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Using Crushed Glass with Sand as a Single and Dual Filter Media for Removal of Turbidity from Drinking Water

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ABSTRACT

The aim of this research is trying to find that environmentally and economically efficient way for reuse industrial solid wastes of glass as an alternative filter media to sand to remove turbidity from drinking water. It is required to set a pilot filtration unit which included mainly three transparent columns. It was used to remove the turbidity of synthetic turbid water that consisted of three filter media. The first and second filters represent single media filters of glass and sand, respectively. The third filter represents a filter of dual media of sand at the bottom layer and glass at the top layer. The single media of glass filter and the dual media of glass-sand filter have a maximum removal efficiency of water turbidity in comparison with the single media of sand filter. The maximum removal efficiencies of glass filter, glass-sand filter, and sand filter are 94% and 95%, and 87%, respectively, at influent turbidity of 25 NTU and a filtration rate of 5 m/h. Statistical analysis using stepwise multiple linear regression models had been carried out by utilizing (DataFit, version 9. 1. 32) program models give a good matching between the measured and the predicted values for simulated drinking water for sand, glass, and glass-sand media with the determination coefficient (R^2) equal to 1.

1. INTRODUCTION

Water treatment is important for human well-being and for the protection of the environment and water is a resource that is essential to the life of humans [1, 2]. The main source for water supply in many parts of the world and in most developing countries is surface water; river water that can be highly turbid is used for drinking purposes [3]. The high concentration of clay and suspended solids, organic compounds are considered the main problem in using surface water as a source of water supply [4]. As is known, the turbidity is utilized to indicate the quality of water and the permissible limit for turbidity of treated water in Iraq and in World Health Organization (WHO) guidelines is equal or less than 5 NTU [5, 6]. In water filtration there are many types of rapid, slow, roughing, multistage filtration, pressure filter and diatoms earth filter (DEF). The slow sand filter (SSF) and rapid sand filter (RSF) also known as rapid gravity filter (RGF) spaciously applied for removing of solids existing in surface waters. The types of RSF and SSF are deep granulated filters and mostly the filter media is graded silica sand. New types of filter media used in recent are solid wastes filings like glass. The glass particles are homogenous and with no grain boundaries, thus reduce the clefts that bacteria can refuge and resist cleaning in backwashing. Other benefits for glass are economically effective, environmentally friendly (as recycled) and less weight of sand [7, 8]. Previous applications of the current study are as follow. Soyer et al. [9] showed Comparing the pulverized glass as recycled with silica sand in a single media filters sand in a single media filters. The column was constructed with height of 250 cm and 10 cm diameter. Each filter filled with 1.04 m of either silica sand or pulverized glass. It was showed that pulverized glass can be used as a good alternate of silica sand in rapid filters. Nasser [10] studied the crushed glass solid wastes in drinking water filtration and noted removal efficiency of 80-95% of turbidity at 5 and 10 m/hr filtration rates, and decreased to 75-85% at 15m/hr. The main aim of the current study was reduction the adverse environmental impacts of piling up solid wastes (glass wastes) by reuse this wastes.

2. MATERIAL

2.1 Glass materials

The Glass materials used in the filter columns of the pilot plant unit were of 100% recycled from solid wastes. They were collected from local manufacturing factories for glass products as discarded solid waste. After collection, the glass solid waste was cleaned, washed and crushed by an electric grinder machine and sieved with Effective Size ES (0.61mm), D60 (0.7 mm), Uniformity Coefficient U.C=(D_{60}/ES)=1.14, Specific Gravity (S.G)=0.943, Porosity=52%. as shown in

Figure 1. The chemical characteristics of glass are shown in the Table 1.

Figure 1. The gradation of glass (0.6-1) mm

Table 1. The chemical characteristics of glass

Components	%
TiO_2	0.01%
Fe_2O_3	0.04%
Mgo	0.2%
SO_3	0.2%
K_2O	0.3%
Al_2O_3	1.3%
CaO	10.5%
Na_2O	13.5%
SiO_2	74%

3. EXPERIMENTAL PROCEDURES

The single and dual media filters were tested in the present study. The filtration rate was (5, 15) m/hr [11] and the predetermined running time was (9) hr/day, while the influent turbidity values of synthetic water were about (25, 50, 100) NTU [12].

