REUSING PULVERISED SOLID WASTES GLASS AS A FILTRATION MEDIUM

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ABSTRACT :

The aim of this research is to find an economically and environmentally efficient way for reusing industrial solid wastes like glass as substitute for sand media to remove turbidity from aqueous solutions. Three different parameters were used and they are; the gradation with its depth, the filtration rate, and influent turbidity to examine the ability of crushed glass as a filter medium. The glass solid wastes for this study collected from different sources and treated by washing, crushing and sieving according to sizes of sand filter media (as a reference in the evaluation of results). 26 runs were made in pilot filtration unit to achieve these above parameters. Every run time for each media was stopped at ratio of effluent turbidity/ influent turbidity $\geq$ 0.7. Removal efficiency (or effluents quality) and run time of the glass media were better than that of the sand media where the run time of the filter medium is a function (index) of turbidity removal efficiency. Many of the filtration curves showed that the sand medium had removal efficiency better than glass at the beginning operating and shortly thereafter but with the passage of time the glass filter medium had better removal and longer run time than the sand medium. There was a superiority for glass filings on the sand media with regards to removal efficiency and the run time length, making them a good alternative for sand filter media.

Keywords: filter media, pulverized glass, reusing, turbidity and water filtration.

اعادة استخدام مسحوق النفايات الصلبة الزجاجية كوسط ترشيح

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الخلاصة :

ان الهدف من هذا البحث هو ايجاد وسيلة كفوءة اقتصاديا" و بيئيا" من اجل اعادة استخدام النفايات الصلبة الصناعية مثل الزجاج كوسط مرشح بديل عن الرمل لأ ازالة العكورة من المحاليل المائية. تم تغيير ثلاث عوامل مختلفة والتي هي تدرج الوسط مع عمقه، سرعة الترشيح و العكارة الداخلة من اجل فحص قدرة مسحوق الزجاج كوسط مرشح.
جمعت النفايات الصلبة الزجاجية لهذه الدراسة من مصادر مختلفة وعولجت عن طريق الغسل والطحن والغربلة اعتمادا على احجام الوسط الرملي (كمرجع في تقييم النتائج). 26 شوط تشغيل اجري بواسطة منظومة ريادية لتحقيق العوامل الثلاثة اعلاه. كل فترة تشغيل لكل مادة توقفت عندما وصلت نسبة العكارة الخارجة الى العكارة الداخلة $\leq$ 0.7 .
كانت كفاءة الازالة (او العكارة الخارجة) و وقت التشغيل للاوساط الزجاجية افضل من تلك للاوساط الرملية حيث ان وقت التشغيل هو دالة او مؤشر لكفاءة الازالة. كثير من منحنيات الترشيح بينت ان الوسط الرملي امتلك كفاءة ازالة افضل من الزجاج عند بداية التشغيل وبعدها بقليل ولكن مع مرور الزمن امتلك الزجاج كفاءة ازالة افضل وفترة تشغيل اطول من الوسط الرملي. وجد تفوقا" لمسحوق الزجاج على الوسط الرملي بخصوص كفاءة الازالة و طول فترة التشغيل، جاعلا اياها بديلا جيدا للوسط الرملي المرشح .

INTRODUCTION :

One of the major goals of sustainable solid wastes management is to enlarge the capacity of its reusing and recycling. Reusing is a reasonable option for materials not adequate for composting, (Hawken, 1994).

In water filtration there are many types of mechanisms which are rapid sand filter (RSF), slow sand filter (SSF), roughing, multistage filtration, pressure filter and diatoms earth filter. The most common factors influencing the selection of filter media were the effective size (ES) or (D_{10}) and uniformity coefficient (UC) as well as other factors like density, grain size, shape, and porosity. The loading rate in a conventional rapid filter is in the range of (5 – 15) m^3/m^2hr with influent turbidity (C_i) not exceed 10 NTU through sand filter media in height of (60-70) cm, D_{10} from 0.4 mm until 1.4 mm and UC $\leq$ 1.5, (Central Organization for Standardization and Quality Control, 2000) and (Eliasson, 2002).

Hudson (1959), Baylis et al., in the AWWA, (1971) and again Hudson (1981), said that the round materials generate purer water than angulate media due to the last have greater porosity. While Trussell et al., (1980) pointed out that usage of angulate material leads to better performance from each side. As well as Kawamura, (1999) announced that angulate particles normally do better than worn and round granules.

Comparing the ability of glass as recycled with sand filter in pilot filtration unit was made by Evans et al., (2002). The depth of single media filters (glass or sand) was 0.9 m. The filtration velocities were between 7.5 and 12.5 m/h. The sand medium had an ES of 0.98 mm while the ES for glass was 0.97 mm. They reported that the glass and sand media produced filtrate water of equal quality. The head loss increasing rate of the glass media was tantamount or a little bit lower than it of the sand medium. The breakthrough time in glass media was longer than that of sand media by (10–15) %.

Rutledge and Gagnon, (2002) examined the use of crushed glass rather than silica sand in dual-media filtration. One filter was composed of pulverized recycled glass and anthracite layers while the other filter contained silica sand and anthracite. Both filters contained a 60 cm deep layer of anthracite over 40 cm of either glass or silica sand. Filtration rate was 5 m/h.

Studying the triturated glass solid wastes as a filter media through pilot filtration unit was carried out by Nasser, (2010). The filter column had diameter of 10 cm, media height of 70 cm and column height of 180 cm, the flow rate was between (5 and 15)m/hr. Various granule sizes and depths of powdered glass were utilized in a single and dual media with sand and porcelaniate. It was found that the glass media had better turbidity removal efficiencies up to (80- 95) % at 5 and 10 m/hr filtration rates, and down to (75- 85) % at 15 m/hr. The dual filters of glass and porcelanite showed the highest removal of bacteria up to an average of 70 % and 50 % at filtration rates 5 and l0 m/hr respectively, where it reached to 20 % at 15m/hr. A decreasing of about 50 % in washing water was required to wash the glass filters. Glass media filters were slower in the development of head losses about (10-55) % less.

Hassan, (2013) evaluated crushed glass as a filtration medium with sand depending on the variation in turbidity levels in the raw water (5, 10, 25, 50, 75, 100 and 200 NTU), type of the filter (single and medium), type of filtration (conventional and direction) and the depth of the filter (25, 35 and 55) cm within filtration velocity of 8 m/hr. A total of 9 different configuration filters with different types and different depths of the filtration media was used, 6 of them were single-media and 3 were dual media which ranged between (25 and 55) cm.

The angular and coarse material is efficient in retention impurities and dirt in the filtration, and offers higher filtration ability than sand. The pulverized glass does not form a cake in the filter, i.e. does not saturate itself in comparison with the sand, (Opta Minerals Inc., 2015).

Objectives of this Study

The main aims of the current research can be shown by means of:

1-Reduction the adverse environmental impacts of piling up solid wastes by reuse this wastes.

2-Encouraging long-term disposal way of some industrial solid wastes for environment improvement with iterative loops closed waste materials recycling between the industrial and water filtration sectors.

3-Examining the crushed of glass solid wastes from local industrial as a filter media comparison with sand filter media.

EXPERIMENTAL WORK :

1- Filter Media

Sand and Gravel

The sand and gravel for this study were brought from the local market, the gradations for sand were (0.6-1, 1-1.4 and 1.4-2) mm. The gradation for gravel (the supporting and drainage system layer for sand and glass media in filtration columns) was (2.5-6.5) mm, (Ministry of Interior, 1992) and (Central Organization for Standardization and Quality Control, 2000). The physical analysis of the sand filter medium which size of (0.6-1) mm showed that it had density of 2577 kg/m^3 and rounded shape. The physical analysis of the other sizes was done.

Glass

The glass wastes were collected from shops selling glass (as discarded) and broken glass bottles. After that, glass wastes were crushed by electric grinder machine which was developed and used as shown in the **Fig. 1**, then washed and sieved into three sizes (0.6-1, 1-1.4 and 1.4-2) mm as shown in the **Fig. 2**. The physical analysis of the glass filter medium which size of (0.6-1) mm showed that it had density of 2426 kg/m^3 and angular shape.

