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Performance of direct filtration with multi-media filters for reuse of wastewater treatment plant effluent: a case study. Baharan industrial wastewater treatment plant

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ABSTRACT

The aim of the present study was to explore the possibility of using the downflow filtration process using multi-media filters as a good alternative to the reuse of wastewater from the wastewater treatment plant of Baharan Industrial Town, Hamadan, Iran. The experiments were carried out with a pilot-scale reactor and three variants of the filter medium including garnet, silica, and anthracite. To achieve the aims of the present study, the effectiveness of three different coagulants including poly aluminum chloride (PAC), sulfate aluminum (Alum), and ferric chloride ($FeCl_3$) were investigated. Different operational parameters, that is, turbidity, total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total phosphorous (TP), and heavy metals were investigated before and after filtration. The results indicated that the best coagulant for the coagulation process was alum (the concentration of 400 mg/L). Also, the maximum removal efficiency of turbidity, TS, TSS, TDS, COD, BOD_5, and TP were 96.99% ± 0.6%, 25.64% ± 3.6%, 97.02% ± 0.6%, 19.31% ± 3.9%, 80.89% ± 3%, 81.6% ± 3%, and 83.20% ± 2.14% at a surface load of 5 m/h after a contact time of 6 h, respectively. The maximum removal rate of heavy metals was 58.9% after 9 h of filter operation at a surface load of 5 m/h. The use of a direct filtration process with multi-bed filters could provide the possibility of use of the wastewater treatment plant effluent of Baharan industrial town in agriculture so that this effluent can be employed as a water resource.

Keywords: Direct filtration; Multi-media filters; Wastewater reuse; Baharan industrial town

1. Introduction

Drought and water shortages in countries around the world, including Iran, have caused many problems, especially in the tropics. Increasing population and subsequent development of industry and agriculture have led to a significant increase in water consumption. Excessive extraction from groundwater aquifers and contamination of surface water have also exacerbated the water shortages. Given the current situation, the use of wastewater is a basic solution to meet water needs [1,2]. Reuse and recycling of treated wastewater for use in various applications such as irrigation of agricultural lands, industrial cooling, aquaculture, and artificial recharge of groundwater aquifers are suitable solutions to deal with the water shortages. Today, the use of treated wastewater for discharge to water intake resources (surface and groundwater) is of great importance as an important and permanent source due to the lack of fluctuations in production throughout the year, lack of

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relationship with annual rainfall, and ease of access [3]. The use of wastewater for various purposes, due to high contact with humans, will lead to severe health risks associated with biological pathogens such as pathogenic bacteria, worms, protozoa, and intestinal viruses; therefore, the protection against these microbial factors should be considered more than other cases [2]. Due to the irreparable damage caused by improper disposal of raw or treated wastewater to the environment, health and environmental guidelines have been enacted regarding discharge to receiving sources, which are known as wastewater disposal standards [4,5]. With the discovery of the relationship between water pollution caused by wastewater discharge and water-related diseases, various engineering methods were introduced to change the water intake points of the river and the need for advanced treatment to provide safe water. In third world countries, especially tropical and subtropical countries, simple, cheap, and reliable technology is needed to access new water resources. In wastewater reuse planning, the type of consumption determines the amount of treatment required, the quality of water produced, and the quality of water distribution and use. One of the cases is the proper use of wastewater from treatment plants for various urban uses [6]. For this purpose, conventional treatment, which is carried out in accordance with the physical and chemical standards of discharge, often cannot bring the microbial and chemical quality of the effluent to an acceptable level for water reuse [7]. Recently, the use of biological processes in either attached and suspended growth in industrial wastewater treatment has been proposed, especially to remove resistant toxic substances, organic matter, and nutrients from industrial effluents [8]. Therefore, the possibility of reuse of the treated wastewater requires an advanced treatment stage on the effluent after biological treatment. For this, advanced treatment processes to achieve quality standards for wastewater reuse include processes based on solid and liquid separation such as chemical coagulation, flocculation, filtration, and disinfection [9]. In the advanced wastewater treatment process, filtration [10], reverse osmosis [11], membrane methods [12], adsorption [13], advanced oxidation processes [14], and natural treatment [15] have been achieved to meet guidelines and standards for wastewater reuse [16]. Among the various advanced wastewater treatment method, the filtration processes have been used as one of the oldest and simplest treatment methods. There are various types of filters, and different factors including economic considerations, contaminant removal efficiency, and saving water consumption for backwash water are effective in selecting the filter type [2]. Traditionally, single media filtration with granular media, such as sand, has been employed to treat water and wastewater, depending upon the flow rate applied. However, filtration with sand media is still unable to remove water impurities including ammonium ions [17]. In the second half of the 20th century, sand media combined with other media such as activated carbon and zeolites have exhibited adequate hydraulic properties and effectiveness in removing pollutants in aquatic solutions [18]. Recently, multimedia filters, which are an upgrade of single and dual media, are used for increasing filtration efficiency. The media combination has additional characteristics apart from removing particulates in the filtration process, as well as removing dissolved organic substances in the adsorption process [19,20].

