Review of Waste Water Reuse with using a Combination Adsorption-Gel Resin Filtration as a Hybrid Process

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Abstract
The "adsorption-ion exchange" system is a newly developed process in water and wastewater treatment operations where the adsorption process in active carbon and silica sand beds as well as the ion-exchange process in resin beds (Gel resins) are used in combination to reduce contamination to acceptable levels suitable for reuse. This system has various applications including in power plants where the beds are of the "fixed" type. By utilizing the adsorption-ion exchange technology which has a high potential for processing a wide volume of wastewater as well as generating a high economic value, this hybrid system can be used to provide clean drain wastewater (wastewater exiting boilers and blow down boilers) with high purity for the water cycle in the power plants. In this study, the mentioned system is used for wastewater treatment in Neyshabour Power Plant to reduce sodium ion level from 1250 mg/lit to 1.9 mg/lit and the COD level from 411 mg/lit to zero. Also, conductivity was reduced from 2180 µS/cm to 560µS/cm. The system demonstrated the capability of eliminating sodium ion up to 99.6%.
Keywords: Silica beds, active carbon filter, resin filter, Gel resin

1.Introduction

Organic and pathogenic materials in repair shop, domestic/sanitary waste water, and the waste water produced by restaurants can pollute the environment and cause physiochemical and thermal changes in the recipient waters. This kind of wastewater has a high percentage of minerals/salts which leads to an increase in the solid material content of the recipient waters, growth of algae, corrosion in the recipient water, generation of toxic gases such as mercaptan, and release of unpleasant odors in the environment(Abrishamchi&Afshar,2005). Industrial waste treatment is generally of three different types: mechanical or physical treatment, biological treatment, and chemical treatment. Selection of these methods is based on the conditions of the site and satisfaction of the process selection criteria. Since establishing a treatment system for resin-containing wastewater is practically uneconomical due to the high concentration of the salts thereof, since ground water levels are decreasing, and since water consumption in power plants (for washing, feeding the drums, green space, raw water storage ponds, etc.) is high, efforts are mostly focused on using suitable separation methods for reducing these lighter contaminants in cleaner wastewater (resulting from such processes as reverse sand filter washing, blow down boilers, and drain boilers). The purpose of this study was to separate sodium ion, eliminate organic load, reduce hardness-increasing

ions, reduce water turbidity, and reduce insoluble suspended particles to acceptable levels for reuse. Also, variations in the following were measured: sodium concentration in resin filters; conductivity; TS (total solids) and COD (chemical oxygen demand) in sand filters and active carbon filters, etc. Fig. 2 shows the schematic of the treatment pilot. According to Mandi et al. (Ayyad,2009)on using sand beds for removing organic and mineral contaminants where wastewater purified by passing it through sand, this kind of treatment, being a combination of physical (adsorption), biological, and microbial load reduction, leads to reduced electrical conductivity and even reduces the contaminants that result from organic acids. On the other hand, research by Ping Yu (Yu&Luo,2002) indicates that the quality of effluents from resin beds is affected by the inlet wastewater compounds, so that sodium concentration at the outlet increases with increasing hardness in the inlet. This increase in sodium density is due to competitive ion ex change reactions involving hardness-increasing ions. Isolation of harmful ions such as sodium ions, calcium ion, organic load removal, reducing turbidity, suspended solids and deliver it to optimal and quality & environmental standards available for mentioned wastewater reuse in the Nishapur plant is the objectives of the research.

2.MATERIALS AND METHOD

Raw effluent quality parameters are presented in Table 1.

Table 1. Raw effluent quality parameters

Parameter	Value
EC(μS/cm)	3610
TS(mg/L)	2244
Na(mg/L)	1250
Ca(mg/L)	156
COD(mg/L)	411

2.1.Adsorption-Ion Exchange Treatment Pilot

The most important instrument for conducting the required tests was an adsorption-ion exchange separation pilot. The various parts of this pilot, shown in Fig.1and Fig.2, are:

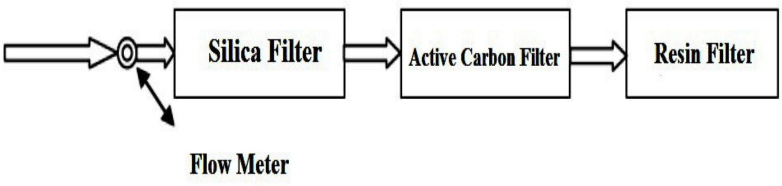

Fig. 1. Schematic of the adsorption-ion exchange system

- Flow meter: This device was installed in the path of the wastewater flow for measuring the inlet wastewater flow rate into the pilot, and can measure flow rates ranging from 1-16 lit/min.
- Chronometer: This device was used for measuring the exact process time, as well as measuring and controlling the flux.
- Silica sand bed: This is a cylinder with a diameter of 50 mm and a height of 450 mm for filtering wastewater.

