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Treatment of Water Using Dual Direct Filtration of Porcelanite Media

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Abstract: The present study was based upon utilization of a direct filtration pilot plant to treat simulated raw water by mixing bentonite clay with tap water. The porcelanite material was used as dual filter media with silica sand for different porcelanite depths. The total filter depth of 1m and porcelanite depth ratios of (30, 50 and 70%). The effective size of porcelanite and sand are 0.8 and 0.5 mm, respectively. The filter has 50% porcelanite ratio which leads to obtain longer running time as compared with the other two filters. The maximum raw water turbidity that can be treated by using this set was 100 NTU with average removal efficiency of 99.4%. The run time was of 9 h and effluent turbidity was <5 NTU. Alum had been used as a coagulant in this study with different dosages to show their effects on the turbidity removal efficiency where the decreasing in alum dosage gave better results of run duration and turbidity removal efficiency.

Key words: Crushed porcelanite, bentonite clay, direct filtration, removal turbidity, alum dosage, pilot plant

INTRODUCTION

Natural waters are always required to be treated for human and industrial consuming. The degree of required treatment will depend on the raw water characteristics. Coagulation, flocculation, sedimentation and granular filtration are typical process train for conventional treatment method which is used to remove colloidal matter and other solid particles from water sources. The direct filtration process consists of the addition of destabilization chemicals (coagulation) followed by some flocculation with no settling and finally filtration. It is clear that the main difference between direct filtration process and conventional treatment method is the removal of solid particles in direct filtration is taken place in the filter media (Kiely, 1996).

The direct filtration process can be an effective and economical alternative to conventional water treatment for low turbidity waters. The possibility of reduction capital cost up to 30% is the chief advantage of direct filtration process. This results from the elimination of settling basin structure, sludge-collecting equipment. The provision in chemical quantities may be ranging from 10-30% because in general a filterable floc production requires lower alum dosage than a settleable floc production, less maintenance and operating costs because of less sludge formation than in conventional treatment in which the sludge is dener (Culp, 1977).

The disadvantage of direct filtration is that, it may be not applicable to raw waters having turbidity greater than 100-200 NTU, color greater than 100 Pt-Co units, color and turbidity each greater than 25 units, plankton exceeding 500-1000 asu/mL or appreciable amount of paper fiber (Driscoll *et al.*, 1998).

There is a small difference in filters construction utilized for direct filtration process from those utilized for conventional treatment. Particles storage amplitude and backwash requirements are the main differences in the run of these two systems where in direct filtration a floc capable of being filtered is the main goal during coagulation-flocculation rather than one capable of settling and all solids removed from the water are stored within the filter bed (Culp, 1977).

Rashid (1989) used two types of filter media, single sand media and dual media of silica sand and anthracite coal in direct filtration pilot plant. It was showed that the single sand media was not able to give any practically accepted filter runs due to the rapid clogging and high rate of head loss accumulation while dual media of both types; coarse and fine graded particles were superior to single media in direct filtration technique and provide high storage capacity for deposited flocs with moderate headloss accumulation rates.

Many researchers evaluated the performance of porcelanite as single and dual filter media. (Al-Ansary, 1998) evaluated the performance of locally Porcelanite Rocks (PR) as a filter media in the treatment of water

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Corresponding Author: Jabbar H. Al-Baidhany, Department of Environmental Engineering, College of Engineering, University of Babylon, Hillah, Iraq supplies. He studied the performance of dual media filter composed of porcelanite and sand. The results showed that the PR filter is more effective in turbidity removal, more length in filter run and less head loss during filtration nearly by (40%).

Al-Bayaty (2006) selected porcelanite rocks to be used as dual media with sand to improve filtration performance in water treatment plants. The pilot filtration consists of three plastic column filters, working parallel and simultaneously. The first contains 70 cm sand ES = 0.72 mm UC = 1.7 the second and third were dual filters (porcelanite of ES = 0.83 mm UC = 1.45 with sand) of different depths using different rates of filtration 5, 10 and 15 m/h. The results showed that the dual filters had better performance than sand filters in turbidity and bacterial removal, less initial head losses and less total head losses at different filtration rates.