The longer life cycle of the filter, the higher filtration rate, and the greater ability to filter the water with high turbidity and suspended solids are the main advantages of multi-media filters, compared to single and dual media filters [21]. Direct filtration, as a method used for treating water, consists of the addition of coagulant chemicals, flash mixing, coagulation, minimal flocculation, and filtration, which has been used for improving surface water quality. High filtration rate, reduced operating and maintenance costs, lower initial investment, and less land requirement due to the elimination of the clarification process before filtration are the advantages of direct filtration compared to conventional filtration [22,23].

Baharan industrial area was selected for this study. The plants with an area of 136×10^4 m^2 are located in Hamadan province which is located in the west of Iran. Currently, 56 active industrial units are operating in this complex industrial unit. These plants discharge their wastewater with a volume of 360 m^3/d directly into the special industrial sewage system. In this wastewater treatment plant, the wastewater from industries is conventionally treated by the biological treatment process. Finally, the effluents directly discharge to the environment which does not conform to wastewater reuse guidelines in terms of physicochemical and microbial properties. In the present study, the effectiveness of direct filtration using a multi-media filter for treating the effluent of the Baharan industrial wastewater treatment plant was investigated.

2. Materials and methods

2.1. Chemicals

The chemicals used in this study include alum, ferric chloride, poly aluminum chloride (PAC). The chemicals used in this study are purchased from the Merck Company, Germany. The purity of ferric chloride, alum, and PAC coagulants used in this study is 99%, 58%, and 29%, respectively.

The most commonly used coagulants are ferric sulfate, aluminum sulfate, ferrous sulfate, and ferric chloride. The most common coagulants for water treatment are aluminum sulfate and iron salts, while alum and lime are mostly used for wastewater treatment. Aluminum sulfate (alum) is used more than iron salts because it is cheaper. The most common coagulants for removing turbidity from water are iron and aluminum salts, including ferric sulfate, aluminum sulfate, and PAC, all of which are synthetic and mineral materials. The use of ferric chloride to remove turbidity is associated with the formation of color in the water, which causes the reddish-yellow and yellow spots on objects, and if its amount in the water is more than 1 mg/L, it causes turbidity and gives the water a medicinal taste. The need for oxygen and high pH for ferrous sulfate and the need for high alkalinity of water to use ferric sulfate and ferric chloride, as well as the low efficiency of these coagulants in case of high concentration of organic matter and dye, are among the problems associated with the use of the mentioned coagulants [24,25].

2.2. Pilot specifications and run

The present study was an experimental study that was conducted using a pilot-scale laboratory with continuous flow. This study was performed on a real sample of effluent from the industrial treatment plant of Baharan industrial town in the chemistry laboratory located in the Faculty of Health of Hamadan University of Medical Sciences. A pilot-scale system was used for this study. The main components of the pilot used in this study were a rectangular cylinder made of Plexiglas with a height of 2 m and a cross-section of 36 cm^2 with a square cube cross-section consisting of overflow to adjust the water height on the bed, and inlet and outlet adjustment valves. Also, a peristaltic pump was used to regulate the inlet flow to the substrate and equipment related to coagulation and flocculation consisting of a mixer and coagulation pool. Discharge of effluent on the bed was done by inlet valves and sampling to measure the desired parameters, as well as washing with water and air compressor was performed by the outlet valve. The direction of flow was down-flow. The substrates used in this study were anthracite, silica, and garnet, and the total height of the substrates in this pilot was 75 cm; this bed included 40 cm of anthracite (ES = 1.4 mm, UC = 1.6) with a specific gravity of 1.6 as the top layer, 25 cm of silica sand (ES = 0.6 mm, UC = 1.6) with a specific gravity of 2.65 as the middle layer, and 10 cm garnet (ES = 0.3 mm, UC = 1.6) with a specific weight of 4.2 as end layer. Fig. 1 shows the real and schematic diagram of the pilot plant. Jar test was performed to determine the optimal type and dose of coagulant using a jar test device and different amounts of coagulant [5]. In this study, three types of common and widely used coagulants including alum, ferric chloride, and PAC, which are used in most treatment processes and are easy to access, were used.

