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Removal Water Turbidity by Crumb Rubber Media

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Abstract

The removal of water turbidity by using crumb rubber filter was investigated .The present study was conducted to evaluate the effect of variation of influent water turbidity (10, 25 and 50 NTU), media size (0.6and 1.14mm), filtration rate (25, 45 and 65 l/hr) and bed depth (30 and 60 cm) on the performance of mono crumb rubber filter in response to the effluent filtered water turbidity and head loss development, and compare it with that of conventional sand filter.

Results revealed that 25 l/hr flow rate and 25 NTU influent turbidity were the best operating conditions. smaller media size and higher bed depth gave the best removal efficiency while higher media size and small bed depth gave lower head loss. The optimum results show that 92.7% removal efficiency and 8.3 mm head loss. The comparison results show that at constant operating conditions, pressure drop for crumb rubber filter is lower than conventional sand filter; about 42% reduction in pressure drop than sand filter and the conventional sand filter has a little enhancement in removal efficiency than crumb rubber filter, 96.8% for sand while for crumb rubber 92.7%.

Keywords*: Turbidity; filtration; crumb rubber media; head loss.*

1. Introduction

Reuse of wastewater often requires, after the conventional secondary processing, advanced/tertiary treatment so as to meet stringent water quality objectives for reuse and to protect public health. Among advanced treatment processes, gravity granular-media filtration has clearly emerged as one of the most efficient and simple processes for removing suspended and colloidal materials including pathogenic microorganisms [1].

Granular media filtration of wastewater is a complex process as the effectiveness of the process is dependent on many interrelated variables and thus there is no generalized approach to the design of full-scale filters [2].

The most important design factors are the characteristics of the filter media including type of filter media, grain size and gradation, properties of wastewater solids to be filtered, and the rate of filtration. Generally, pilot scale studies are usually undertaken to evaluate the performance of the filter media to be used for filtering the wastewater in question. In the absence of a pilot study, the design must be based on experience with similar filter influent wastewater at other installations. Scrap tires are a solid waste, which are produced in increasing rates every year in particular in Iraq. They have been usually disposed in landfills or tire piles with serious environmental risks. This problem may assume a larger importance in areas of tropical climate with precarious sanitation conditions moreover scrap tires piles consist a serious fire hazard [3].

About 280 million scrap tires were generated in 2000 with an annual growth of about 26%, and there are about 2000 million scrap tires in stockpiles in the US [4]. It takes a considerable time for scrap tires to decompose in natural systems. With rainwater accumulating in the void space, scrap tire stockpiles are ideal breeding grounds for mosquitoes, insects and rodents. The discarded tires can cause both health and environmental problems [5].

The management and disposal of scrap tires are of great concern in the United States. An innovative crumb rubber filtration technology has been developed to treat wastewater at Penn State Harrisburg [6].

It was found that crumb rubber is an excellent filter media for downward granular media filters. In comparison to traditional granular media filters (e.g., sand, anthracite, etc.), because of its elasticity, the crumb rubber filter allows higher filtration rate, lower head loss, longer filtration run time, and better effluent quality. Because of its high filtration rate and low density media, the crumb rubber filter is much smaller and lighter than the conventional filters. After a filtration cycle, the crumb rubber can be backwashed with upward flow of filtered water. Because of low density of rubber material, the crumb rubber filter can be backwashed at a much lower backwash water flow rate than the conventional sand/anthracite filter ($20m^3/hm^2$ versus $52.5m^3/hm^2$) [7] .

The removal of turbidity, particles, phytoplankton and zooplankton in water by crumb rubber filtration; were investigated by Tang, et al [8], they concluded that there was a substantial reduction achieved. Of the three variables, filter depth, media size and filtration rate, media size had the most significant influence. Smaller media size favored higher removal efficiency of all targeted matter. There was no apparent relationship between removal efficiency and filter depth. Higher filtration rate resulted in lower removal efficiency and higher head loss. Compared with conventional granular media filters, crumb rubber filters required less backwash, and developed lower head loss.

A potential use of tire crumb is as a filter in pollution control applications. Past studies have shown that tire crumb can be used as an effective filter medium achieving similar results compared to using a sand/anthracite filter to remove turbidity and suspended solids. It was also indicated that the head loss associated with running water through tire crumb as opposed to the standard sand/anthracite media is significantly less [9].