Pilot Filtration Unit

A pilot filtration unit was set up to examine the glass solid wastes materials filings as a filter media comparison with sand filter media to remove turbidity from synthetic polluted water. The **Fig. 3** showed a schematic diagram of pilot filtration unit and the **Fig. 4** showed pictures for the pilot filtration unit.

Filtration Columns

Four columns of transparent plastic were designed and set up to run in parallel with down flow direction. Each column was 5.7 cm in diameter according to Kawamura (2000), indicated “the size of the filter column should be (100) times the ES of the filter medium”. Each column length is 240 cm.

Under each medium were used stainless steel mesh 0.3 mm in size to support the media and to prevent exit the small granules.

1- Preparation of Turbid Water

For making synthetic turbid water, the pure clay like bentonite was passed through sieve size of 200 µm and used. It was found when putting 0.1 g of this bentonite in 1 L of tap water and mixed for (30-45) min the resulted turbidity was (29-32) NTU.

2- Experimental Runs

Samples of effluent were collected and tested at certain time interval (each 30 min) during the run time. The filtration run continued until the effluent turbidity $(C)/C_i \geq 0.7$ without relying on headloss. The summary of experimental runs was given in **Table 1**.

3- Backwashing

The filter media from run No. 6 to run No. 13 were backwashed by distilled water at velocity calculated form equation **(1)**, (Qasim, et al., 2000).

$$U_b = D_{60} \qquad \textbf{(1)}$$

Where: U_b = back wash rate, m/min
D_{60} in (mm)

RESULTS AND DISCUSSION :

Introduction

Examine the ability of glass filings as filter media was done through change three different parameters. At first, the filtration rate (υ_{F}) and the C_i were fixed but the size and its height of media were changed every rune time until five runs. After the fifth run, the longest run was chosen, the size with its depth and the C_i were fixed but the υ_F was changed until four runs, this was done in the second stage. At third stage, the C_i was changed to four runs but the size with its height and the υ_F were fixed.

It was compared and discussed the results of run times between the sand medium and solid wastes filings. From the experimental data, it can be noticed that the crushed of glass solid wastes were better than the sand media filter in terms of run time and thus better removal efficiency (i.e. the run time of the filter medium is a function (index) of turbidity removal efficiency).

The best removal efficiency achieved for the glass medium in spite of its porosity (but the granular distributions were convergent between them) greater than that of the sand media, where the shape of the grains of the glass medium was angular, since the angular grains give better efficiency than rounded as Trussell et al., (1980) and (Opta Minerals Inc., 2015) said.

Assessment the ability of solid wastes in filtration process were done due to the following physical parameters:

1. First Stage (Effect of Change the Gradation and its Depth of Media)

In this stage, the thickness of media gradations was changed within five combinations of media at group No. 1, 2, 3, 4 and 5, as shown in **Table 1** and **Fig**. **5**, **6**, **7**, **8** and **9**, respectively. The υ_F was 5 m/hr and the C_i was about 17 NTU.

The best result for all media (longest run time) was done in first run (group No.1) within the C_i (average) = 17 NTU and the υ_F = 5 m/hr where the media had consisted only from size (0.6-1) mm. This result is in good unison with (Degremont, 1991) who showed that more straining occur in the fine media.

The small media grains removed a higher percentage of the applied suspended matter than large grains do. This can be explained in two ways. First, the surface -to-volume ratio of the smaller grains is greater than that of the larger grains and the greater surface area offers more opportunity for floe particles to accumulate. Second, the opportunity for bridging between grains is greater for the smaller grains because distances are shorter, (Tien and Ramarao, 2007).

When depth of the size (0.6-1) mm was reduced and used size of (1-1.4) mm or (1.4-2) mm, the porosity of media increased (UC decreased), so the removal efficiency and run time was decreased with fixing the υ_F and the C_i. This behavior indicates that the turbidity removal happens at all height of filter medium. But the effect of size (1.4-2) mm on run time was greater than the effect of size (1-1.4) mm with fixing the depth of both layers because of the UC for the first size was smaller than it for the second and the D_{10} for the first size was bigger than it for the second. This result is in good agreement with (Kang and Shah, 1997) who showed that when the porosity of media was increased, the filtration efficiency was decreased.

The run time for the sand filter media reduced by 3.5, 14.2, 7.14 and 21.4 % in run No. 2, 3, 4 and 5, respectively with average of 11.56 % while the run time for the glass filter media reduced by 3.22, 9.67, 6.45 and 19.35% in run No. 2, 3, 4 and 5, respectively with average of 9.67 %. The glass media had run time longer than it for the sand media by (10.7-16.6) %. The glass filter medium was slightly better than the sand media and the second was more influenced when the gradation and its depth was changed.

2. Second Stage (Effect of Increase the Flow Rate)

In this stage, it was chosen the gradation (0.6-1) mm in depth of 50 cm for both media types because of it possessed longest run time. The C_i was fixed at (approximately) 17 NTU and the υ_F was increased to 6, 7.5, 8.5 and 10 m/hr, as shown in **Fig. 10**, **11**, **12** and **13**, respectively.

As seen from the second stage (run No. 1, 6, 7, 8 and 9 in the **Table 1**), the low filtration velocity (5m/h) generated longest run time (i.e. lowest average of effluent turbidity) and this upshot is in a good matching with (Degremont, 1991) who reported that employing low filtration velocities result in more attachment by adhesion on filter media.

When the flow rate was increased, the mean value (average) of effluent turbidities was also increased but run time was decreased. When filtration velocity was increased, the shear off for particulate matters was also increased, in other words, the particles quickly penetrate deeply into the filter media and have an inclination to egress with the effluent water, and this result is in good compatibility with (Tobiason et al., 2011) who said that the using of higher filtration rates shortens the filter cycle.

The run time for sand reduced by 7.14, 21.4 2, 32.14 and 39.28 % in run No. 6, 7, 8 and 9 respectively with average of 24.99 % while the run time for the glass media reduced by 6.45, 22.58, 29.03 and 35.48 % in run No. 6, 7, 8 and 9, respectively with average of 23.38 %. The run time for the glass media was longer than it of the sand media by (9.1- 17.6) %. The sand media was more influenced by increase the flow rate.

3. Third Stage (Effect of Increase the Influent Turbidity)

In this stage, the thickness of media gradations was fixed at group No. 1 and the υ_F was fixed at 5 m/hr while the C_i was increased to (approximately) 20, 24.5, 27 and 30 NTU at run No. 10, 11, 12 and 13, as shown in **Fig. 14**, **15**, **16**, and **17**, respectively. The longest run time was at C_i (approximately) = 17 NTU.

It was noticed that the running time was decreased with increasing of C_i for all media. When influent turbidity was increased, the deposition of particles through the filter medium was also increased which leads to increase secession, where the detained particles can became partially detached and be driven deeper into the medium and carried off in the filtrate. The results is in good consistency with (Moran et al., 1993) and (Crittenden et al., 2012) who showed that the detachment is highly dependent on specific deposit. Removing of particles in granular bed filters is not an irreversible operation and detachment of particulate matters may carry out throughout the filtration cycle. Detachment happens when shearing forces (flow rate) are higher than the adhesive forces that capturing the particles.

When influent turbidity was increased, the average of effluent turbidity was also increased with decrease of run time at these runs, while the average of removed turbidity was increased by increase the influent turbidity.

The run time for sand reduced by 7.14, 21.42, 32.14 and 39.28 % in run No. 10, 11, 12 and 13, respectively with average of 24.9 % while the run time for glass reduced by 6.45, 19.35, 29.03 and 38.7 % in run No. 10, 11, 12 and 13, respectively with average of 23.3 %. The run time for the glass media was longer than it for the sand media by (10.7- 15.78) %.

Backwash Results .

The details of backwashing for second and third stage were shown in **Table 2.** The backwashing results showed that the time and the amount of water required to clean up the sand medium greater than that of glass medium due to the differences in weight.