2.3. Method of analysis

After transferring the effluent from the wastewater treatment plant of Baharan Industrial Town to the Environmental Chemistry Laboratory of the Department of Environmental Health Engineering, the effect of conventional variables on the coagulation process including pH (alum: pH = 5.5–7, PAC: pH = 6.5–8.5, and ferric chloride: pH = 5.5–7.5) and concentration of coagulant (alum: 5–50 mg/L, PAC: 2–15 mg/L, and ferric chloride: 10–50 mg/L) was investigated separately and during the rapid mixing (120 rpm), slow mixing (20 rpm) and settling

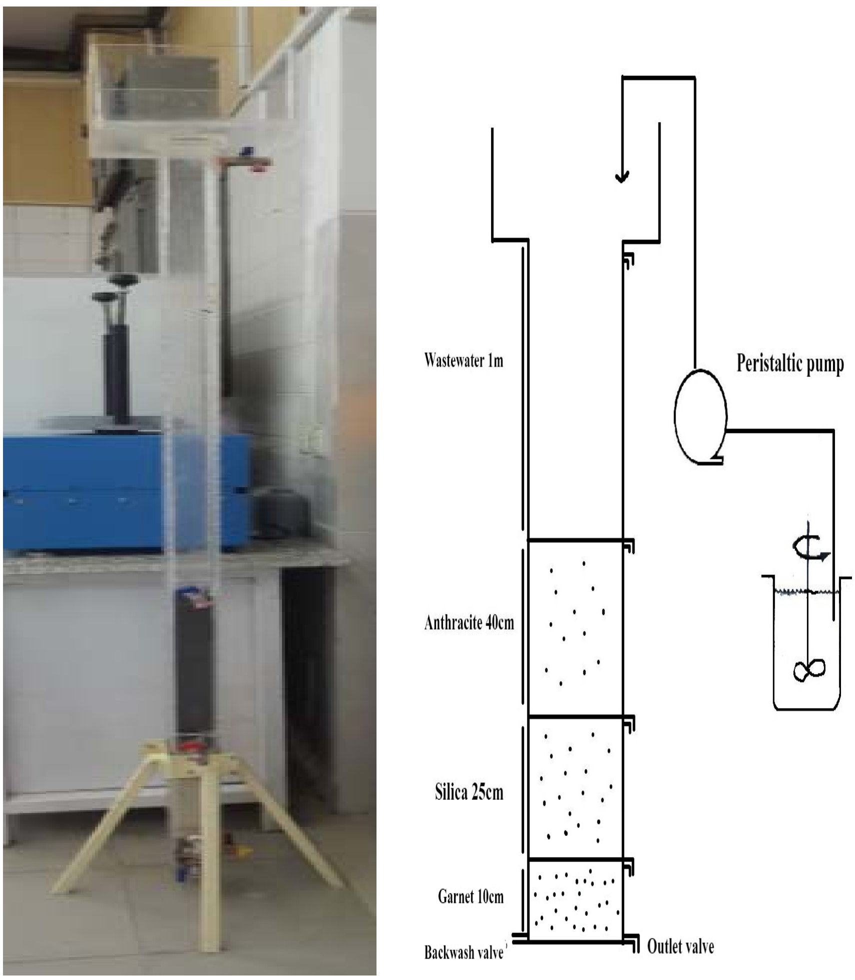

Fig. 1. Real (a) and schematic (b) diagram of the pilot plant.

(20 min) steps. The turbidity of the effluent was determined at each stage of the experiments, and finally, the best type and concentration of coagulant was determined. Coagulation steps were performed on the actual sample using the optimal type and dose of coagulant and injected on the substrate using a peristaltic pump at 3 levels of the surface load of 5, 8, and 12 $m^3/m^2/h$. Each time, the desired surface of the reactor was tested 3 times, the average results were reported. The experiments were performed to measure the output characteristics of the filter at intervals of 3 h every 24 h of filter operation to determine the physical and chemical parameters. Tests of turbidity, pH, total phosphorus (TP), total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and heavy metals including cadmium, chromium, and lead were performed on the inlet and outlet samples of the filter, according to the standard method guidelines [26]. Then, the results of each stage of the experiments were compared with the standards of the Environmental Protection Organization of Iran, and Excel software was used to draw the graphs.

3. Results

Jar test was used to determine the optimal type and dose of coagulants in different turbidities. In this experiment, three coagulants of ferric chloride, alum, and PAC were used. The results of turbidity removal with each of the coagulants are shown in Tables 1–3.

According to Table 1, mixing with different amounts of aluminum sulfate (alum) coagulant was performed using the initial turbidity of 80.6 NTU at a pH of 7. The jar test was performed during rapid mixing of 120 rpm (for 1 min), slow mixing of 20 rpm (for 15 min), and settling for 20 min. The results showed that alum at the dose of 400 mg/L had the highest removal efficiency. By increasing the amount of coagulant from 100 to 400 mg/L, secondary turbidity was decreased and the turbidity removal efficiency was increased, and with increasing coagulant amount to more than 400 mg/L, the secondary turbidity increased and as a result, the turbidity removal efficiency decreased.