Schematic pilot used for the wastewater treatment system are presented in Fig.2

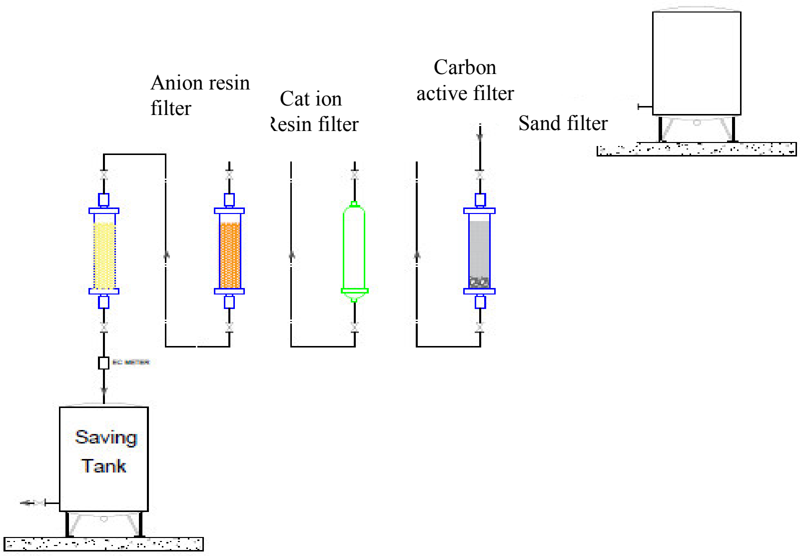

Figure2: Schematic pilot used for the wastewater treatment system

The experiments on the silica bed mostly involved TS, COD, and conductivity and were conducted upon sampling the inlet (raw effluent) and silica sand filter outlet.

- The up-down flow active carbon column with a height of 280 mm and diameter of 50 mm: The experiments on the active carbon bed mostly involved COD and paint particles.
- Resin column as a cation-anion mixture containing permeable S100-G1 gel: The experiments on the resin bed mostly involved measuring sodium and calcium ions, paint, and conductivity upon sampling the outlet from the resin
- A polyethylene hose with a diameter of 5mm and length of 1.9m for connecting the active carbon silica column, the resin column, and the flow meter.
- A PVC hose with a diameter of 1 cm used as a protective sleeve at the inlet and outlet of the silica,

active carbon and resin columns. The gap between the sleeve and the pipe was filled with aquarium glue.

3.RESULTS AND DISCUSSION

3.1.Effect of Various Parameters on the TS Elimination via Sand Filters

3.1.1.Effect of Various Flow Fluxes on TS Elimination via Silica Filter at Various Ratios of Silica Sand (Coarse and Fine Grades)

After passing the wastewater from pre-treatment system, wastewater enters the silica filter and residual contaminations of turbidity in the filters were used.

Residual contaminations in outlet water of pre-treatment system are suspended solid particles. These particles are mainly or in terms of size and weight are small or its density difference with water is low and should be removed from the water by silica filter.

An effective factor on sand filter efficiency is the ratio of fine to coarse sands as well as the order thereof. Usually, fine particles are placed at the top and coarser particles at lower layers. As silica sands show greater resistance to erosion, it leads to reduced wear in the system (Environmental Laboratory test results,2015).

The experiments were conducted in the following three silica ratios and three flux flows of 0.51, 0.917, and 1.38 m3/min.m^2:

1.Fine silica sand (medium size particles with d=0.6mm) height = 20 cm; coarse silica sand (medium size d=2.6mm) height = 20 cm

2.Fine silica sand (medium size particles with d=0.6mm) height = 30 cm; coarse silica sand (medium size d=2.6mm) height = 10 cm

3.Fine silica sand (medium size particles with d=0.6mm) height = 35 cm; coarse silica sand (medium size d=2.6mm) height = 5 cm

The purpose of these experiments was to evaluate the effect of sand layer ratios on TS and COD elimination and to use filters in series for increasing TS elimination efficiencyFig.3 shows the variations of TS at the sand filter outlet in terms of various coarse and fine sand ratios and at various fluxes.