CONCLUSIONS :

1. The results of the sieving and physical analysis for crushed glass solid wastes were sometimes spaced and sometimes convergent from that of sand media like ES, UC, density and shape. The filtration efficiency and operating time in the angular grains were better than them in the rounded (semi spherical) grains. The filtration efficiency in the less density media better than the filtration efficiency in the higher density media for difference in the shape of granules.
2. Many of the filtration curves showed that the sand medium had removal efficiency better than the glass medium at the beginning of operating and shortly thereafter, but with the passage of time, the glass medium had better removal and longer run time than the sand medium.
3. Whenever the operating time of the filter medium was longer, the average of effluent turbidity was less at same run. Thus more efficient media.
4. When filtration velocity was increased, the shear off for particles was also increased, i.e. the particles had an inclination to egress with the effluent water.
5. When the inlet turbidity was increased, the average of removed turbidity was also increased but run time was decreased.
6. The backwashing for sand media required time and amount of water greater than that of glass filter media, and to a lesser extent the glass media, due to the differences in density.

FIGURES AND TABLES

Fig. 1: Glass crushing by electric grinder machine

Fig. 2: Sieving process for glass

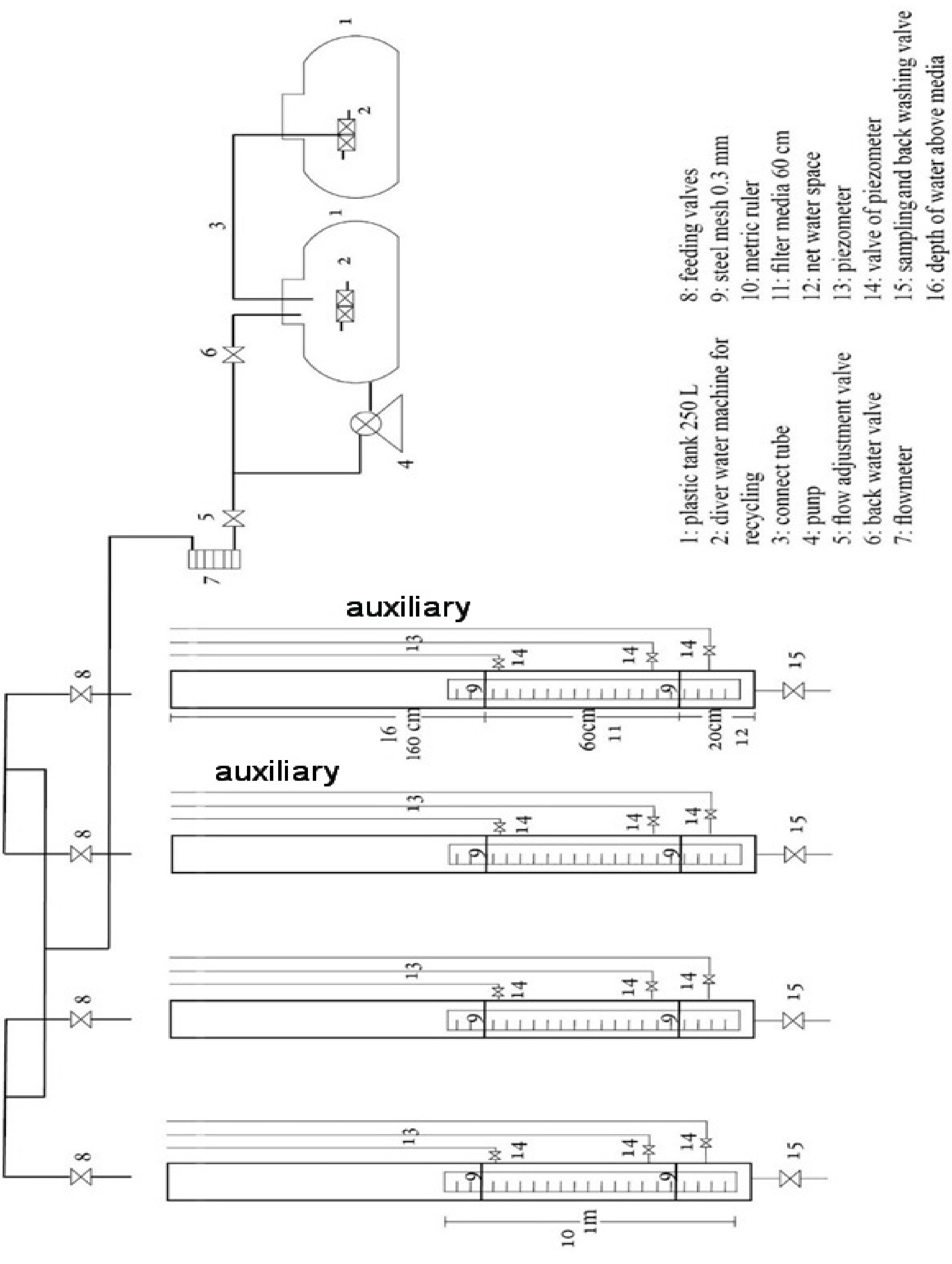
1: plastic tank 250 L
2: diver water machine for recycling
3: connect tube
4: pump
5: flow adjustment valve
6: back water valve
7: flowmeter
8: feeding valves
9: steel mesh 0.3 mm
10: metric ruler
11: filter media 60 cm
12: net water space
13: piezometer
14: valve of piezometer
15: sampling and back washing valve
16: depth of water above media
auxiliary
auxiliary
160 cm
60cm
20cm
1m

Fig. 4: The pilot filtration unit: **(a)** Front view **(b)** Side view

Table 1: The summary of experimental runs

No. of run	No. of group	Media (size) mm	D_{10} (mm)	UC	Layer depth (cm)	υ_F (m/hr)	C_i (NTU) (average)
1	1	Sand (0.6-1)	0.6	1.21	50	5	17
		Glass (0.6-1)	0.625	1.28	50	5	17
2	2	Sand (0.6-1) + Sand (1-1.4)	0.6 + 1	1.21 + 1.17	35 + 15	5	17
		Glass (0.6-1) + Glass (1-1.4)	0.625 + 1	1.28 + 1.2	35 + 15	5	17
3	3	Sand (0.6-1) + Sand (1-1.4)	0.6 + 1	1.21 + 1.17	25 + 25	5	17
		Glass (0.6-1) + Glass (1-1.4)	0.625 + 1	1.28 + 1.2	25 + 25	5	17
4	4	Sand (0.6-1) + Sand (1.4-2)	0.6 + 1.48	1.21 + 1.114	35 + 15	5	17
		Glass (0.6-1) + Glass (1.4-2)	0.625 + 1.46	1.28 + 1.14	35 + 15	5	17
5	5	Sand (0.6-1) + Sand (1.4-2)	0.6 + 1.48	1.21 + 1.114	25 + 25	5	17
		Glass (0.6-1) + Glass (1.4-2)	0.625 + 1.46	1.28 + 1.14	25 + 25	5	17
6	1	Sand (0.6-1)	0.6	1.21	50	6	17
		Glass (0.6-1)	0.625	1.28	50	6	17
7	1	Sand (0.6-1)	0.6	1.21	50	7.5	17
		Glass (0.6-1)	0.625	1.28	50	7.5	17
8	1	Sand (0.6-1)	0.6	1.21	50	8.5	17
		Glass (0.6-1)	0.625	1.28	50	8.5	17
9	1	Sand (0.6-1)	0.6	1.21	50	10	17
		Glass(0.6-1)	0.625	1.28	50	10	17
10	1	Sand (0.6-1)	0.6	1.21	50	5	20
		Glass (0.6-1)	0.625	1.28	50	5	20
11	1	Sand (0.6-1)	0.6	1.21	50	5	24.5
		Glass (0.6-1)	0.625	1.28	50	5	24.5
12	1	Sand (0.6-1)	0.6	1.21	50	5	27
		Glass (0.6-1)	0.625	1.28	50	5	27
13	1	Sand (0.6-1)	0.6	1.21	50	5	30
		Glass (0.6-1)	0.625	1.28	50	5	30

Table 2: The details of backwashing for stage 2 and 3

media	U_b = d_{60} (m/min) (0.6-1) (mm)	Discharge (m^3/min)	Time (min) (average)	Volume of water (m^3)	Expansion bed (average) (%)
Sand	0.73	$1.86*10^{-3}$	22	0.041	20
Glass	0.8	$2.04*10^{-3}$	18	0.036	25