Factorial design was used in this study. The approach reduced the experimental burden while was effective in seeking high quality results to analyze the effects of factors and interactions.

The main objective of this work is to evaluate the performance and effectiveness of sand filters by utilizing crumb rubber as filter media which is a locally available solid waste material.

2. Experimental work and Materials

Sieve analysis was used to calculate the size distribution of crumb rubber and sand. Sieve analysis was carried out by shaking a weighted sample of crumb rubber and sand using (Endicot sieve shaker) through a set of sieves that have progressively smaller openings. After completion the shaking period (about 25 min), the mass of sample retained on each sieve is measured using Sartorius precision balance. The results of sieve analysis are generally expressed in terms of the percentage of the total weight of sample that passes through different sieves. The geometric mean size, effective size, and uniformity coefficient. are tabulated in Table (1), analyzed in Ministry of Oil, Petroleum Development and Research Center, Baghdad, Iraq.

A pilot plant was constructed in order to study the effectiveness of crumb rubber as a filter media. As shown in Fig. 1 PVC column with 5cm inner diameter and 1 meter length was used,. Turbid water was prepared in a tank by adding kaolin (red kaolin from local material),) to tap water with manual mixing. After sufficient settling period of time (about 10 to 30 min. depending on the required turbidity) to allow settling of large particles, turbid water was pumped to a gravity feeding tank to be used as an influent to the filtration column. Two different size of crumb rubber 0.6 and 1.14 mm was used.

For each size (0.6, 1.14 mm), the filter column was loaded to a depth of 30 and 60cm respectively. Before each filter run, the filter was backwashed by air scour and then water.

For each filter configuration, the filter was operated at three measured influent flow rates 25, 45, and 65 m/hr respectively using a calibrated rotameter. The effluent turbidity was measured using turbidity meter (Hi 98703 HANNA).The head loss through the filter media was measured using the difference between the water level in the filter column and the water level in the glass tube connected to the bottom of the filter column both reading and recorded at fixed time intervals along the experimental duration time of 120 minutes. Porosity of 0.617 and 0.62 for sizes 0.6 and 1.14mm were determined by the measurement of the dry weight of the media initially loaded to the filter column and the media depth.

The performance of the optimal crumb rubber filtration conditions were compared with sand (the same size, influent turbidity, influent flow rate, and bed height) by measuring the head loss and the effluent turbidity.

Table 1,
Sieve analysis parameters and physical charactaristis for crumb rubber and sand.

	Crumb rubber		**Sand**
Size, mm	0.6-1	1.14-1.18	0.6-1
Effective size, mm	0.6	1.14-1.18	0.61
Uniformity coefficient	1.388	1.487	1.41
Density g/cm^3	0.114	0.114	0.255
Porosity	0.617	0.62	0.506

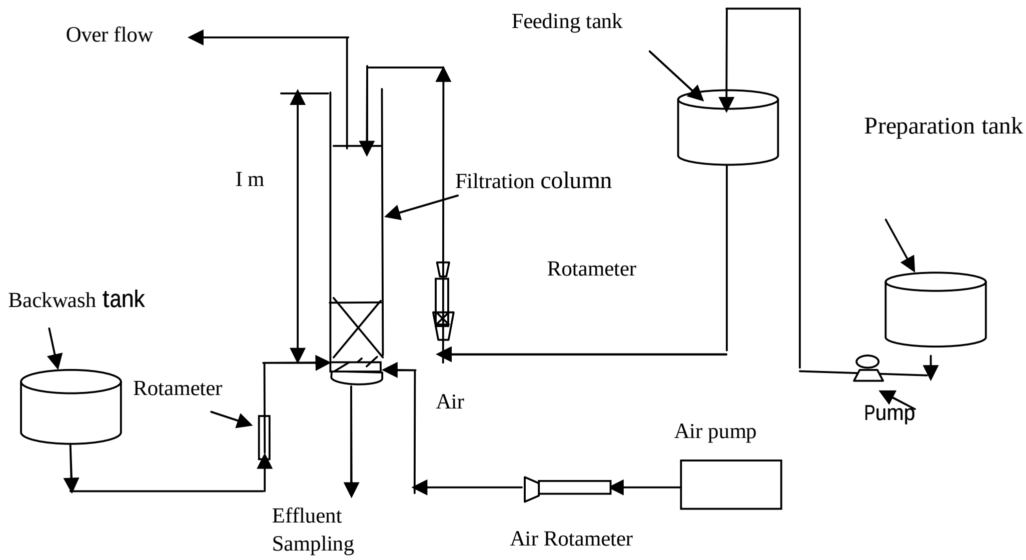

Fig. 1. Experimental setup of the crumb rubber filter.