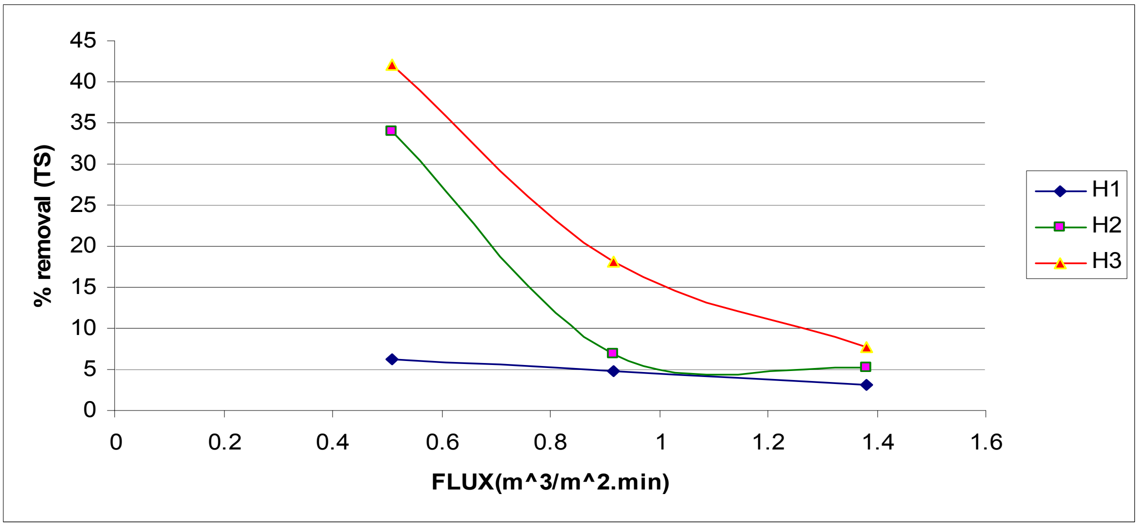

Figure3: Effect of flux on TS elimination at the outlet of silica filter with various coarse, fine ratios at three fluxes of 0.51, 0.917, and 1.38 m3/min.m^2

H1:20 cm height of tiny sand silica+20 cm height of coarse sand silica

H2: 30 cm height of tiny sand silica+10 cm height of coarse sand silica

H3: 35 cm height of tiny sand silica+5 cm height of coarse sand silica

Previous studies showed that TS elimination decreases at increasing fluxes. On the other hand, the best efficiency for TS elimination is obtained for a bed with 87% of fine and 13% of coarse silica. This is consistent with the guidelines offered in water treatment procedures using sand filters, where the contact between the fluid and the bed and the effective contact are greater. Leading to a greater filtration surface at a constant volume which in turn increases filtering quality.

According to the water filtration flow rate relation in sand filters described as $Q=A*\Delta P/\mu*R$, an increase in linear velocity is always accompanied by a pressure drop across the filter during the filtration process.

Fig. 4 compares the effects on TS elimination of increasing the height of the sand bed (via placing two silica filters in series) from an initial height of 40 cm to a final height of 80 cm at the optimum flux of 0.51 m3/min.m^2