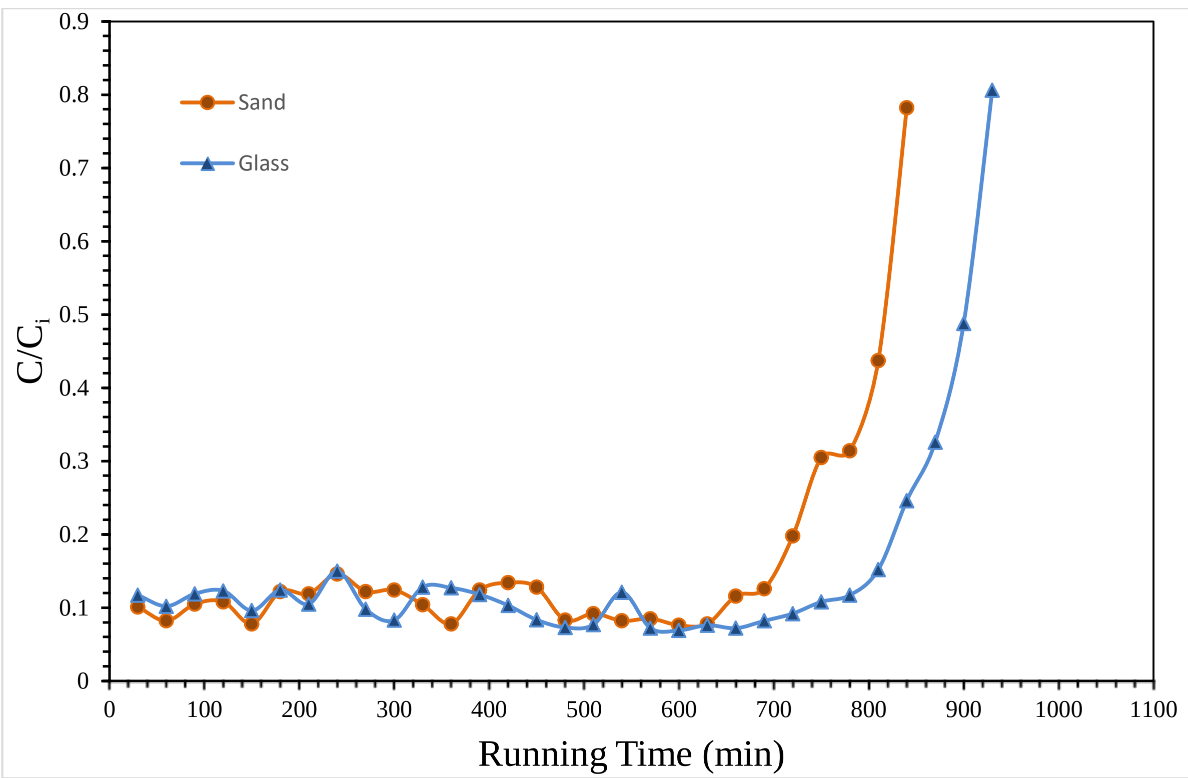

Fig. 5: Ratio of effluent turbidity with run time for run No. 1 within group No. 1 at υ_F = 5 m/hr and C_i (average) = 17 NTU.

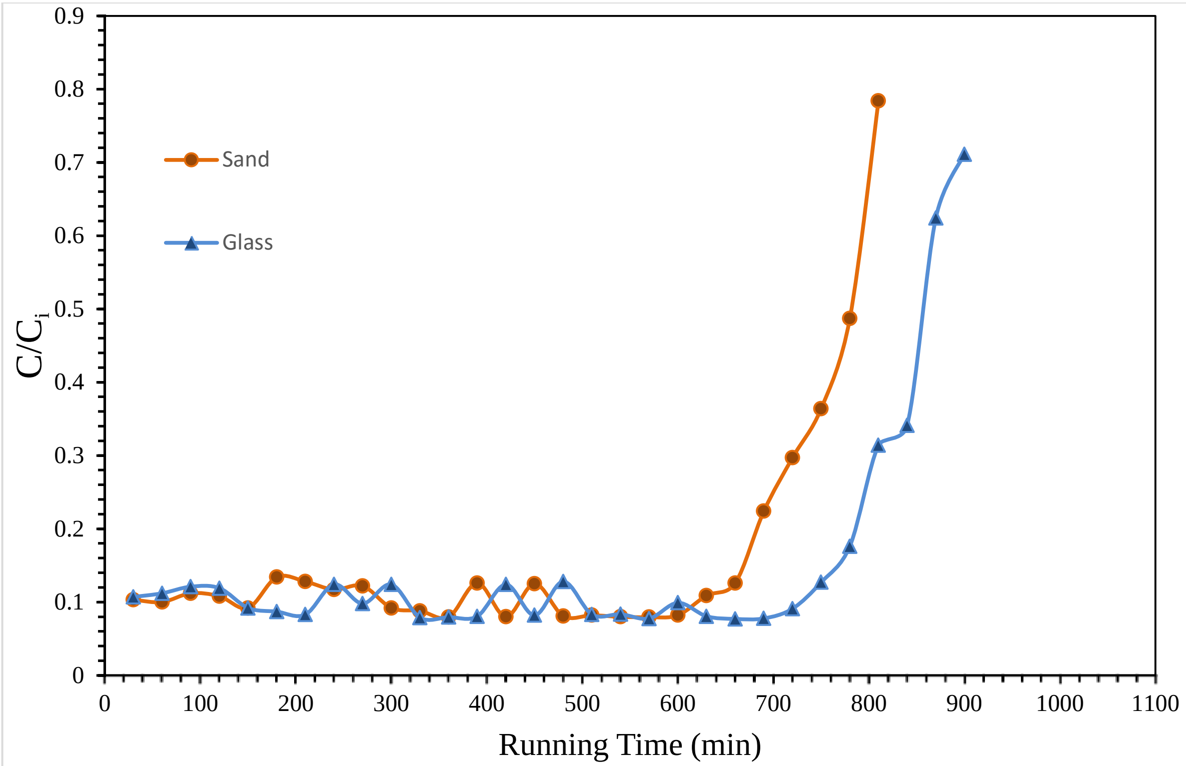

Fig. 6: Ratio of effluent turbidity with run time for run No. 2 within group No. 2 at υ_F = 5 m/hr and C_i (average) = 17 NTU