Figure 2. Schematic diagram of the pilot plant

The schematic pilot plant as shown in Figure 2 used in the present study is constructed of three filters column, each column having 100 cm long and 8.3 cm diameter. The arrangement of filters was as follow: firstly, the glass filter was filled with 80 cm of glass; secondary, the sand filter was with 80 cm of sand; and finally, the glass-sand filter was filled with 40 cm sand at the bottom layer and 40 cm glass at the top layer with particle size of (0-0.6mm) and its very effect on the accuracy of the experimental results [13]. The bottom end of each column is fitted with plastic cap. In the bottom of the cap, there is a hole of 12 mm in diameter for the outlet of the filtered water and also such hole is used to connect the inlet of backwash water. At top of each medium, there is a stainless steel mesh of 0.3 mm in its size to prevent media-like glass to be out from column. In order to prevent the escaping of small granules of media during operation, each nozzle is fitted with a stainless steel mesh of 0.3 mm in size.

4. RESULT AND DISCUSSION

Figures 3-8 shows that the results of turbidity removal efficiency of the single and dual media filters with a filtration rate of (5, 15) m/hr and influent water turbidity of (25, 50, 100) NTU, where, the single media of glass filter and the dual media of glass-sand filter have a maximum removal efficiency of water turbidity in comparison with the single media of sand filter at same operation conditions because the flat shape can be created an available surface area for accumulating deposits and increasing the removal efficiency of turbidity. Therefore, the glass filter and glass-sand filter gave the maximum removal efficiency of water turbidity in comparison with the single media of sand filter at same operation conditions because the flat shape can be created an available surface area for accumulating deposits and increasing the removal efficiency of turbidity. Therefore, the glass filter and glass-sand filter gave the maximum removal efficiency of water turbidity in comparison to that from the sand filter and these results in a good agreement with studies [14, 15].

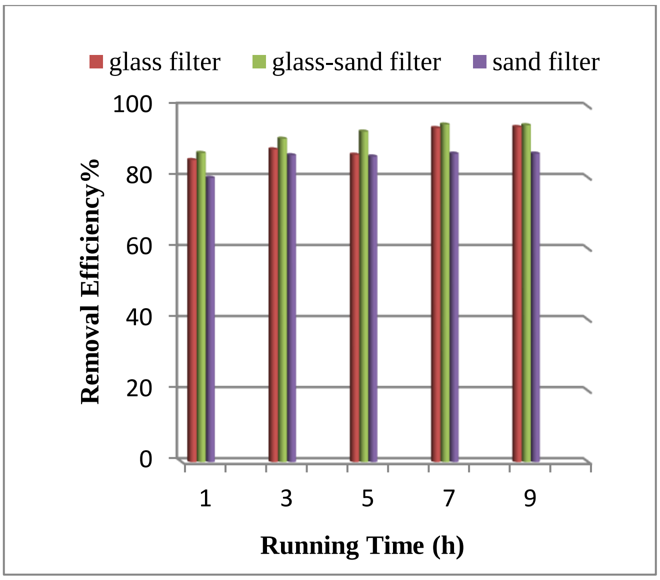


Figure 3. The turbidity removal efficiency as a function of Time for Filters at Influent Turbidity=25 NTU, Filtration Rate=5 m/h