3. Results and Discussion

3.1. Effectof Size and Influnt Flow Rate on Pressure Drop and Turbidty

Four experimental sets were carried out to study the effect of granuler size, bed height,influent flow rate, and influent turbidities on pressure drop and the percent turbidity removal are shown in Figs.(2-5).It can be seen from these figures that the best flow rate was 25 l/h, higher filtration rate resulted in lower turbidity removal efficiency and the best influent turbidity was 25 NTU for all media size .It is clear that lower flow rate causes higher pressure drop,while higher flow rate causes more chanelling between the crumb particles which led to a lower pressure drop.

3.2. Optimum Filtration Conditions for the Crumb Rubber

The percentage turbidity removal and pressure drop values were found from Figs (2- 5) for each of the sets 1, 2, 3, and 4 individually as shown in Table 2.

The best turbidity removal efficiencies for the two media sizes 0.6 and 1.14 mm were 92.7% ,90.8% respectively at constant bed height of 50 mm . These results clearly indicate that the media size played an important role in turbidity removal. This observation was expected since a smaller media size corresponds to a smaller pore size, consequently more solid matter could be strained by the filter media.

Also it can be seen from these figures that the bed height has less effect on removal efficiency. The best pressure drop was 8.3 cm H_2O for 1.14 mm media size and 30cm bed height while for 0.6 mm media size and 30 cm bed height was 29 cm. For small media size the fine grains tend to settle on the top of the filter, which will easily clog the filter bed surface, and cause a high head loss.

3.3. Comparison between Optimal Conditions of Crumb Rubber Filtration and Sand

Comparing the optimum conditions of crumb rubber with sand at influent flow rate 25 l/h, influent turbidity 25NTU.The results for pressure drop and turbidity removal efficiency with time were plotted and as shown in Figs 6 and 7.

Table 2.
Optimum filtration conditions.

	Turbidity			**Pressure drop**		
	Removal %	**Fitting equation**	R^2	**Pressure drop cm H_2O**	**Fitting equation**	R^2
Set no.1	91.2	$y=-.006x^2+1.376x+10.25$	0.971	29	$y = 0.001x^2 + 0.006x + 9.087$	0.964
Set no.2	92.7	$y = -0.006x^2 + 1.421x + 16.59$	0.926	35.1	$y = 0.001x^2 + 0.030x + 11.69$	0.929
Set no 3	90.6	$y = -0.005x^2 + 1.357x + 7.574$	0.982	8.3	$y = 0.000x^2 + 0.001x + 2.598$	0.945
Set no.4	90.8	$y = -0.005x^2 + 1.362x + 8.382$	0.979	16.7	$y = 0.000x^2 + 0.003x + 5.201$	0.947

