presented in Figure 6 shows that percentage of turbidity removal varied from a minimum of 83.5% for filtration rate 120 m^3/m^2/day and initial turbidity 3.5 NTU (Highest filtration rate and lowest initial turbidity) to a maximum of 95% for filtration rate 80 m^3/m^2/day and initial turbidity 12.5 NTU (Lowest filtration rate and highest initial turbidity). The same reasons, as mentioned before, could interpret the improvement of turbidity removal with decreasing the filtration rate. The turbidity removal efficiency can be more obvious within higher influent turbidity. It may return to the increment of the influent turbidity causes particle accumulation within the first part of the filter. Figure 7 gives a comparison of the Iron removal efficiency for different filtration rates. The iron removal efficiency was calculated as follows:

$$\text{IRE\%} = \frac{\text{Iron } C_i - \text{Iron } C_e}{\text{Iron } C_i} \qquad Eq.(4)$$

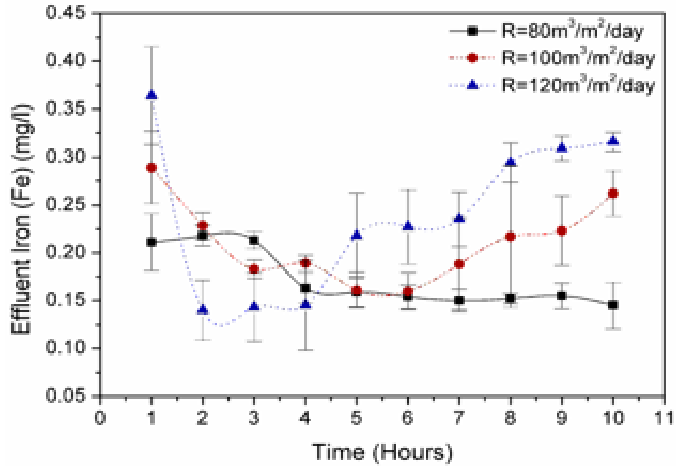
where IRE is iron removal efficiency, Iron C_i is influent iron concentration and Iron C_e is effluent iron concentration. The results presented in Figure 7 shows that the percentage of iron removal varied from a minimum of 79% for filtration rate 120 m3/m2/day and initial iron concentration 1 mg/l (Highest filtration rate and lowest initial iron concentration) to a maximum of 97% for filtration rate 80 m3/m2/day and initial iron concentration 5 mg/l (Lowest filtration rate and highest initial iron concentration). It is obvious to see that the removal efficiencies for both turbidity and iron decrease as the filtration rates increase, while the removal efficiencies increase as initial turbidities and iron concentration increase.



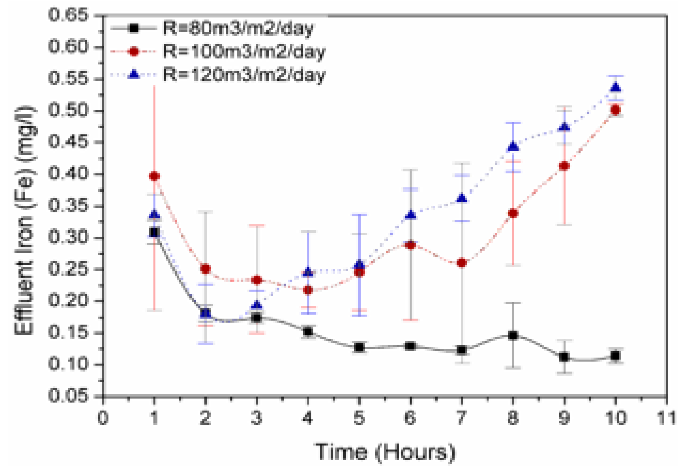
(a) T_i = 3.5 NTU, Fe_i = 1 mg/l



(b) Ti = 6 NTU, Fei = 2 mg/l



(c) Ti = 8 NTU, Fei = 3 mg/l



(d) Ti = 12.5 NTU, Fei = 5 mg/l

Figure 5: Effluent Iron concentration versus time at different filtration rates and influent iron concentrations