In addition, mixing with different amounts of PAC coagulant was performed at the initial turbidity of 80.6 NTU and pH of 7. The jar test was performed during rapid mixing of 120 rpm (for 1 min), slow mixing of 20 rpm (for 15 min), and settling for 20 min. The results showed that PAC had the highest removal efficiency at a dose of 240 mg/L. By increasing the amount of coagulant from 120 to 240 mg/L, secondary turbidity was reduced and the turbidity removal efficiency was enhanced, and with increasing coagulant amount to more than 240 mg/L, the secondary turbidity increased, and as a result, the turbidity removal efficiency decreased. Table 2 shows the findings from the jar test using the PAC coagulant.

At initial turbidity of 80.6 NTU and pH = 7, mixing with different amounts of ferric chloride coagulant was performed. The jar test was performed during rapid mixing of 120 rpm (for 1 min), slow mixing at 20 rpm (for 15 min), and settling for 20 min. The results showed that ferric chloride at a dose of 500 mg/L had the highest removal efficiency. By increasing the amount of coagulant from 100 to 500 mg/L, secondary turbidity was declined and the turbidity removal efficiency was increased, and with increasing coagulant amount to more than 500 mg/L, the secondary turbidity

Table 1
Removal of turbidity using different concentrations of alum coagulant in jar test

Coagulant dose (mg/L)	100	200	300	400	500	600
Primary turbidity (NTU)	80.6					
Secondary turbidity (NTU)	24.9	7.85	5.05	2.94	3.26	4.46
Removal efficiency (%)	69.11	90.26	93.73	96.35	95.95	94.47

Table 2
Turbidity removal rate using different concentrations of PAC coagulant in jar test

Coagulant dose (mg/L)	120	160	200	240	280
Primary turbidity (NTU)	80.6				
Secondary turbidity (NTU)	33	27.5	21.4	18.8	25
Removal efficiency (%)	59.06	65.88	73.45	76.67	68.98

Table 3
Turbidity removal rate using different concentrations of ferric chloride coagulant in jar test

Coagulant dose (mg/L)	100	200	300	400	500	600
Primary turbidity (NTU)	80.6					
Secondary turbidity (NTU)	45.85	19.4	15.3	12.4	4.17	12
Removal efficiency (%)	43.11	75.93	81.02	84.62	94.83	85.11

increased and as a result, the turbidity removal efficiency decreased. Jar test findings for ferric chloride coagulant are shown in Table 3.

The turbidity of the inlet effluent to the filter (before coagulation operation) at surface loads of 5, 8, and 12 m/h was 73.1 ± 5.5, 78.1 ± 7.8, and 66.7 ± 5.8 NTU, respectively. Fig. 2 shows the trend of turbidity changes in filter operation of 24 h at different surface loads. After coagulation and passing through from the filter, the average output turbidity at surface loads of 5, 8, and 12 m/h, after filter operation of 24 h, was 7.5 ± 2.5, 11.7 ± 2, and 13.6 ± 2.5 NTU, respectively.

The average of total solids entering the filter at surface loads of 5, 8, and 12 m/h was 2,156 ± 15.7; 2,022 ± 30; and 2,169 ± 28.4 mg/L, respectively. Fig. 3 shows the changes in total solids after filtration at different surface loads after 24 h. After coagulation and filtration, the average total solids output at surface loads of 5, 8, and 12 m/h were 1,793.5 ± 30; 1,702.4 ± 26.9; and 1,883.06 ± 14 mg/L after filter operation of 24 h, respectively.

The average TSS entering the filter at surface loads of 5, 8, and 12 m/h was 175.5 ± 15, 187.36 ± 18, and 160.1 ± 16 mg/L, respectively. Changes in suspended solids after coagulation and passing through from the filter in the time interval of 24 h at different surface loads are shown in Fig. 4. After coagulation and passing through the filter, the average TSS output at surface loads of 5, 8, and 12 m/h were 17.98 ± 3.6, 28.18 ± 2.8, and 32.68 ± 3.9 mg/L after 24 h of filter operation, respectively.

The average total dissolved solids entering the filter at surface loads of 5, 8, and 12 m/h were 1,981.3 ± 38; 1,834.7 ± 45; and 2,009.7 ± 35 mg/L, respectively. Fig. 5 shows the changes in dissolved solids in 24 h of filter operation and at different surface loads. After coagulation and passing through from the filter, the total solids of the output solution at surface loads of 5, 8, and 12 m/h were 1,775 ± 51.7; 1,674.18 ± 28; and 1,850.38 ± 8.7 mg/L at filter operation of after 24 h, respectively.