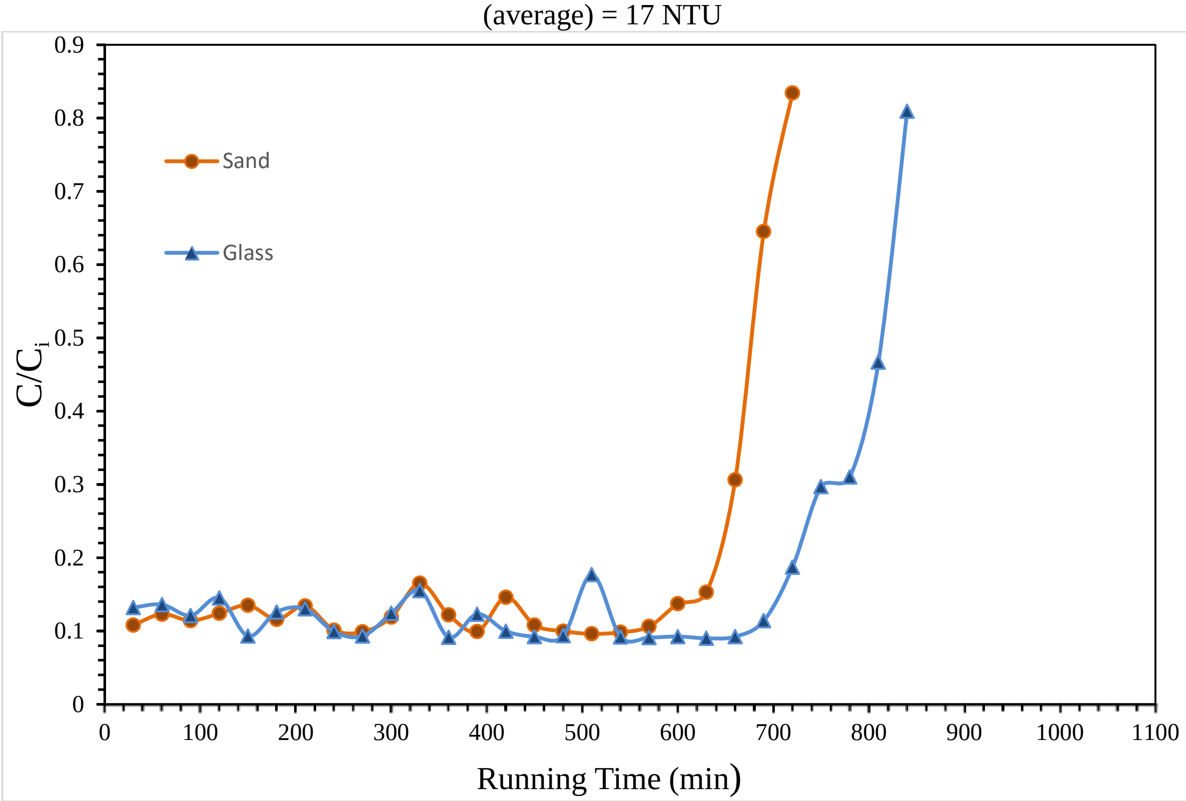

Fig. 7: Ratio of effluent turbidity with run time for run No. 3 within group No. 3 at υ_F = 5 m/hr and C_i (average) = 17 NTU.

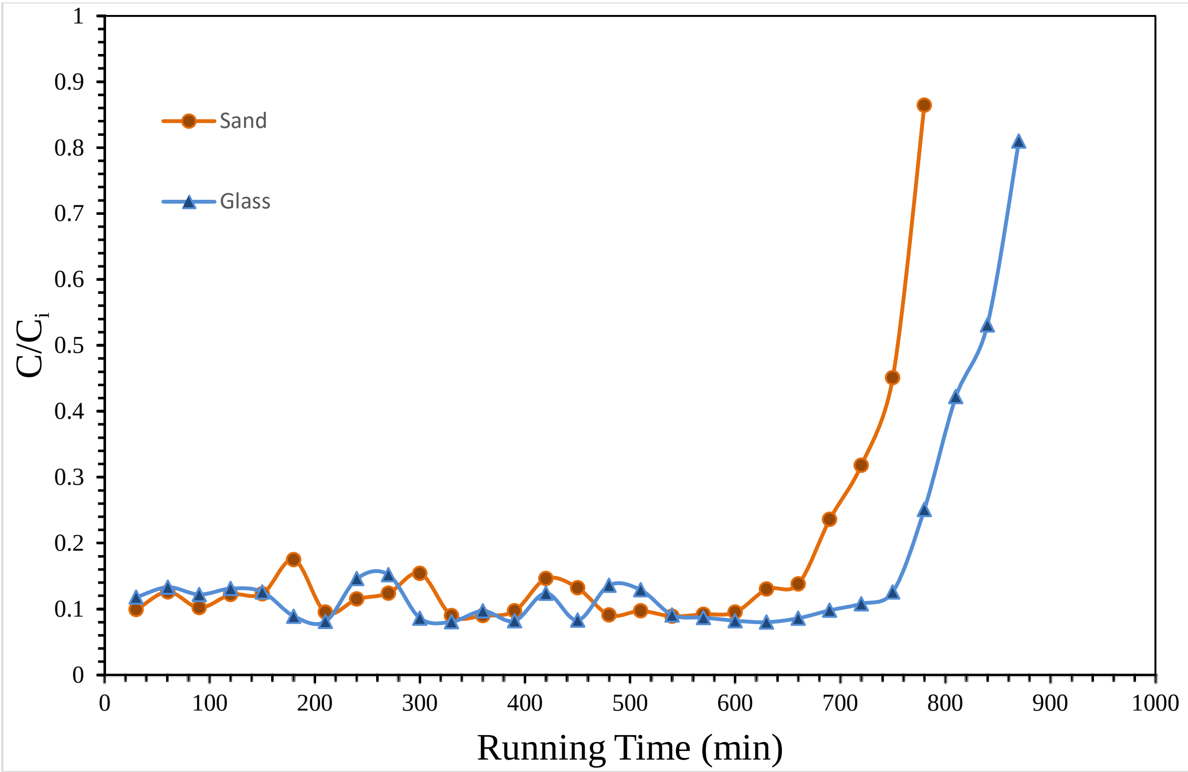

Fig. 8: Ratio of effluent turbidity with run time for run No. 4 within group No. 4 at υ_F = 5 m/hr and C_i (average) = 17 NTU.

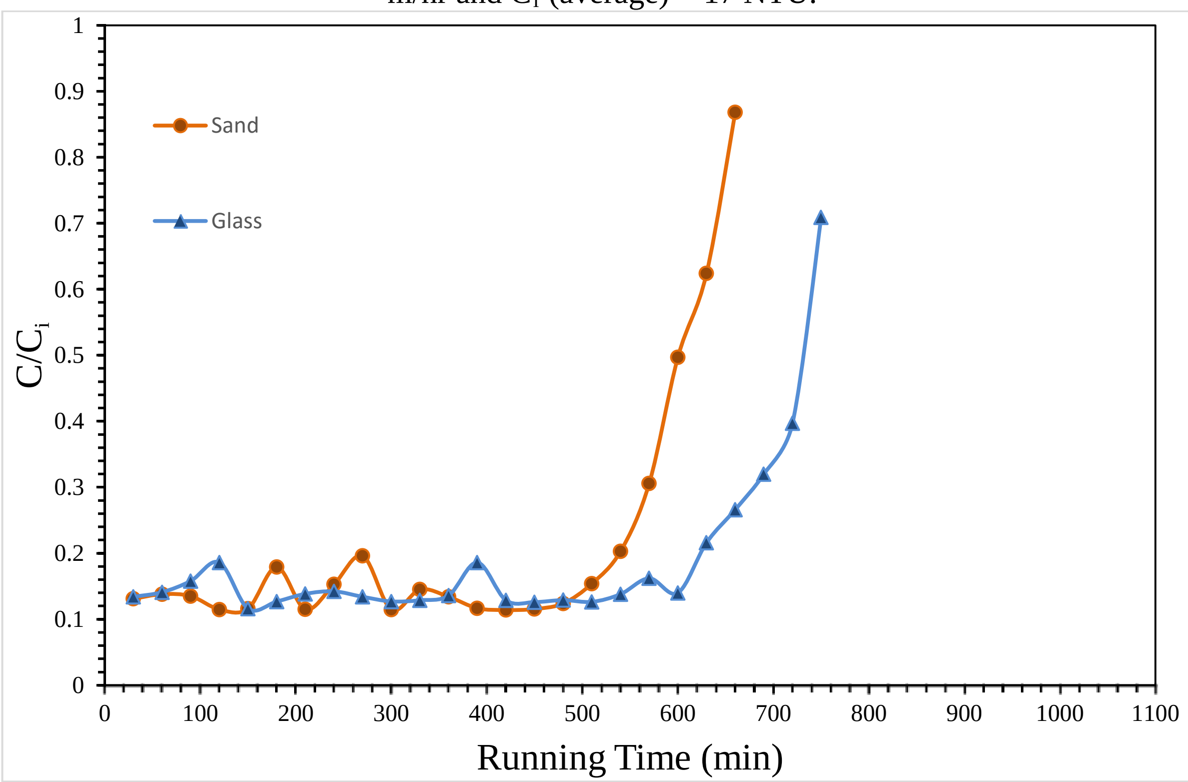

Fig. 9: Ratio of effluent turbidity with run time for run No. 5 within group No. 5 at υ_F = 5 m/hr and C_i (average) = 17 NTU.