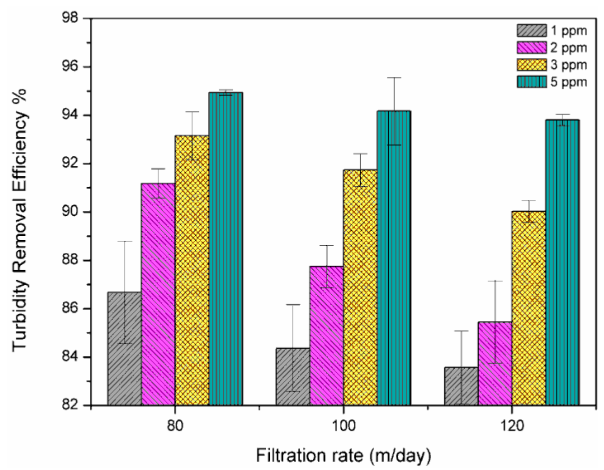


Figure 6: Turbidity removal efficiency with different filtration rates and initial iron concentrations of 1,2, 3, and 5 mg/l

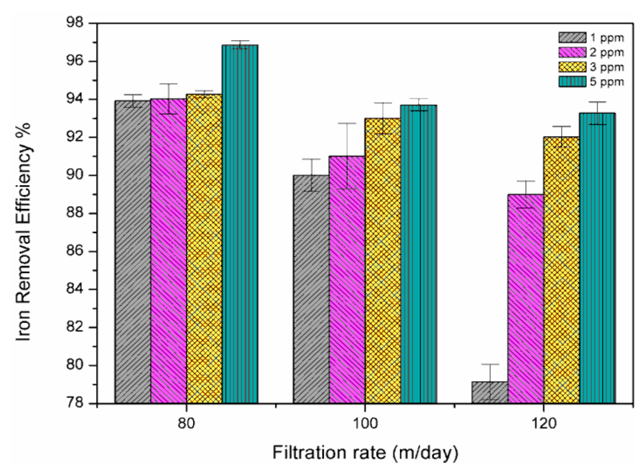


Figure 7: Iron removal efficiency with different filtration rates and initial iron concentrations of 1,2, 3, and 5 mg/l

This returns to the high tendency of iron and turbidites to cross the filter at a high filtration rate, that associates with greater water shear forces at the EPS surfaces.

3.5 Filterability Index

The calculated turbidity filterability indexes for various experimental conditions are plotted in Figure 8. One of the most evident effects of a rate increase from 80 to 120 m/day is that the FI values increased as shown in Figure 8. This means that higher rates result in lower filtrate quality and/or higher head loss values. Return to Equation (1), at constant influent water quality, small head loss (H), long filter run time (t), and low effluent quality (Qe), and high filtration rate (V) will yield a small filterability index (FI) and better filtration performance (31). From Figure 8, at the low filtration rate, the high influent turbidity gives small FI and better filtration performance because of the reasonably elapsed time for turbidity evacuation. However, a high filtration rate provides small FI and better filtration performance at low influent turbidity because of the simplicity of turbidity removal. These results are consistent with Crittenden et al (25). Figure 9 shows the Filterability Index variation for different initial iron concentrations. As the filtration rate increases, the filterability index increases. The increase in FI values results mostly from effluent quality deterioration when the filtration rate is increased.

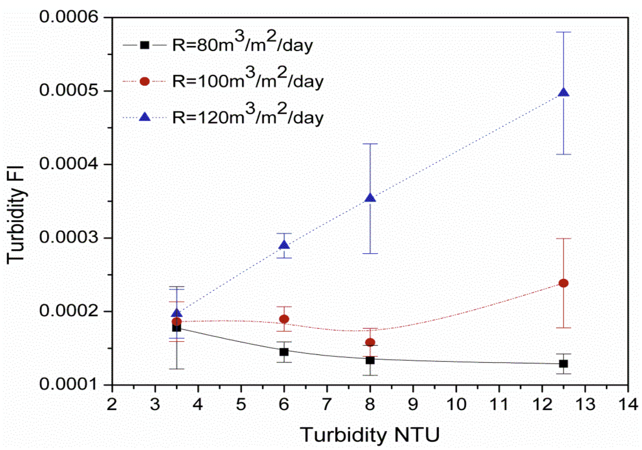


Figure 8: Filterability index for different influent turbidities at different filtration rate