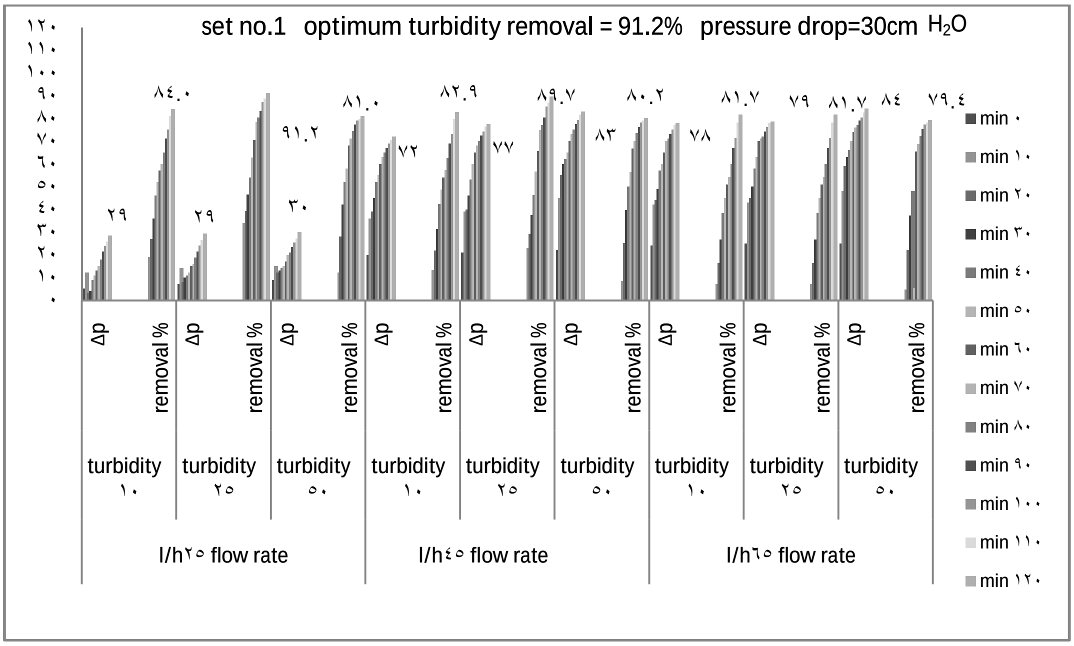

Fig. 2. Set no.1, turbidity removal efficiency and pressure versus time at particle size 0.6mm and bed height =30cm

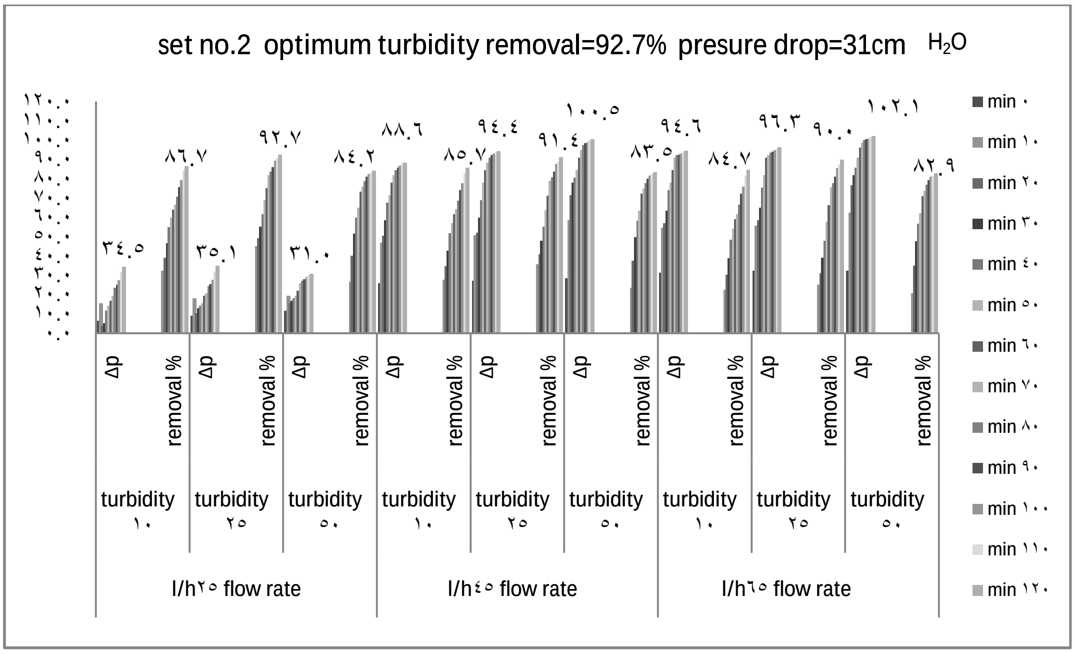

Fig. 3. Set no.2, turbidity removal efficiency and pressure drop versus time at particle size 0.6 mm and bed height 50cm