The average COD of the effluent entering the filter at surface loads of 5, 8, and 12 m/h was 270.5 ± 8, 185.76 ± 5, and 180.06 ± 6 mg/L, respectively. Fig. 6 shows the COD changes in the filtration output at different surface loads after 24 h. After coagulation and passing through from the filter, outlet COD at a surface load of 5, 8, and 12 m/h, at filter operation of 24 h, was 93.39 ± 4.2, 65.73 ± 3.7, and 85.87 ± 3.5 mg/L, respectively.

BOD_5 input to the filter at surface loads of 5, 8, and 12 m/h was 135.3 ± 4, 92.1 ± 2, and 88.8 ± 5 mg/L, respectively. Changes in BOD_5 at different surface loads at filter operation of 24 h are shown in Fig. 7. After coagulation and passing through from the filter, BOD_5 output at surface loads of 5, 8, and 12 m/h, after 24 h, was 45.6 ± 3, 31.7 ± 2.2, and 41.9 ± 2.2 mg/L, respectively.

The average total phosphorus input to the filter (before coagulation operation) at surface loads of 5, 8, and 12 m/h was 5 ± 0.14, 4.3 ± 0.12, and 5.4 ± 0.1 mg/L, respectively. Fig. 8 shows the trend of total phosphorus changes at different surface loads at filter operation of 24 h. After coagulation and passing through from the filter, total phosphorus output at surface loads of 5, 8, and 12 m/h, after filter operation of 24 h, was 1.43 ± 0.13, 1.59 ± 0.12, and 2.29 ± 0.15 mg/L, respectively.

The concentrations of heavy metals chromium, cadmium, and lead entering the filter at a surface load of 8 m/h were 0.073, 0.342, and 2.21 mg/L, respectively. Changes in these heavy metals after coagulation and passing through from the filter in the time interval of 24 h at different surface loads are shown in Fig. 9. After coagulation and passing through from the filter, the output concentrations of chromium,

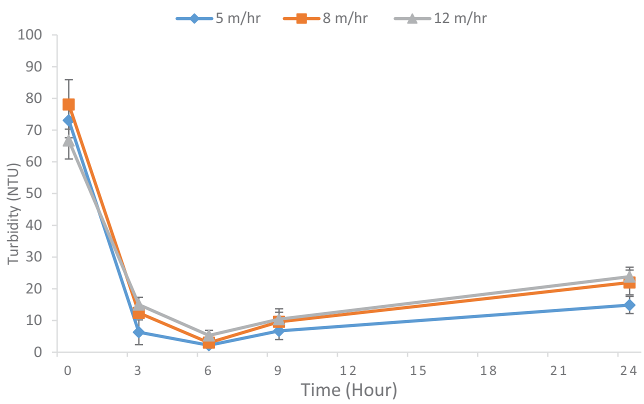

Fig. 2. Turbidity changes before and after filtration at surface loads of 5, 8, and 12 m/h. Coagulant: alum, optimal dose: 400 mg/L, and pH = 7.

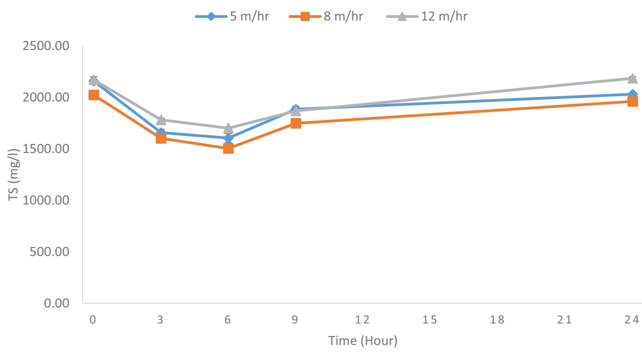

Fig. 3. Total solids (TS) changes before and after filtration at surface loads of 5, 8, and 12 m/h. Coagulant: alum, optimal dose: 400 mg/L, and pH = 7.

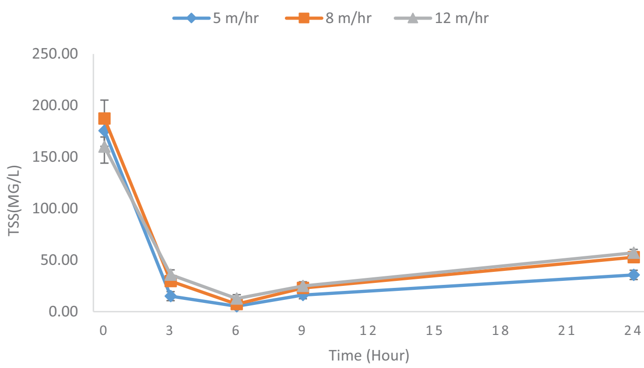

Fig. 4. Suspended solids (TSS) changes before and after filtration at surface loads of 5, 8, and 12 m/h. Coagulant: alum, optimal dose: 400 mg/L, and pH = 7.

cadmium, and lead metals, after filter operation of 24 h at a surface load of 8 m/h, were 0.03, 0.26, and 1.241 mg/L, respectively.