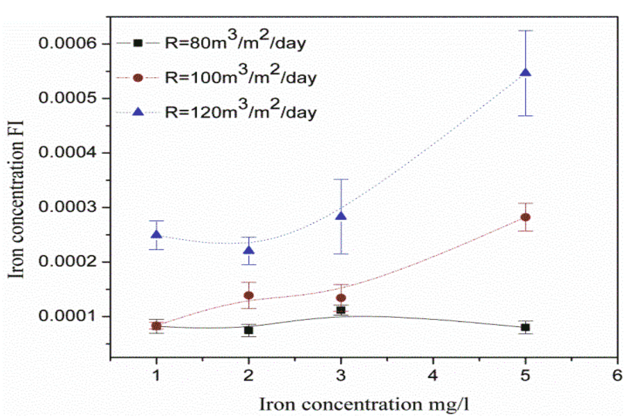


Figure 9: Filterability index for different influent iron concentrations at different filtration rate

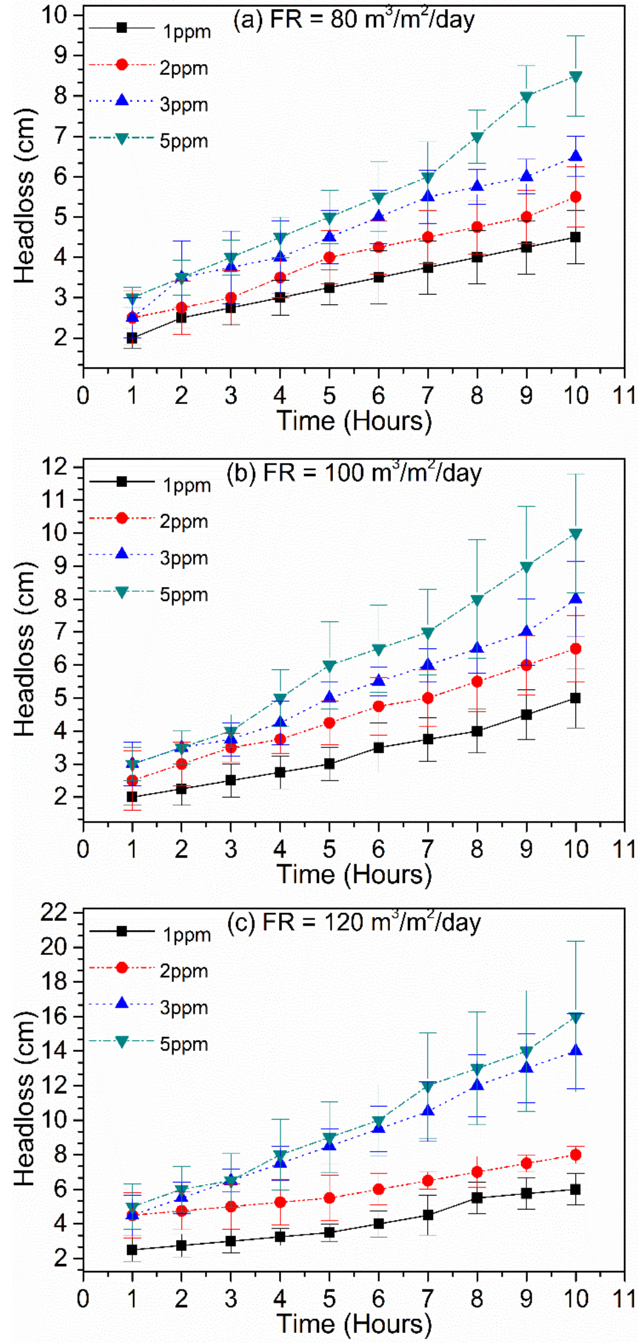


Figure 10: Filter headloss as a function of filtration time at filtration rate (FR) of 80 $m^3/m^2/day$ (a); 100 $m^3/m^2/day$ (b); and 100 $m^3/m^2/day$ (c)

3.6 Headloss:

Figure 10 shows the relationship between the headloss and filter run time at different filtration rates with different iron concentrations. As expected the headloss increased with filter run time. As the filtration process progresses, iron particles retained in the voids lead to a decrease in the filter bed voidage. The resistance of the bed to the water flow will increase due to the size reductions of the interstitial spaces between EPS grains.