Objectives of study: The main aim of conducting this experiment is to evaluate the performance of direct filtration process using dual media of sand and porcelanite with different depths. The other aim is to investigate the maximum raw water turbidity that can be treated with this process for running time equal or greater than 8 h with effluent turbidity equal or <5 NTU.

MATERIALS AND METHODS

Porcelanite: The porcelanite rocks used in this study were brought from the General Establishment for Geological Survey and Mineralogy/Ministry of Industry and Mineral (GEGSM), from Akashat site in the Western region of Iraq. Porcelanite rocks were delivered in a large size. The first step is crashing and sieving of rocks to obtain granular porcelanite with grain size of 2-0.6 mm. The washing of the granular porcelanite with distilled water and then drying in an electrical oven of 120°C for one night is the second step. The effective size of porcelanite media was of 0.8 mm Fig. 1 shows the grain size distribution of crushed porcelanite. The chemical and physical analysis of porcelanite is shown in Table 1.

Sand: The sand used in the filter media has effective size of 0.5 mm and uniformity coefficient of 1.56 Fig. 2 shows their grain size distribution.

Bentonite clay: Turbid water is prepared by mixing bentonite clay with tap water. The bentonite clay is passed from sieve of 0.075 mm opening. A required weight of bentonite clay, to prepare a specific turbidity is soaked in 1 L of tap water for 24 h and then diluted in the feed tank. The relationship between turbidity and weight of bentonite clay for the synthetic water used in this study is shown in Fig. 3.

Table 1: Chemical and physical analysis of porcelanite sample that had been used

Chemical composition	Percentage
Fe_2O_3	6.43
Al_2O_3	0.54
SiO_2	88.21
CaO	1.38
Effective size (mm) E.S	0.8
Uniformity Coefficient U.C	1.625
Specific Gravity S.G	1558
Porosity	0.52

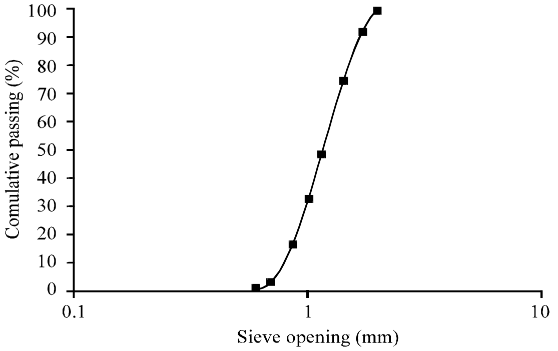

Fig. 1: Particles size distribution of crushed porcelanite that had been used

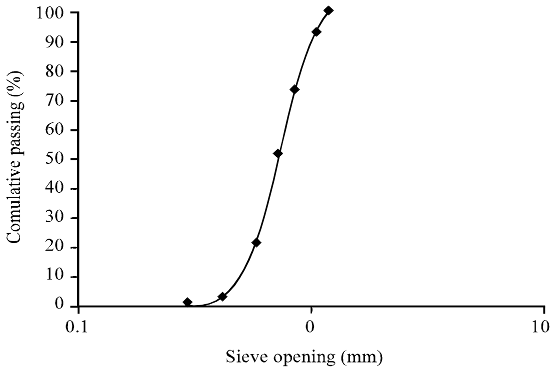

Fig. 2: Particles size distribution of sand that had been used

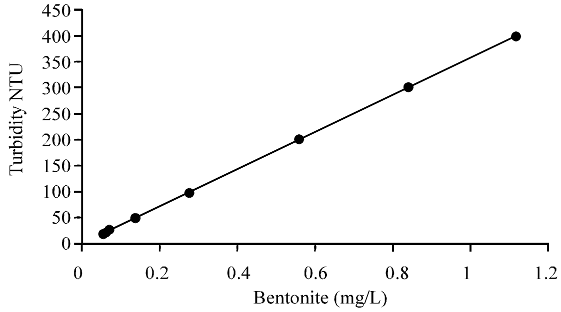

Fig. 3: Relation of turbidity-bentonite used in this study

Alum: Alum was used as a coagulant. The chemical designation for alum is $Al_2(SO_4)_3.18H_2O$. The