4. Discussion

The results presented in Tables 1–3 indicate that in presence of different turbidity amounts of the effluent from the treatment plant and during the use of three different coagulants, that is, ferric chloride, aluminum sulfate, and PAC and after rapid mixing, slow mixing, and sedimentation, aluminum sulfate (alum) was the best coagulant for the coagulation process at the concentration of 400 mg/L, based on the turbidity removal efficiency obtained in the Jar test. The results of other studies showed that the type of coagulant and its dosage varies depending on the type of wastewater. For example, Zazoli et al. [27] conducted a study on COD removal using lime, alum, and ferric chloride and observed that the use of alum was better at neutral pH than at acidic pH due to the formation of alum flocs with the low solubility at neutral pH. Due to the formation of fine and soluble bubbles at lower concentrations and the formation of fine bubbles and re-stabilization of the solution, the optimal concentration of 400 mg/L was considered. Alum was used in this study due to its advantages compared to other coagulants. The benefits of alum include lower consumption, less sludge production, and faster settling [28]. Due to the high turbidity of the tested effluent, it seems that the predominant mechanism in the coagulation process using alum is surface adsorption and charge neutralization. In this mechanism, if the amount of coagulant consumed exceeds the required level, re-stabilization may occur and lead to an increase in the turbidity of the output.

The results obtained from employing this laboratory-scale process in removing turbidity indicate that at surface loads of 5, 8, and 12 m/h, turbidity removal is 89.71% ± 2.7%, 84.96% ± 3.93%, and 79.57% ± 4.58%, respectively. According to the standard recommended by the Environmental Protection Organization of Iran for wastewater discharge [4],

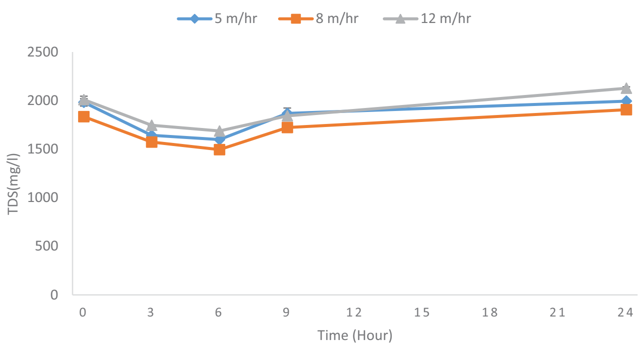

Fig. 5. Changes in total dissolved solids (TDS) before and after filtration at surface loads of 5, 8, and 12 m/h. Coagulant: alum, optimal dose: 400 mg/L, and pH = 7.

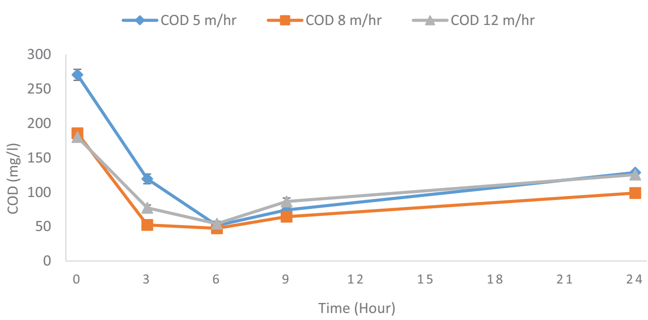

Fig. 6. COD changes before and after filtration at surface loads of 5, 8, and 12 m/h. Coagulant: alum, optimal dose: 400 mg/L, and pH = 7.

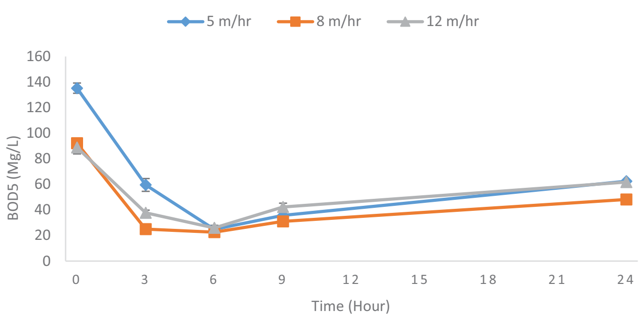

Fig. 7. Changes in BOD_5 before and after filtration at surface loads of 5, 8, and 12 m/h. Coagulant: alum, optimal dose: 400 mg/L, and pH = 7.