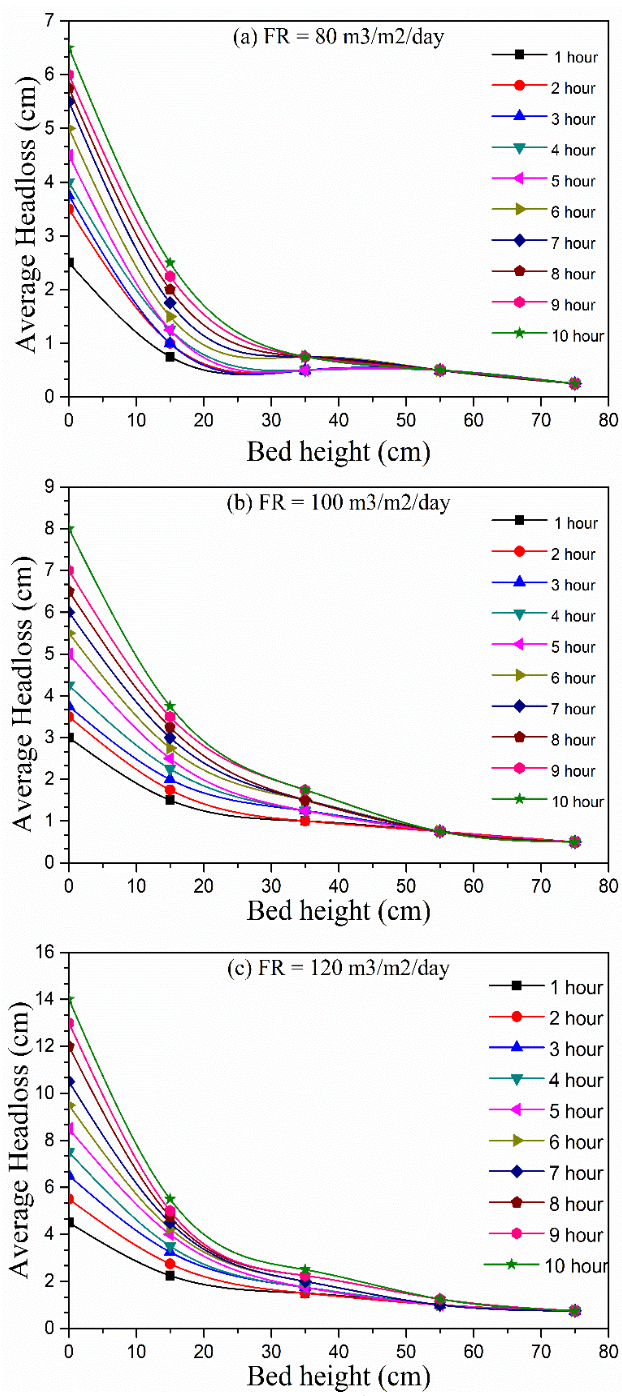


Figure 11: Headloss variation along filter bed versus time at Fe = 3 mg/l and Filtration Rate (FR) of 80 m^3/m^2/day (a); 100 m^3/m^2/day (b); and 100 m^3/m^2/day (c)

Increasing resistance with time leads to increasing the headloss. In Figure 10, the increment rate of headloss was gradual with filtration run time. The headloss development is mostly linear with filter run time. The flow rate also affected the headloss; the higher flow rates resulted in greater headloss as it contributed to higher solid loading. The headloss development was increased with increasing the influent iron concentration. It can be noted that the headloss in the filter was very low, the reason is the use of up-flow expanded polystyrene (floating media) filter. Floating media filters are claimed to have high retention capacity with low head loss development compared to conventional sand filters. Figure 11 presented the head loss versus the different depths of the filter bed. It was noticed that; most of the particles were removed in the first 50 to 60 cm of the filter bed; the headloss development in the first 50 cm is remarkable. The reason could be that most iron particles are trapped in the first 50 cm of the filter, causing the reduction of filter bed voids. The resistance of the bed to the water flow will increase due to the size reductions of the interstitial spaces between EPS grains. Increasing resistance with time leads to increasing the headloss.

3.7 Filter bed Expansion:

Backwash rate of 1200 m3/m2/day achieved an expansion of 18% which seems to be adequate according to Anderson et al (36), expansion less than 15% will likely cause inadequate cleaning of the filter. This percent was calculated from the following equation (36):

$$PBE = \frac{Length\ of\ expansion}{Length\ of\ expandable\ media} X100 \qquad Eq.(5)$$

where PBE is the percent of bed expansion.