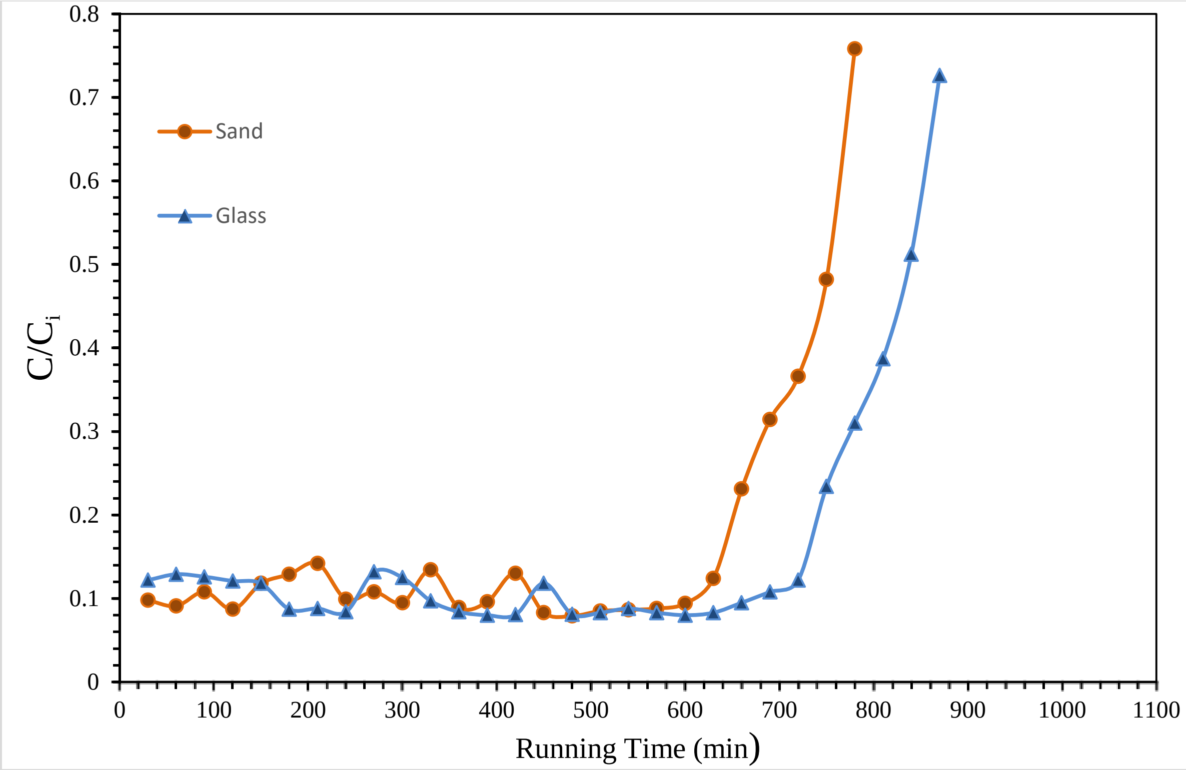

Fig. 10: Ratio of effluent turbidity with run time for run No. 6 within group No. 1 at υ_F = 6 m/hr and C_i (average) = 17 NTU.

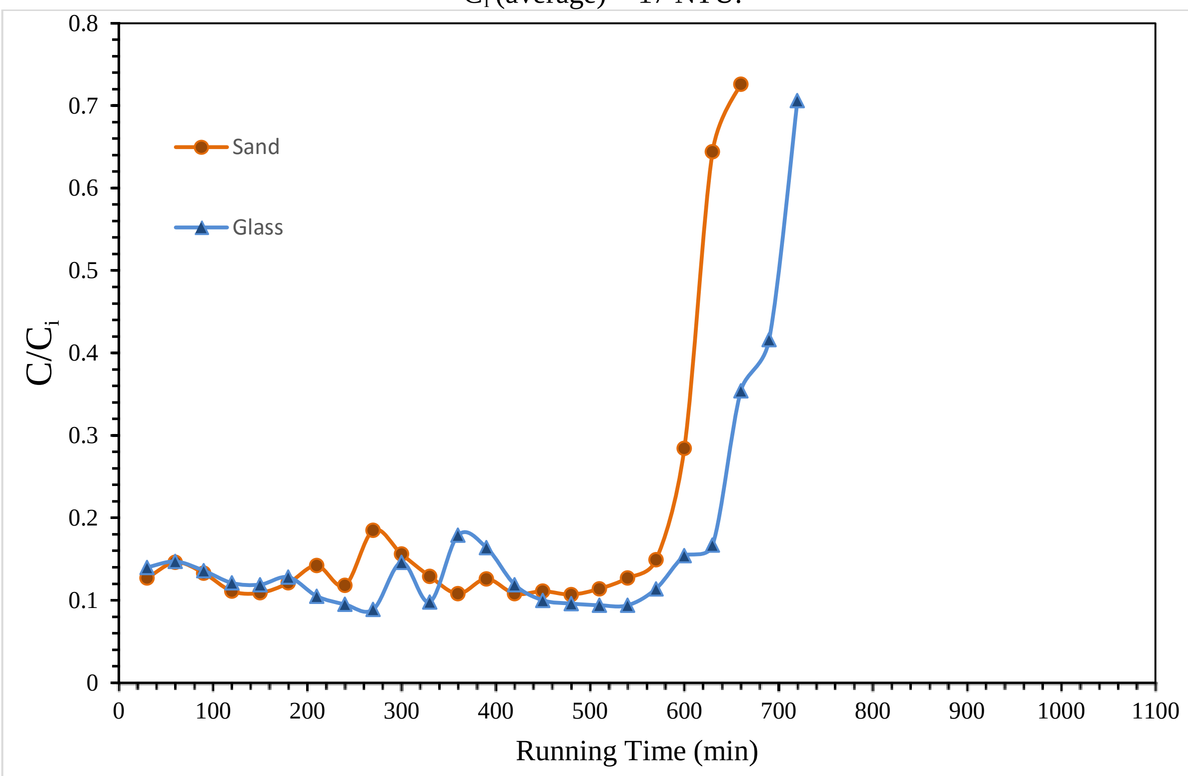

Fig. 11: Ratio of effluent turbidity with run time for run No. 7 within group No. 1 at υ_F = 7.5 m/hr and C_i (average) = 17 NTU.

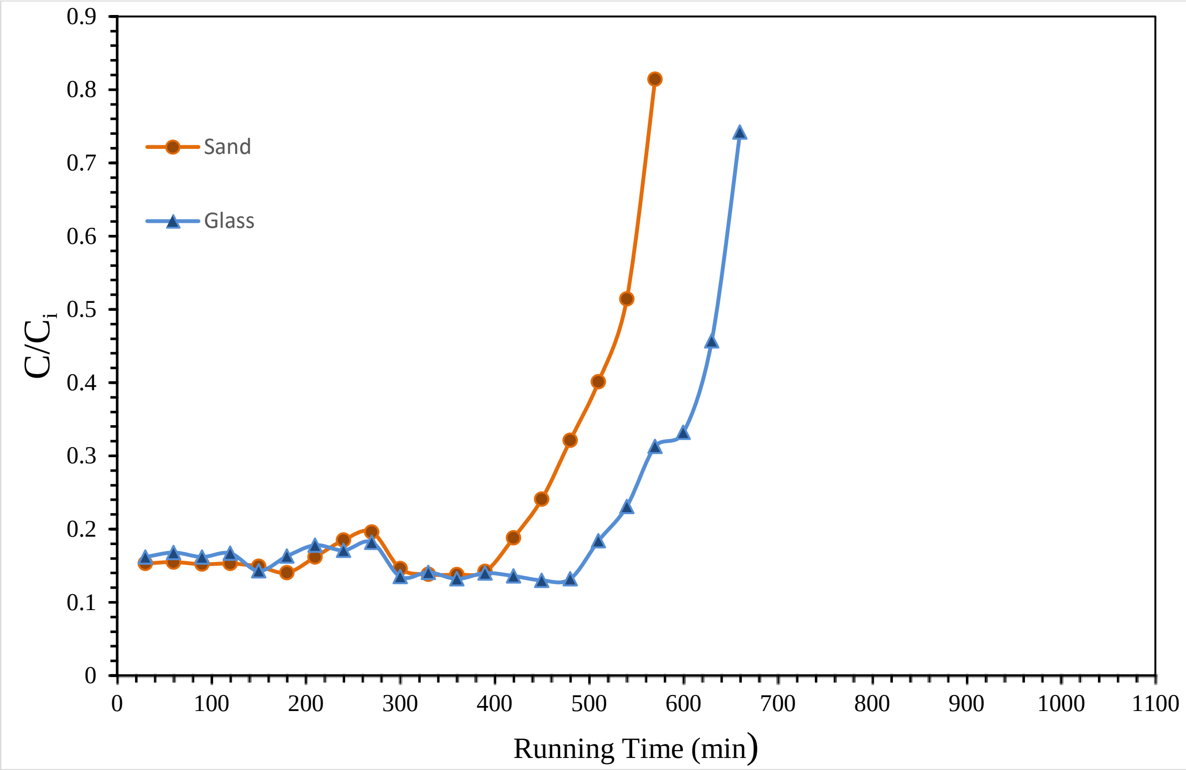

Fig. 12: Ratio of effluent turbidity with run time for run No. 8 within group No. 1 at υ_F = 8.5 m/hr and C_i (average) = 17 NTU.