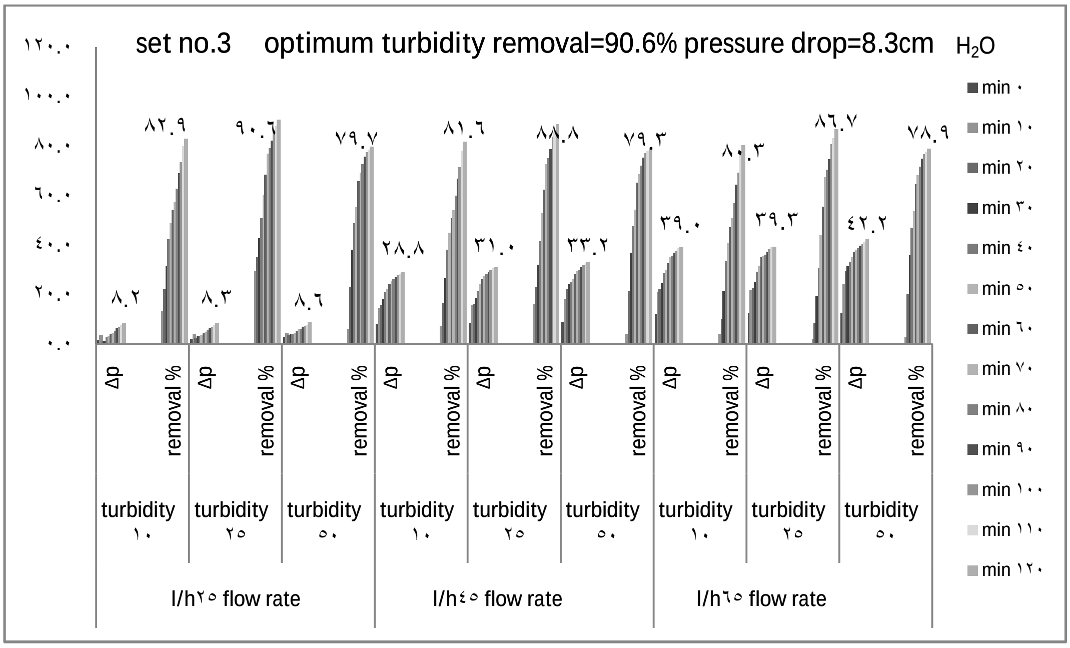

Fig. 4. Set no.3, turbidity removal efficiency and pressure drop versus time at particle size 1.14mm and bed height 30cm.

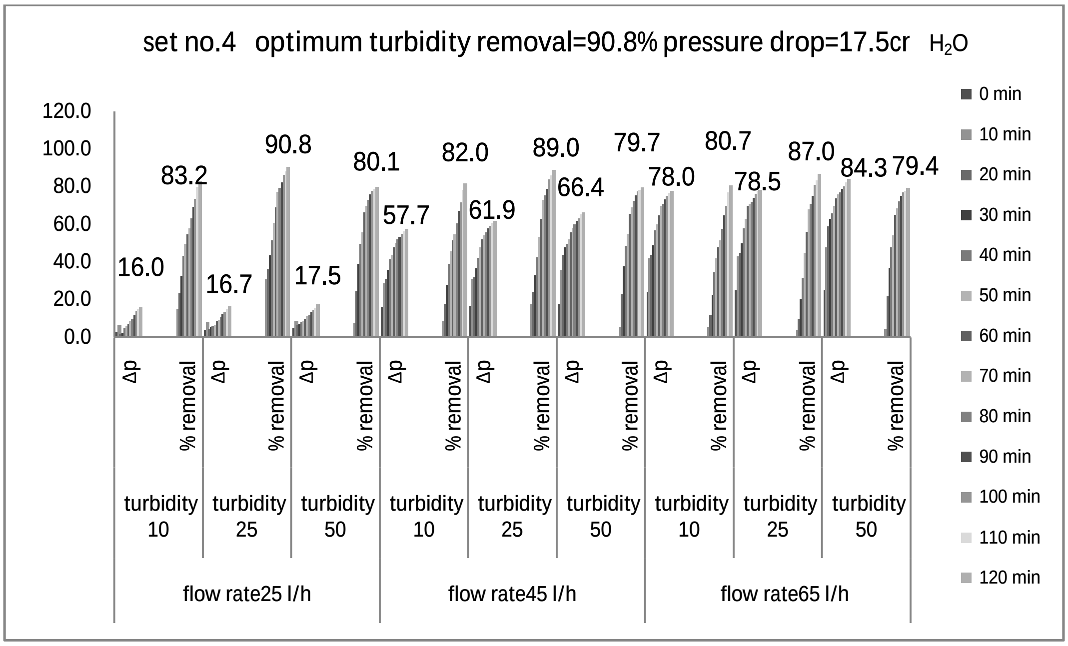

Fig. 5. Set no.4, turbidity removal efficiency and pressure drop versus time at particle size 1.14 mm and bed height 50cm.