4 Conclusions

A study on a pilot plant was conducted to observe the iron filtration process using EPS as a floating medium. Different iron concentrations and filtration rates have been tested. The study results showed that the effluent iron concentration and turbidity are greatly affected by the variations of the flirtation rate and the influent iron concentration. The iron and turbidity removal efficiencies increase with the increase of the influent iron concentration for the same filtration rate. Each of the filtration rates and the influent iron concentration has a great influence on the head loss through the filter run. With the increase of any one of the previous parameters the head loss increases. The lightweight of the expanded polystyrene can enhance the cleaning process. It could be concluded that the EPS filter is a promising technology for water purification systems. SDS has shown a considerable ability to remove iron as a coagulant in water. However, a tracer study should be conducted to examine the SDS secondary contamination in drinking water.

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Ethical issue

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

Competing interests

I declare that no conflict of interest would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution to data collection, data analyses, and manuscript writing.

References

1. Marsidi N, Hasan HA, Abdullah SRS. A review of biological aerated filters for iron and manganese ions removal in water treatment. Journal of Water Process Engineering. 2018;23:1-12 DOI: http://dx.doi.org/10.1016/j.jwpe.2018.01.010.
2. Lopez-Gunn E, Jarvis WT. Groundwater governance and the Law of the Hidden Sea. Water Policy. 2009;11(6):742-62 DOI.
3. Baruth EE. Water Treatment Plant Design (; American Water Works Association, and American Society of Civil Engineers. New York: McGraw-Hill; 2005.
4. Brika B. Investigation of geometric properties of media particles for floating media filter: Stellenbosch: University of Stellenbosch; 2010.
5. Ramavandi B. Treatment of water turbidity and bacteria by using a coagulant extracted from Plantago ovata. Water Resources and Industry. 2014;6:36-50 DOI: http://dx.doi.org/10.1016/j.wri.2014.07.001.
6. Chaturvedi S, Dave PN. Removal of iron for safe drinking water. Desalination. 2012;303:1-11 DOI: http://dx.doi.org/10.1016/j.desal.2012.07.003.
7. Liu G, Zhang Y, Knibbe W-J, Feng C, Liu W, Medema G, et al. Potential impacts of changing supply-water quality on drinking water distribution: A review. Water research. 2017;116:135-48 DOI: http://dx.doi.org/10.1016/j.watres.2017.03.031.
8. Vigneswaran S, Setiadi T. Flocculation study on spiral flocculator. Water, Air, and Soil Pollution. 1986;29(2):165-88 DOI: http://dx.doi.org/10.1007/BF00208407.
9. EPA. Drinking Water Contaminants: Secondary Drinking Water Regulations: Guidance for Nuisance Chemicals; 2021 [Available from: http://water.epa.gov/drink/contaminants/secondarystandards.cfm.
10. Bourke N, Carty G, Crowe M, Lambert MJPbtEPA, Ireland. Water treatment manuals filtration. 1995 DOI.
11. Hong J, Ko D, Hwang YJJoHM. Disulfide polymer grafted polypropylene/polyethylene filter media for selective cadmium removal. 2020:123060 DOI.
12. El Etriby H, Menlibai M, editors. Sewage tertiary treatment using floating media filters. Second International water technology conference Alexandria, Egypt; 1997 DOI.
13. Ngo H, Vigneswaran S. Application of floating medium filter in water and wastewater treatment with contact-flocculation filtration arrangement. Water Research. 1995;29(9):2211-3 DOI:http://dx.doi.org/10.1016/0043-1354(95)00016-E.
14. El-Etriby HK, Radwan KH, Aawad HAJBotFoEMU. Manganese removal from ground water using expanded polystyrene beads as filtering media.(Dept. C.(Public Works)). 2020;39(4):42-51 DOI.
15. Bratskaya S, Schwarz S, Chervonetsky D. Comparative study of humic acids flocculation with chitosan hydrochloride and chitosan glutamate. Water Research. 2004;38(12):2955-61 DOI:http://dx.doi.org/10.1016/j.watres.2004.03.033.