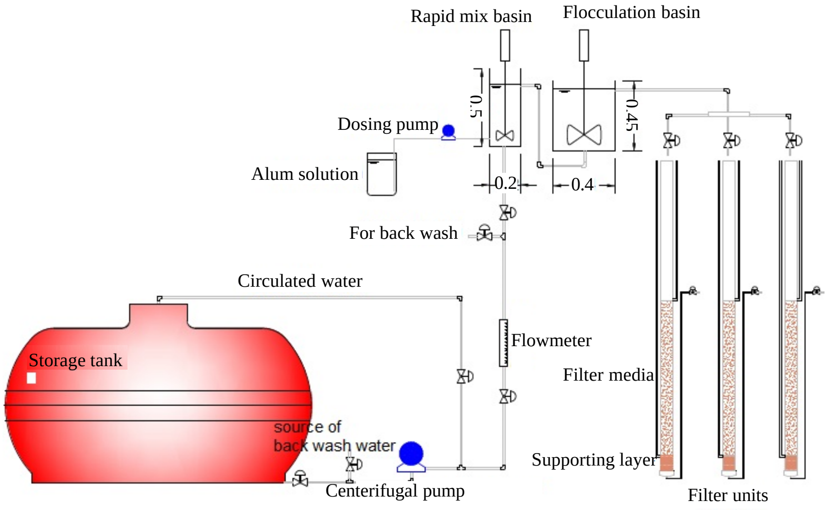

Fig. 4: Schematic diagram of the pilot plant used in the survey

Table 2: The first alum dosage used

Turbidity value (NTU)	Alum dosage (mg/L)
25	15
50	20
100	25
200	25

concentration of the solution used in this study was 0.1% which to be prepared using tap water and then mixed in a polyethylene tank having a volume of 20 L.

Pilot plant and filter columns: A 1000 L volume polyethylene tank was used to prepare a synthetic raw water by mixing tab water with bentonite clay. A centrifugal pump was used to feed the synthetic raw water from the tank to the coagulation basin. A part of raw water was circulated to the feed tank to achieve a proper agitation of water. Dosing pump type of aqua was used for feeding alum solution of required dosage to rapid mix basin. In the rapid mix basin, the destabilization of colloids was achieved. The dimensions of rapid mix basin are 20×20×50 cm with water depth of 40 cm. After that the raw water is transported to flocculation basin by gravity flow. This basin promotes the formation of bigger floc by agglomeration of small ones. The dimensions of flocculation basin unit is 40×40×45 cm with water depth of 40 cm. The level of flocculation basin is 3 cm below rapid mix basin because of head loss.

The filter unit consists of three plastic filters columns. Each column is 8 cm in diameter and height of 200 cm. The filters are designed and built to run in parallel with down-flow direction. 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. The total depth of filter media inside filter column is of 1 m. For pressure drop readings, each column is fitted with two transparent plastic tubes, these tubes are parallel to the filter column one of them is at the bottom and the other is at the top of filter media. The diameter of each tube is 10 mm. In order to prevent the escaping of the filter media during operation, each nozzle is fitted with a steel mesh. The drainage system of all filter configurations is made of gravel-supporting layer. The grain size of the supporting layer is 3-6.5 mm and the height of the layer is of 10 cm height. The under-drain system serves supporting the filter medium, collecting the filtered water and distributing the backwash water into the filter. Figure 4 shows the schematic diagram of the pilot plant used in the experiment.