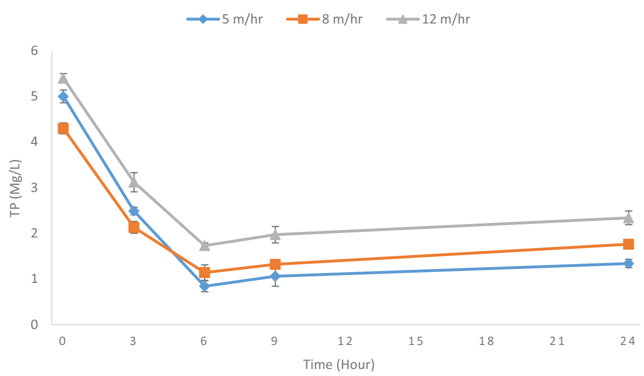

Fig. 8. Changes in total phosphorus before and after filtration at surface loads of 5, 8, and 12 m/h. Coagulant: alum, optimal dose: 400 mg/L, and pH = 7.

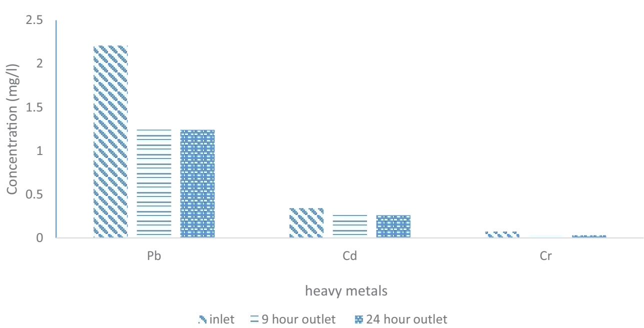

Fig. 9. Changes of heavy metals (chromium, cadmium, and lead) before and after filtration at a surface load of 8 m/h. Coagulant: alum, optimal dose: 400 mg/L, and pH = 7.

turbidity of the effluent up to 50 NTU has been allowed for discharge to surface waters and agricultural uses. The process that used in this study has been able to reduce the turbidity of the effluent from the treatment plant to 7.5, 11.75, and 13.6 NTU at surface loads of 5, 8, and 12 m/h, respectively. The results of the study of Kazemi Noredinvand et al. [23] showed that in the field of elimination of the studied quality parameters such as turbidity in all surface loads, pilot of two-layer direct filtration has a better performance than the pilot of the single-layer direct filtration. The use of the direct filtration process at a surface load of 7 m/h is possible for Ahwaz Water Treatment Plant No. 2 if the number of filter layers increased and filter bed materials with suitable physical characteristics are used [23]. According to their study, the use of three different substrates in this study increased the turbidity removal efficiency. Fallahizadeh et al. [29] also studied the removal of natural organic matter, turbidity, and color from surface water by combining advanced coagulation process and direct filtration; the results also showed that under optimal conditions (pH, $FeCl_3$ dose, and input flow of 6.2, 95 L/h, and 40 mg/L, respectively), 95% of turbidity was removed. Delbazi et al. [30] compared the efficiency of the one-layer filter with sand substrate and the two-layer filter with Leica and anthracite substrates for removing organic matter and turbidity. The results showed that the turbidity removal rates by one-layer filter (sand), two-layer filter (anthracite and sand), and two-layer filter (Leica and sand) were 69%, 80%, and 74%, respectively. Therefore, it can be expressed that the turbidity removal efficiency by two-layer filtration is higher compared to one-layer filtration with equal conditions. Anthracite is also very effective as a strong absorber with many pores in removing taste, odor, color, and turbidity. Therefore, according to the results of this study, anthracite has also acted as an adsorbent and has caused the removal and reduction of turbidity [30].

The results obtained from employment of this process on a laboratory scale for the removal of TS showed that at surface loads of 5, 8, and 12 m/h, total solid removal efficiencies were 16.85 ± 2.5, 15.81 ± 1, and 13.21 ± 0.27, respectively. In a study conducted by Hosaini et al. [19] on the application of fluidized bed filtration in secondary wastewater treatment for reuse, the results showed that in different surface and organic loads, the removal efficiency of TS is very low so that the maximum removal without considering the surface load and total solids load is 2%.

The results of this laboratory-scale process for the removal of TSS indicate that at surface loads of 5, 8, and 12 m/h, TSS removal efficiencies were 89.75% ± 2.7%, 84.96% ± 3.4%, and 79.59% ± 3.4%, respectively. According to the definition of filtration, filtration is the separation of solids from liquids; in the filtration process, the liquid passes through a porous medium to separate the suspended solids as much as possible, and the main purpose of filtration is to separate the suspended solids. Therefore, in this study, suspended solids, as well as flocs formed in the flocculation stage, were removed by screening and filtration mechanisms. Removal of suspended solids by surface removal is also at the top of the bed, and deep removal is inside the filter bed [21]. According to a study conducted by Nazari Garavand et al. [31], wastewater treated by mineral garnet has a significant efficiency in the removal of suspended solids. According to their study, due to the adsorption property of garnet, solids were adsorbed on the garnet bed, so garnet increased the removal efficiency of solids by using adsorption.