16. Devrimci HA, Yuksel AM, Sanin FD. Algal alginate: A potential coagulant for drinking water treatment. Desalination. 2012;299:16-21 DOI.
17. Bobka MS. The 21CFR Online Database: Food and Drug Administration Regulations Full-Text. Medical reference services quarterly. 1993;12(1):7-15 DOI.
18. Bondi CA, Marks JL, Wroblewski LB, Raatikainen HS, Lenox SR, Gebhardt KE. Human and environmental toxicity of sodium lauryl sulfate (SLS): evidence for safe use in household cleaning products. Environmental health insights. 2015;9:EHI. S31765 DOI.
19. Odud L. EXPANDED POLYSTYRENE IN WATER SOFTENING TECHNOLOGIES. Коммунальное хозяйство городов. 2017(137):87-92 DOI.
20. Schöntag JM, Pizzolatti BS, Jangada VH, de Souza FH, Sens ML. Water quality produced by polystyrene granules as a media filter on rapid filters. Journal of Water Process Engineering. 2015;5:118-26 DOI: http://dx.doi.org/10.1016/j.jwpe.2015.02.001.
21. Kwon D-Y, Kwon J-H, Jo G-J. Removal of algae and turbidity by floating-media and sand filtration. Desalination and Water Treatment. 2014;52(4-6):1007-13 DOI.
22. Schöntag JM, Moreira FM, Sens ML. Filtration capacity on rapid filters and adsorption characteristics of polystyrene granules. Environmental technology. 2017;38(16):2013-23 DOI: http://dx.doi.org/10.1080/09593330.2016.1244569.
23. Orlov V, Martynov S, Kunytskiy S. Energy saving in water treatment technologies with polystyrene foam filters. Journal of Water and Land Development. 2016 DOI: http://dx.doi.org/10.1515/jwld-2016-0042.
24. Morosini DF, Baltar CAM, Duarte-Coelho AC. Iron removal by precipitate flotation. Rem: Revista Escola de Minas. 2014;67(2):203-7 DOI: http://dx.doi.org/10.1590/S0370-44672014000200012.
25. Crittenden JC, Trussell RR, Hand DW, Howe KJ, Tchobanoglous G. MWH's water treatment: principles and design: John Wiley & Sons; 2012. DOI: http://dx.doi.org/10.1002/9781118131473.
26. Missimer T, Lopez O. Laboratory measurement of total porosity in unconsolidated quartz sand by two integrated methods. J Geol Geophys. 2018;7(448):2 DOI.
27. Zyara AM. Removal of viruses from drinking water by chlorine and UV disinfections: Itä-Suomen yliopisto; 2018. DOI.
28. Rostami S, Raki E, Abdollahi A, Goldanlou ASJPT. Effects of different magnetic fields on the boiling heat transfer coefficient of the NiO/deionized water nanofluid, an experimental investigation. 2020;376:398-409 DOI: http://dx.doi.org/10.1016/j.powtec.2020.08.045.
29. Singer MM, Tjeerdema RS. Fate and effects of the surfactant sodium dodecyl sulfate. Reviews of environmental contamination and toxicology: Springer; 1993. p. 95-149:http://dx.doi.org/10.1007/978-1-4613-9529-4_3.
30. Ives KJ, editor A new concept of filterability. Ninth International Conference on Water Pollution Research; 1979: Elsevier; DOI: http://dx.doi.org/10.1016/B978-0-08-022939-3.50016-7.
31. Kang SF, Shieh CC, Chiang TH. Filtration performance of a plastic-sand dual-media filter. Journal of Environmental Science & Health Part A. 1999;34(7):1533-52 DOI: http://dx.doi.org/10.1080/10934529909376910.
32. Tchio M, Koudjonou B, Desjardins R, Prévost M, Barbeau B. A practical guide for determining appropriate chemical dosages for direct filtration. Canadian Journal of Civil Engineering. 2003;30(4):754-7 DOI: http://dx.doi.org/10.1139/l03-037.
33. Jiao R, Fabris R, Chow CW, Drikas M, van Leeuwen J, Wang D. Roles of coagulant species and mechanisms on floc characteristics and filterability. Chemosphere. 2016;150:211-8 DOI: http://dx.doi.org/10.1016/j.chemosphere.2016.02.030.
34. Hunce SY, Soyer E, Akgiray Ö. Use of filterability index in granular filtration: effect of filter medium type, size and shape. Water Supply. 2019;19(2):382-91 DOI: http://dx.doi.org/10.2166/ws.2018.083.
35. Visvanathan C, Werellagama D, Aim RB. Surface water pretreatment using floating media filter. Journal of environmental engineering. 1996;122(1):25-33 DOI: http://dx.doi.org/10.1061/(ASCE)0733-9372(1996)122:1(25).
36. Anderson K, Chescattie E. Incorporating filter bed expansion measurements into your backwashing routine. AWWA AQTC Conference2003 DOI.
37. Organization WH. Guidelines for drinking-water quality, third. Geneva; 2004.