Experimental procedure: Four values of the influent turbidity of 25, 50, 100, 200 NTU prepared by mixing bentonite clay with tap water according to the Fig. 3. Jar test was accomplished for each four turbidity values to determine the first alum dosage which must be added. The first dosage of alum for each four turbidity values is shown in Table 2.

Filtration rate of each filter is maintained constant of (5 m/h). The pH value of synthetic raw water is measured for each run beginning, it should be in the range of 5.5-7.5 according to AWWA (2000). The effect of change in alum dosage was also studied for each turbidity value by adjusting the dosing pump. The water levels in the piezometers were recorded at the starting of each run and at fixed time intervals each 1 h to determine the head losses along the filter depth.

Samples of the effluent were collected at certain time intervals each 1 h during the run and then the turbidity was measured. Filter failure may happen as a result of turbidity breakthrough to more than the maximum allowable limit of 5 NTU or because of headloss termination. Backwashing for each filter column was done by passing tap water upward through the filter media at flow rate of 4 l/min.

RESULTS AND DISCUSSION

The dual media filters of porcelanite and sand in different depths were tested through arrangement of filters as follow; filter No.1 of 70 cm sand and 30 cm porcelanite, filter No. 2 of 50 cm sand and 50 cm porcelanite and filter No. 3 of 30 cm sand and 70 cm porcelanite. The porcelanite media was as the top layer while the sand media was as the bottom layer in the filter column arrangement.

Figure 5-16 show the results of turbidity removal efficiency of porcelanite dual media filters for influent raw water turbidities of 25, 50, 100, 200 NTU with different

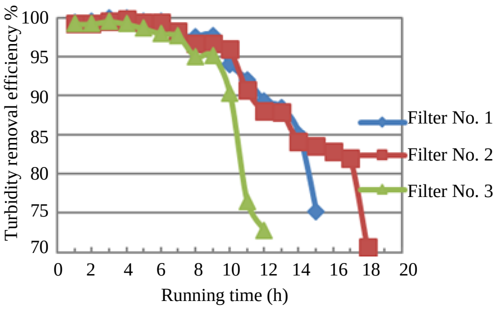

Fig. 5: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 25 NTU, alum dosage = 15 mg/L

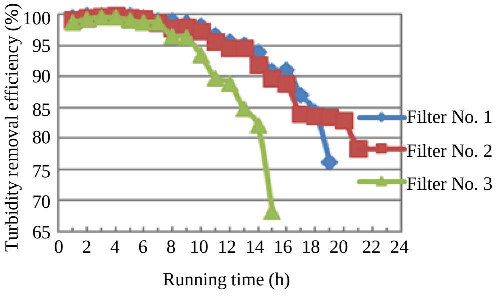

Fig. 6: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 25 NTU, alum dosage = 10 mg/L

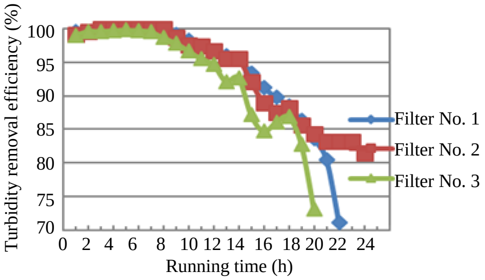

Fig. 7: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 25 NTU, alum dosage = 5 mg/L

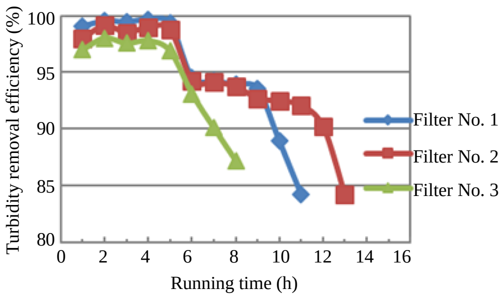

Fig. 8: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 50 NTU, alum dosage = 20 mg/L