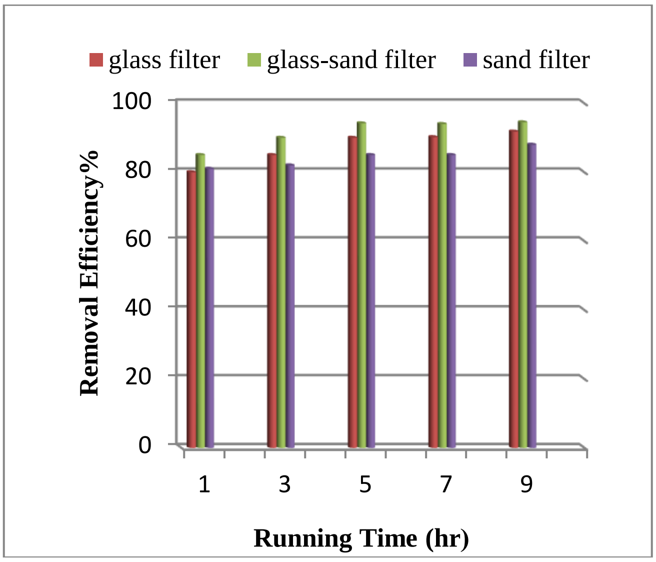


Figure 4. The turbidity removal efficiency as a function of Time for Filters at Influent Turbidity=50 NTU, Filtration Rate=5 m/h

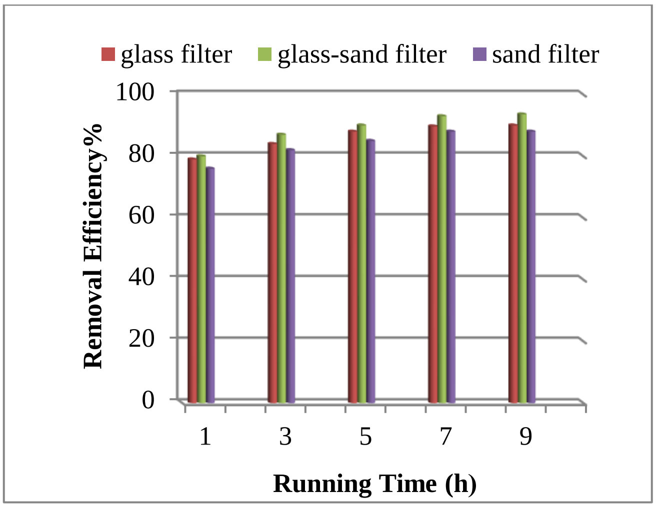


Figure 5. The turbidity removal efficiency as a function of Time for Filters at Influent Turbidity=100 NTU, Filtration Rate=5 m/h

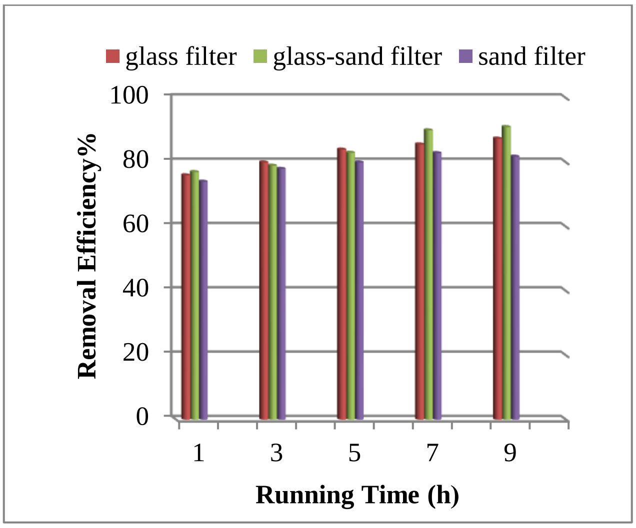


Figure 6. The turbidity removal efficiency as a function of Time for Filters at Influent Turbidity=25 NTU, Filtration Rate=15m/h