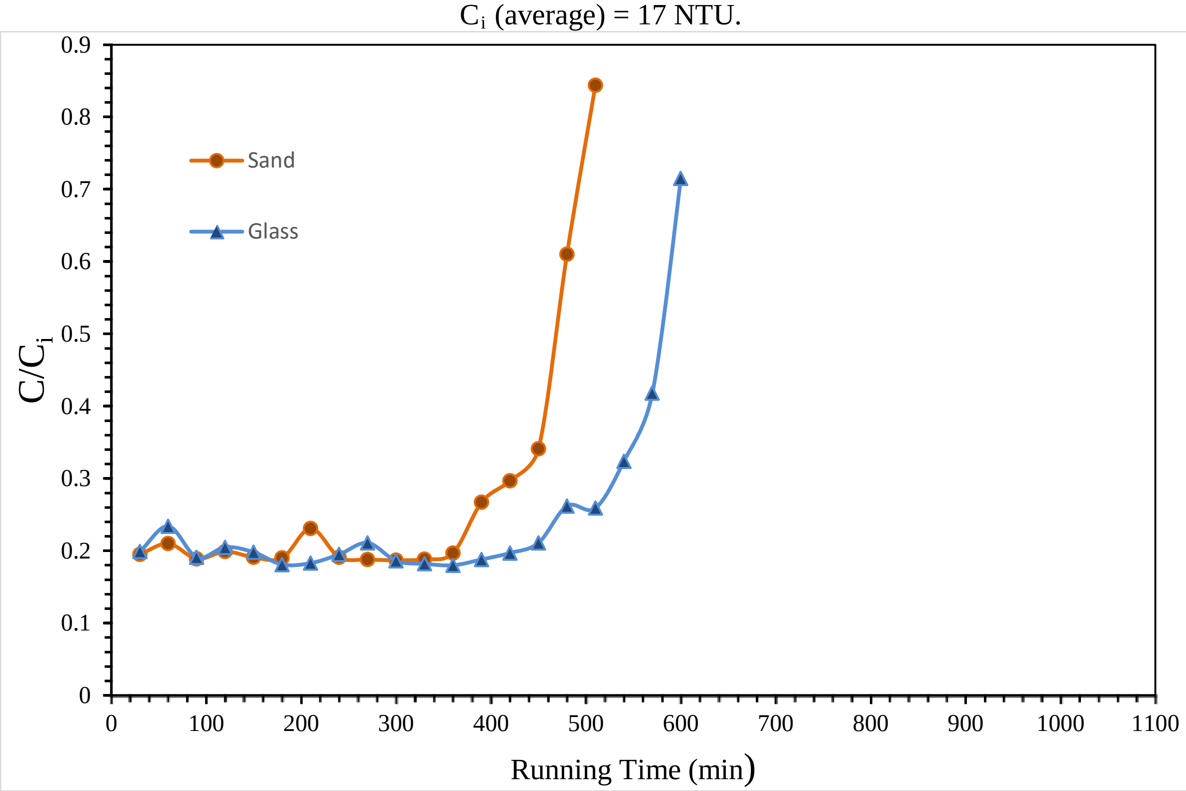

Fig. 13: Ratio of effluent turbidity with run time for run No. 9 within group No. 1 at υ_F = 10 m/hr and C_i (average) = 17 NTU.

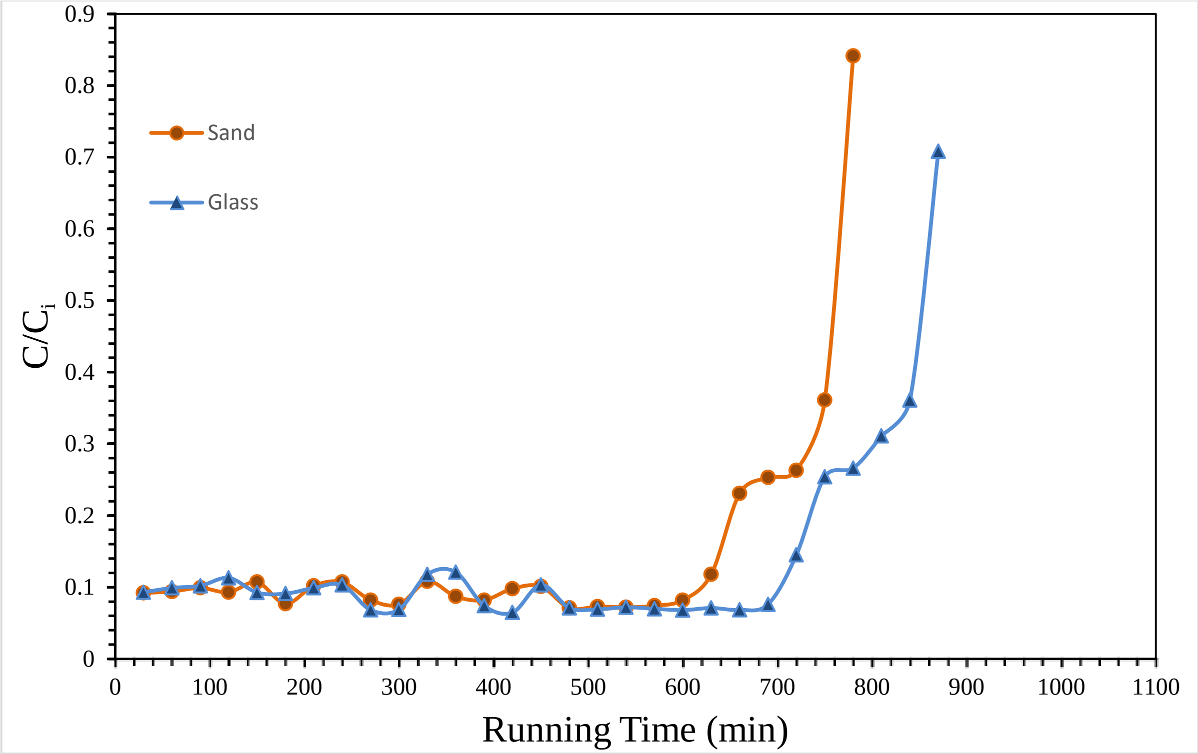

Fig. 14: Ratio of effluent turbidity with run time for run No. 10 within group No. 1 at υ_F = 5 m/hr and C_i (average) = 20 NTU.