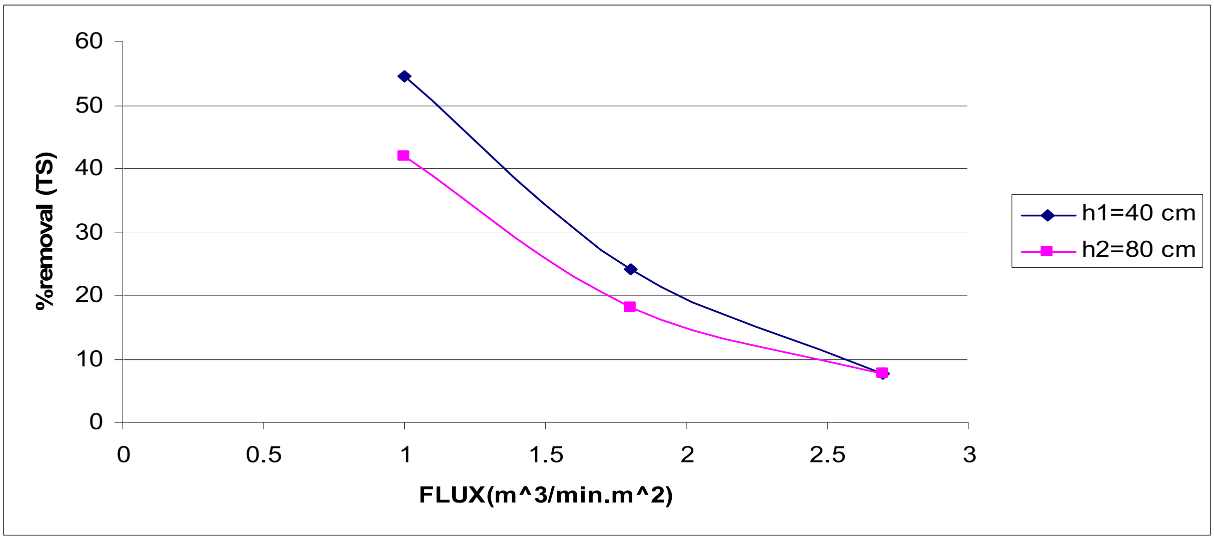

Figure4: Effect on TS elimination at the outlet of silica filters (87% fine and 13% coarse particles) obtained at filter heights of 40 cm and 80 cm

Fig.4 shows that placing the silica filters in series status does not affect TS elimination at high fluxes. However, as the flux is decreased to 0.51 m3/min.m^2, the elimination percentage increases from 42% to 54.6%. This is the result of increased contact surface and increased duration of filtering due to increasing length of the bed. Silica filters in periods of 2 to 3 days need to wash and the work is done by backwash with treated water and can take more than 15 minutes. Of course, in high fluxes and in terms of industrial back wash it done by mix of water and compressed air.

3.2.Effect of Flux on COD Elimination in Silica Filters with various Coarse/Fine Sand Ratios

Using sand filters is a physical method for eliminating suspended particles in wastewater. Since suspended particles are only part of the total TS that exist in effluents, and since suspended particles include both unstable (organic) and stable (mineral) substances, silica filters play a significant role in COD elimination. Fig. 5 shows the COD elimination percentages obtained in the experiments at three silica ratios and three fluxes of 0.51, 0.917, and 1.38 m3/min.m^2(Boyer&Singer,2008 ;Shojaosadat,2006).

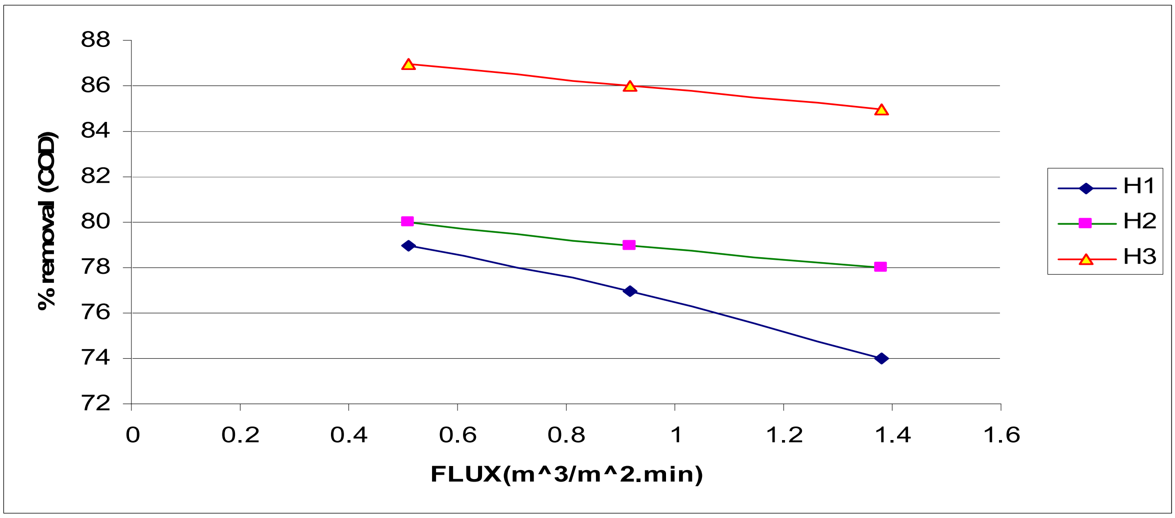

Figure 5 : COD elimination at the outlet of silica filters at different coarse and fine sand ratios and at various values of flux, namely, 0.51, 0.917, 1.38 m3/min.m^2

H1:20cm height of tiny sand silica +20 cm height of coarse sand silica

H2:30cm height of tiny sand silica+10 cm height of coarse sand silica

H3:35 cm height of tiny sand silica +5 cm height of coarse sand silica

During a similar sand filter process implemented at a wastewater treatment facility in north Esfahan, 85% of the COD was eliminated(Abrishamchi,2005;Boyer&singer,2006;Ritchie&perdue,2003).