The results obtained from the laboratory scale of this pilot in the removal of soluble solids (TDS) showed that at surface loads of 5, 8, and 12 m/h, TDS removal efficiencies were 10.39% ± 2.7%, 8.75% ± 1.6%, and 7.93% ± 0.38%, respectively. Dadashzadeh et al. [32] investigated the effect of changing the bed and surface load of pressurized sand filters on improving the removal of water quality parameters of the Moallem Kola water treatment plant in Sari. The results showed that in the best condition, simultaneous use of silica and anthracite, TDS removal efficiency was 23.54%. Maifadi et al. [33] conducted a study entitled analysis and pre-treatment of hair salon wastewater using a multi-bed filtration system. The results revealed the reduction of TDS from 309.5 to 211.4 mg/L (31.7%) for site 1 and from 315 to 226 mg/L (28.2%) for site 2. This decrease occurred due to adsorption by the activated carbon in the filter substrates studied [33].

The results achieved from the process studied on a laboratory scale in BOD_5 removal indicate that BOD_5 removal efficiencies were 66.3 ± 3, 65.6 ± 2.5, and 52.8 ± 2.3 at surface loads of 5, 8, and 12 m/h, respectively. Activated carbon is used more than other adsorbents in conventional adsorption systems. It is made from a wide variety of carbonaceous raw materials such as coal (anthracite, bituminous, and brown coal), wood, peat, and coconut shells. The advantage of this adsorbent is its strong bond with organic matter. Therefore, it is very effective in treating effluents containing a high amount of organic matter. According to former studies, the anthracite used in the substrate has reduced BOD_5 to the desired level due to its high adsorption property [34].

The employment of the studied process on a laboratory scale for COD removal shows that at surface loads of 5, 8, and 12 m/h, COD removal efficiencies were 65.48% ± 3%, 64.62% ± 2.5%, and 52.31% ± 2.2%, respectively. Abdollahzadeh Sharghi et al. [35] studied the efficiency of the coagulation and flocculation processes for removing contaminants from the textile dyeing plant and showed that the highest COD removal efficiency related to alum coagulant was obtained at a concentration of 40 mg/L, which could be due to the formation of coarse neutral metal hydroxides and trapping of colloidal particles in them by sweeping mechanism [35]. According to their study, the use of the coagulation process using alum coagulant has increased the COD removal efficiency in the present study.

The results related to total phosphorus removal by this process indicate that at surface loads of 5, 8, and 12 m/h, total phosphorus removal efficiencies were 71.35% ± 1.16%, 63.08% ± 1.89%, and 57.59% ± 1.79%, respectively. Englande et al. [36] showed that significant amounts of phosphorus are lost when aluminum or iron salts are used. Isolation of suspended solids has also been shown to be effective in reducing nutrients to very low levels. Therefore, the alum used in the present study has been able to significantly reduce the total amount of phosphorus from the wastewater. Total phosphorus was also reduced due to the presence of anthracite and its adsorption properties in this study. As shown in the research of Jiang et al. [37], the adsorbent removal capacity for TP using anthracite, biological ceramics, shale, and quartz sand was 85.87, 81.44, 65.59, and 55.98 mg/kg, respectively.

The use of this process on a laboratory scale in the removal of heavy metals such as chromium, cadmium, and lead showed that at a surface load of 8 m/h, the removal efficiencies of heavy metals were 58.9%, 23.39%, and 43.80%, respectively. According to the study of Tang et al. [38], the mechanism of heavy metals removal with organic matter in the coagulation process is very complicated. Colloidal particles in water absorb heavy metals through charge absorption and ion exchange. Neutralization of the charge of iron/aluminum hydroxide compounds plays an effective role in the accumulation of colloidal particles during the deposition process. During the deposition process, the formed floc traps some heavy metal ions and leads to increased adsorption in this process [38]. According to the study of Azizi and Sobhanardakani [39], the presence of more and larger pores in anthracite (compared to sand), having an angular shape during processing operations, and consequently, a stronger surface adsorption property (compared to sand) lead to eliminating large particles, flocs, and some harmful compounds by the anthracite layer, while most small particles are absorbed in the sand layer. According to studies conducted by Tang et al. [38] and Azizi and Sobhanardakani [39], the presence of coagulant, as well as substrate layers such as anthracite, have been involved in the removal of heavy metals studied.

5. Conclusion

In the present study, the results obtained from the application of direct filtration and multi-bed filters specified the appropriate ability of this method to remove various pollutants from the treated effluent for reuse purposes. The use of a direct filtration process with multi-bed filters could provide applicability of the wastewater treatment plant effluent of Baharan industrial town for use in agriculture; so that this effluent can be employed as a water resource.

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