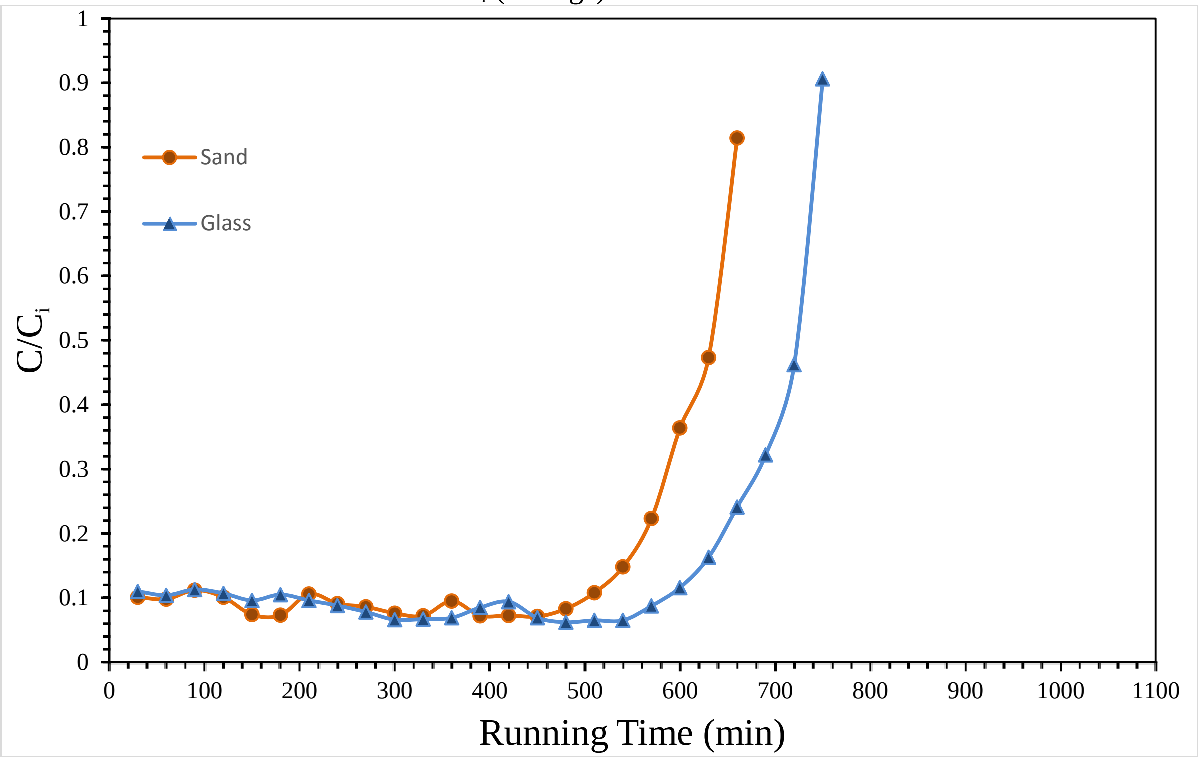

Fig. 15: Ratio of effluent turbidity with run time for run No. 11 within group No. 1 at υ_F = 5 m/hr and C_i (average) = 24.5 NTU.

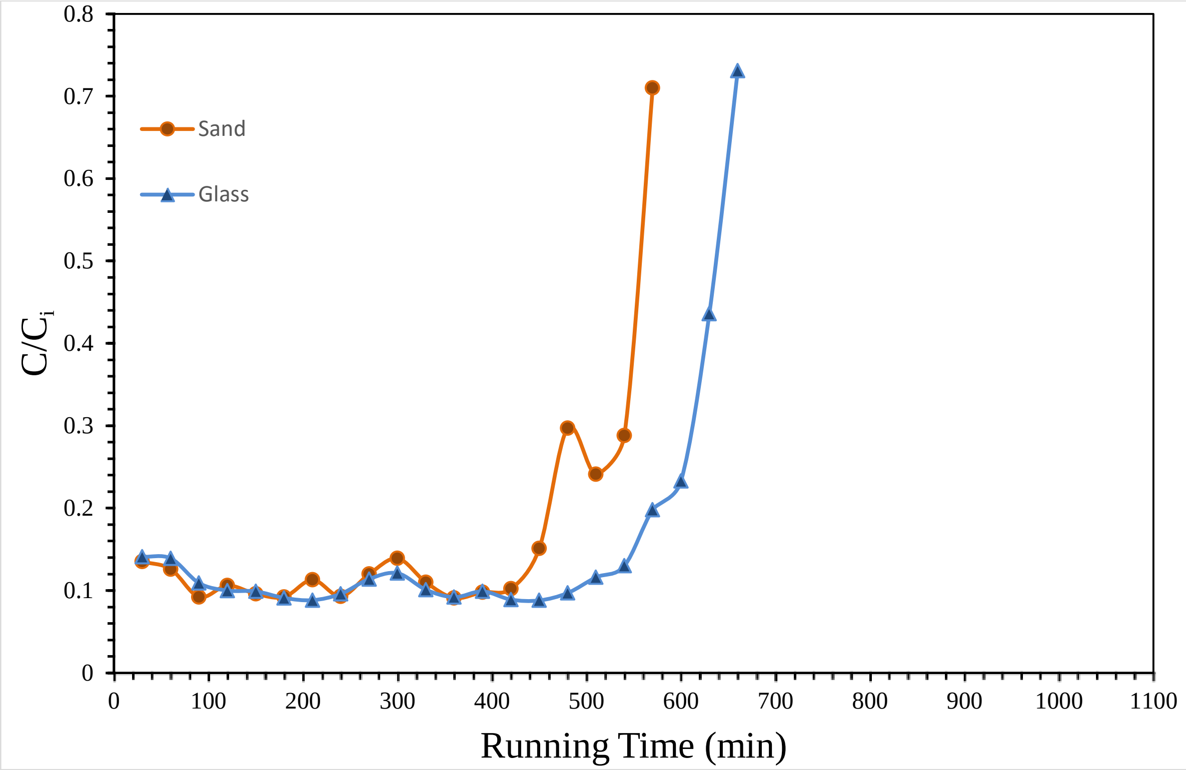

Fig. 16: Ratio of effluent turbidity with run time for run No. 12 within group No. 1 at υ_F = 5 m/hr and C_i (average) = 27 NTU.

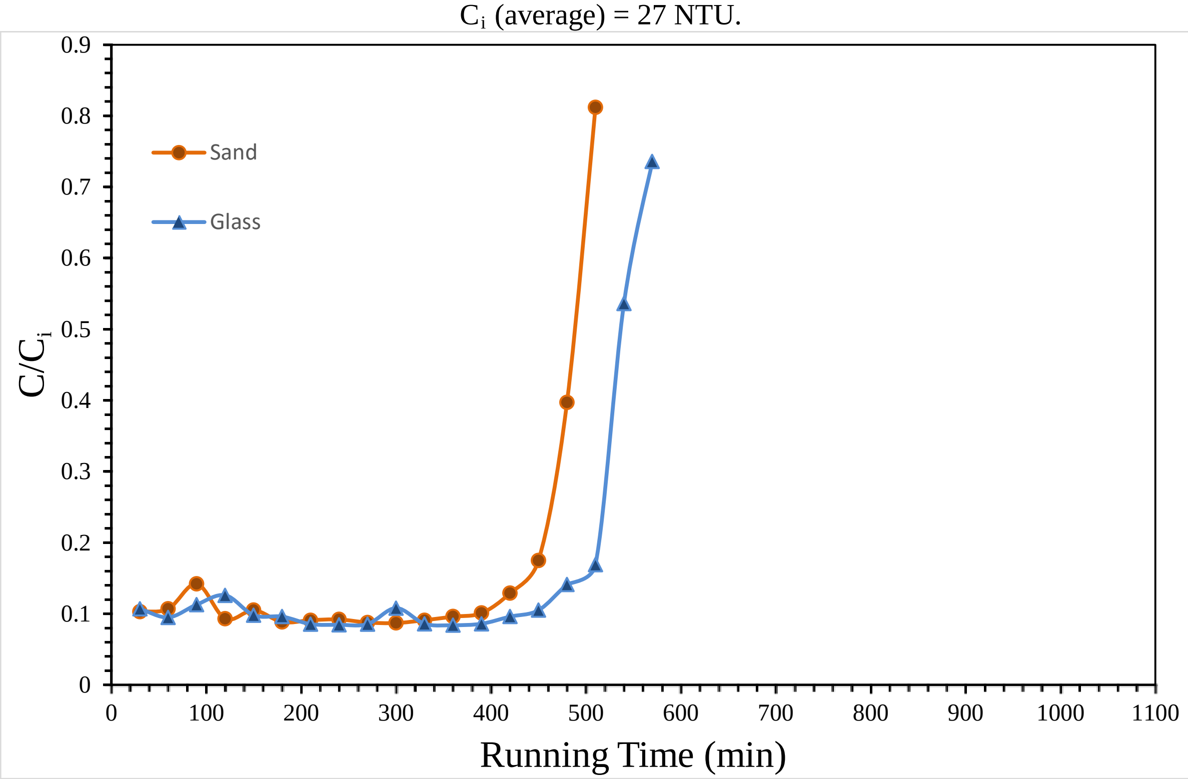

Fig. 17: Ratio of effluent turbidity with run time for run No. 13 within group No. 1 at υ_F = 5 m/hr and C_i (average) = 30 NTU.

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