3.3.Effect of Flux on Sodium Concentration inside Resin Column under Experimental Conditions

Given that a portion of the treated wastewater by filtration pilot for Irrigation of green spaces use considers, so pollution control due to sodium ions is important in quality of the pilot effluent treatment.

In a resin bed, Gel resins (a strong cat ion made of a permeable gel in the form of hydrogen) with a 2 eq/l capacity substitute sodium ions as wastewater is passed over the resin bed, releasing hydrogen as they do so(Yu & Lue,2000).

The effect of fluorite on sodium density is shown in Fig.6. As can be seen, increasing the flux is accompanied by a (negligible) reduction in sodium elimination. Fig. 6 compares the effects of a permeable gel resin and an (non Gel resin)ordinary resin of the same grade on sodium elimination at various fluxes.

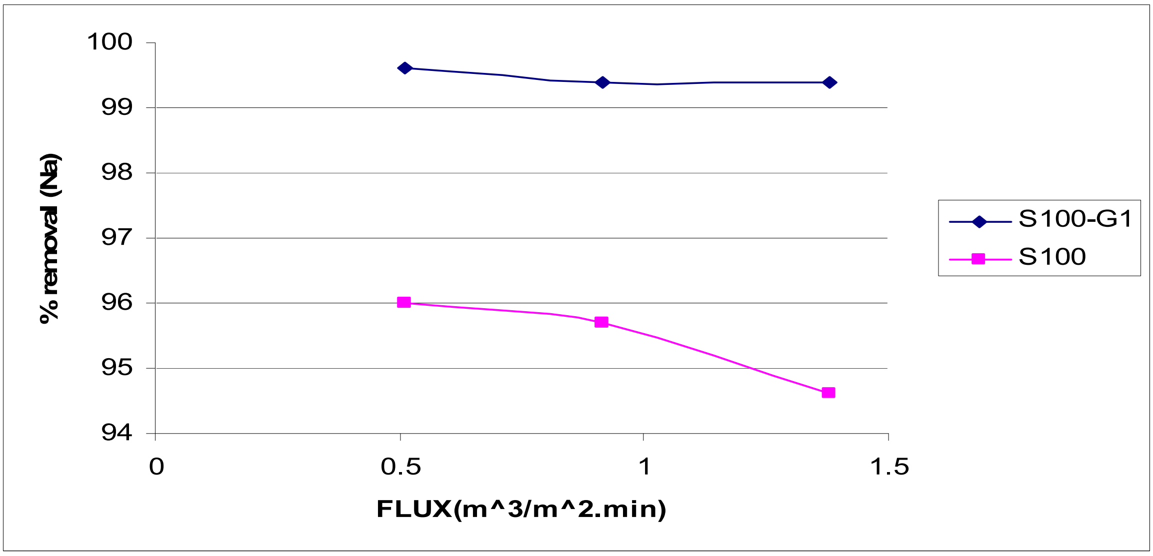

Figure 6: Comparison of ordinary and Gel resins in terms of sodium ion elimination at different fluxes **S100-G1**: Gel Resin

S100: ordinary resin (non Gel resin)

Fig.6 shows that as the flux increases, using S100 ordinary resins(non Gel resin) decreases filter efficiency in eliminating sodium ions. The reason is that at lower flux, the contact time between the ions and the ion-exchange resins increases, leading to a more efficient ion-exchange reaction(Ping&Yunbai,2002 ;Watson&Lawrence,2003;Singe&.Bilyk,2002;Stumm&Morgan,1996).

Due to the fact that S100-G1(Gel resin) resins capacity (2 eq/l) is greater than that of S-100 resins, and that these resins are permeable gels which turn into jelly-like substances in the fluid, they demonstrate less sensitivity to linear velocity variations(Shojaosadat,2006;Jarvis&Mergen,2008).