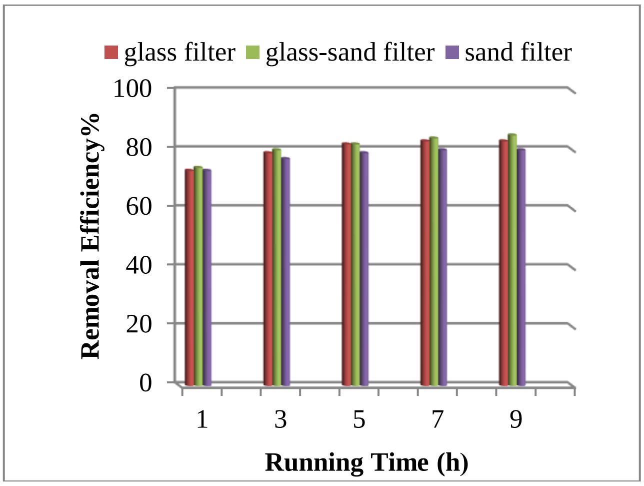


Figure 7. The turbidity removal efficiency as a function of Time for Filters at Influent Turbidity=50 NTU, Filtration Rate=15m/h

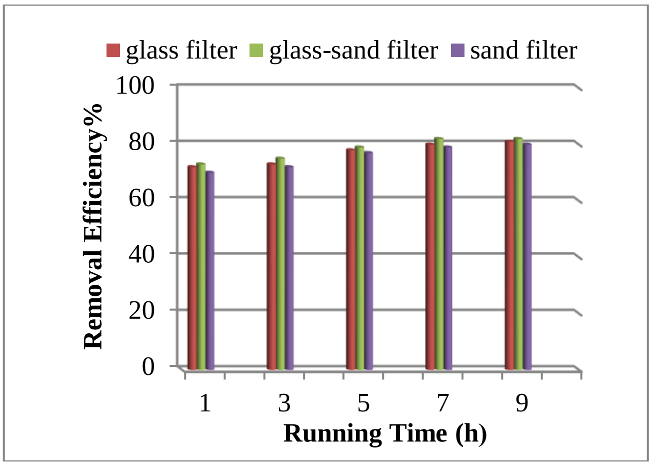


Figure 8. The turbidity removal efficiency as a function of Time for Filters at Influent Turbidity=100 NTU and Filtration Rate=15m/h

5. REGRESSION MODEL FOR TURBIDITY REMOVAL

Statistical analysis using stepwise multiple linear regression models had been carried out by utilizing (DataFit, version 9. 1. 32) program to simulate the experimental data for turbidity removal with electromagnetic field [16]. The dependent and independent parameters used in the present study were given in Table 2.

Table 2. The dependent and independent parameters for filters media

Parameter	Description	Typed
Y	Efficiency	Dependent
X1	Influent turbidity	Independent
X2	Effluent turbidity	

5.1 Statistical model for turbidity

The number of models for the turbidity removal with filters media was emerged by this program and the best model was used as revealed in Table 3.

Table 3. Statistical model for removal turbidity for filter media

Model	Coefficient of determination (R2)	Variable	Value
$Y=a-(b^*X_1)+(c^*X_2)$	1	a	100
		b	-5
		c	4.09E-19, 1.515E-16 and 4.097E-17 for glass, sand and glass-sand filters, respectively
		a	100

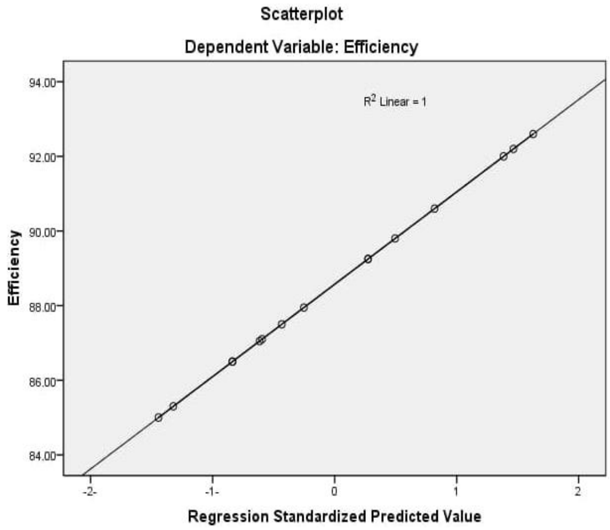
The efficiency equation for filters media was written due to the variable values as follows:

$Y=100-50\ X_1+4.09*10-19\ X_2$ for glass filter
$Y=100-50\ X_1+1.515*10-16\ X_2$ for sand filter
$Y=100-50\ X_1+4.09*10-17\ X_2$ for glass-sand filter

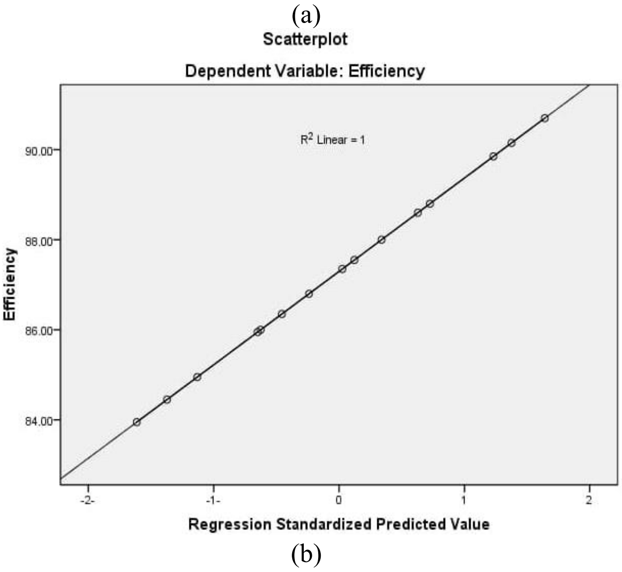
5.2 Verification of statistical model for removal turbidity with filters media

There are several ways to test the accuracy or validity of regression equations to demonstrate whether any of them are used here considered statistically.

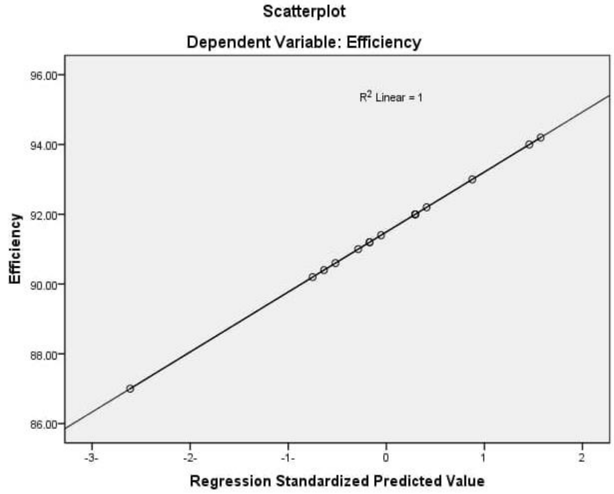
Figure 9 clearly shows that the expected models are effective, as shown by the best fit line slop (slope=1).



(a)



(b)



(c)

Figure 9. Field and estimated data turbidity removal with (a) sand; (b) glass; and (c) glass-sand filter media using suitable model (Liner-Liner)

The value of R^2 is the most critical measure of model accuracy, so the model is highly accurate when R^2 is equal to 1 and above this value.

6. CONCLUSIONS

The solid wastes filings of glass are treated, reused, examined in the filtration process to remove turbidity from aqueous solutions. Generally (except some cases), whenever the running time for the filter medium was longer, the effluent turbidity was low at same run. The single media of glass filter and the dual media of glass-sand filter have a maximum removal efficiency of water turbidity in comparison with the filter of sand, when the inlet turbidity was increased, the removal efficiency was also increased but run time was decreased. The maximum removal efficiencies of glass, glass-sand filter, and sand filter are 94% and 95%, and 87% respectively.

Statistical analysis by utilizing (DataFit, version 9. 1. 32) program models give a good matching between the measured and the predicted values for sand, glass, and glass-sand media with the determination coefficient (R^2) equal to 1.

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NOMENCLATURE

Subscripts

WHO	World Health Organization
DEF	Diatoms Earth Filter
SSF	The Slow Sand Filter
RSF	Rapid Sand Filter
RGF	Rapid Gravity Filter