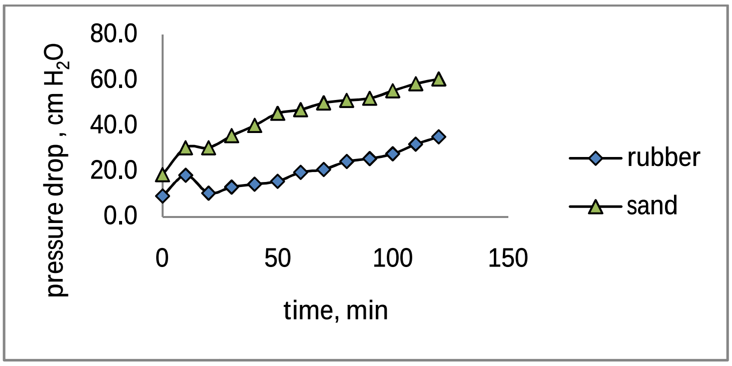

Fig. 6. Comparison for pressure drop cm H_2O with time between crumb rubber and sand (particle size= 0.6mm) and percent optimum removal turbidity= 92.7%.

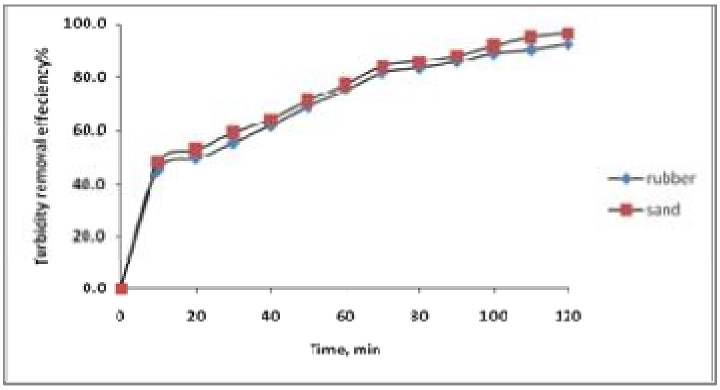

Fig. 7. Comparison for %turbidity removal with time between crumb rubber and sand (particle size =0.6mm).

4. Conclusions

1. Flow rate affects on removal efficiency and head loss, increasing flow rate cause decreasing in removal efficiency and increase in head loss .The best flow rate was 25l/h and the best influent turbidity was 25NTU for all sets.
2. Smaller media size and higher bed depth gave the best removal efficiency while higher media size and smaller bed depth gave better head loss.
3. The optimum removal efficiency and head loss for crumb rubber filter were 92.7% and 8.3mm respectively.
4. At constant operating conditions conventional sand filter has little enhancement in removal efficiency than crumb rubber.
5. The head loss developed in crumb rubber filter is less than that in sand filter, by about 42% reduction in pressure drop than sand filter at the same operating conditions.

5. References

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ازالة عكورة المياه باستعمال المطاط كوسط ترشيح

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الخلاصة

تضمن البحث دراسة امكانية استخدام مخلفات الاطارات (المطاط) كماده مرشحه احادية لازالة عكورة الماء من خلال اختبار كفاءة المرشح لتاثير التغير في عكورة الماء الداخل(١٠، ٢٥ ،٥٠ وحدة عكورة)، حجم الحبيبات (٠.٦ و ١.١٤ملم)، معدل الجريان (٢٥، ٤٥، ٦٥) لتر/ساعة، و ارتفاع الوسط (٣٠ ، ٦٠) سم على مقدار العكورة الخارجة وارتفاع عمود الماء ومقارنتها مع مرشح الرمل التقليدي ولمدة ساعتين حيث تم سحب نموذج كل عشرة دقائق .
تم التوصل الى ان افضل النتائج كانت عند معدل جريان ٢٥ لتر/ساعة و ٢٥ وحدة عكوره ،كما ان افضل نسبة ازالة بلغت ٩٢,٧% كانت عند حجم حبيبات ٠,٦ ملم و ٦٠ سم ارتفاع الوسط وان ارتفاع عمود المياه كان اقل عند حجم حبيبات ١,١٤ ملم و ٣٠ سم ارتفاع الوسط حيث بلغ ٨,٣ ملم .
وعند مقارنة نتائج مرشح المطاط مع المرشح الرملي عند نفس الظروف كان ارتفاع عمود المياه في مرشح المطاط اقل من المرشح الرملي بحوالي ٤٢% مع ان نسبة الازالة للعكورة كانت افضل في المرشح الرملي حيث بلغت ٩٦,٨% بينما مرشح المطاط ٩٢,٧% .