After a while, from the resin was used its treatment term decrease and should be done reduction treatment on it that includes the following steps:

1- Backwash which the water from the bed resin upwards flow and its aim is suspending the granular resin.
2- Injection of Healer chemicals which about resin gel permeable of hydrochloric acid is 6%.
3- slow wash because of the distribution of chemicals across the resin bed and resulting better chemical contact with the resin granules and ultimately quick wash due to removal residuals regenerative material, until the resin filter to be ready for re- service, such as, the advantages of resins gel permeation change color from light brown to dark red in period of saturation resins that can be predicated with this change color the reduction of filter.

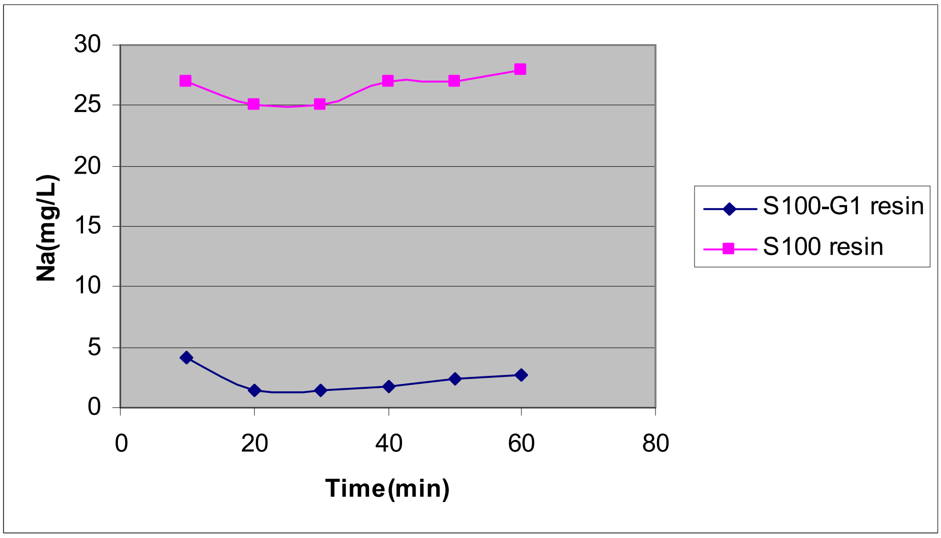

Figure7: Comparison of concentration sodium ion when passing waste water through the resin filters
S100-G1: Gel Resin
S100: ordinary(non Gel resin) resin

As we can be seen in Figure7, the first, due to lack of uniform flowing and adequate concentration polarization, and the existence of surface resistance against ion-exchange reactions, the rate of sodium ions out of the resin filter is slightly higher, but with lapse and run time gain and from the Ten minutes into the second, the concentration of sodium ions output is relatively constant. But according to the diagram, the removal efficiency using Gel resin was higher and has with less volatility than conventional resins and is practically saturated later, that is due to higher capacity of Gel resins. Given that the Gel resins used are kind of gel permeation which actually their performance based on molecular screen and filtration with gel, so, the Ions based on size isolated by gel with characterized porous and large molecules not able to enter the gel network, While small molecules completely into the gel network are inserted. Whatever the gel is firmer we can use more inflow.

CONCLUSIONS

The results obtained by using an adsorption-ion exchange pilot showed that TS elimination in the silica column considerably increased as a result of increasing the ratio of fine silica (average size d=0.65mm) to coarse silica (average size d=2.6 mm). The greatest TS elimination (42%) was obtained at a flux of 0.51 m3/min.m^2, 87% fine silica, and 13% coarse silica in the filter. It was observed in a complementary experiment that placing two 40 cm silica columns in series (i.e. increasing the height of the silica bed) resulted in an increase in TS elimination from 42% to 54.6% (at a flux of 0.51 m3/min.m^2). At greater discharges, however, serial filters do not considerably affect TS elimination.

The outlet wastewater from the active carbon filter was devoid of any organic loads and a higher efficiency for turbidity reduction and paint particles reduction was observed at lower linear velocities.

As compared with ordinary (impermeable non-gel) resins, S100-G1 (permeable gel) resins showed a higher efficiency in removing harmful ions.

Using index resins is more economical since these resins change their color to dark red when saturated. Using these resins showed that variations of flow rate and flux had little effect on their performance

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