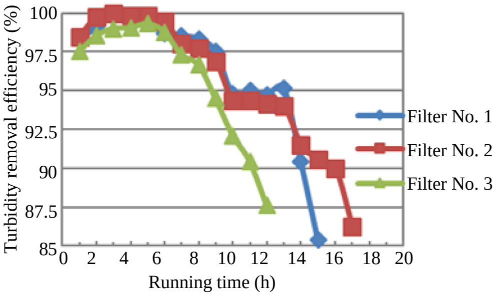

Fig. 9: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 50 NTU, alum dosage = 15 mg/L

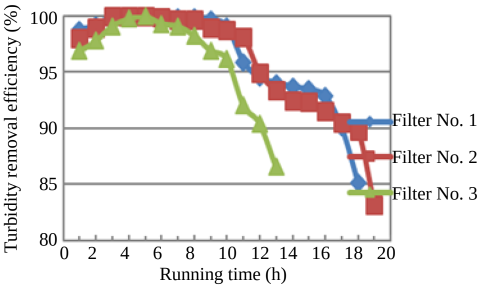

Fig. 10: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 50 NTU, alum dosage = 10 mg/L

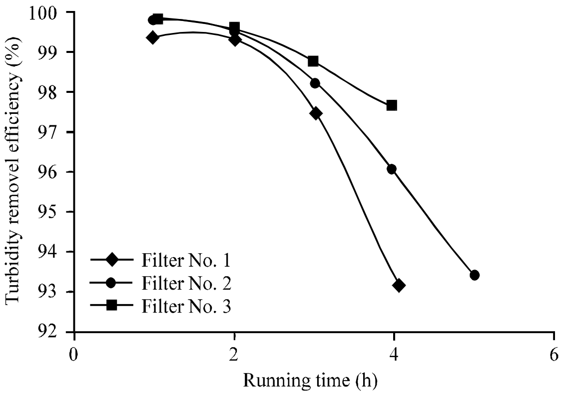

Fig. 11: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 100 NTU, alum dosage = 25 mg/L

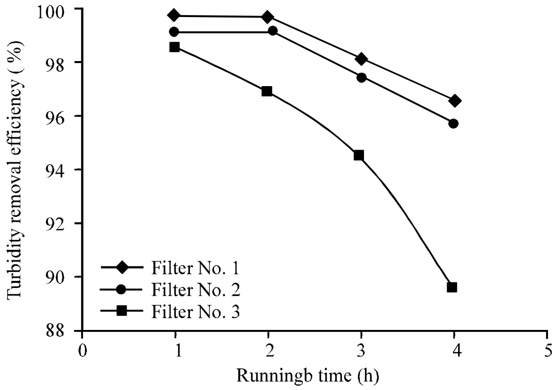

Fig. 14: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 200 NTU, alum dosage = 25 mg/L

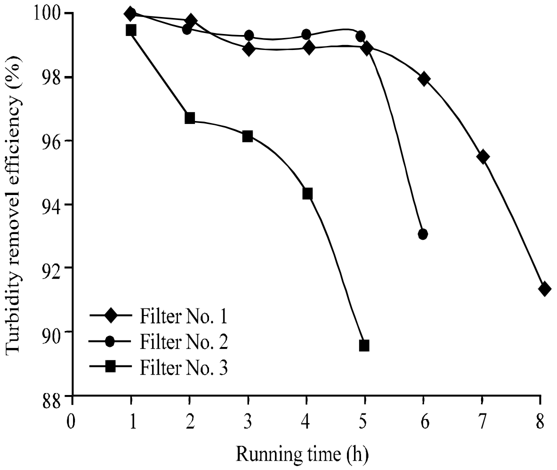

Fig. 12: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 100 NTU, alum dosage = 20 mg/L

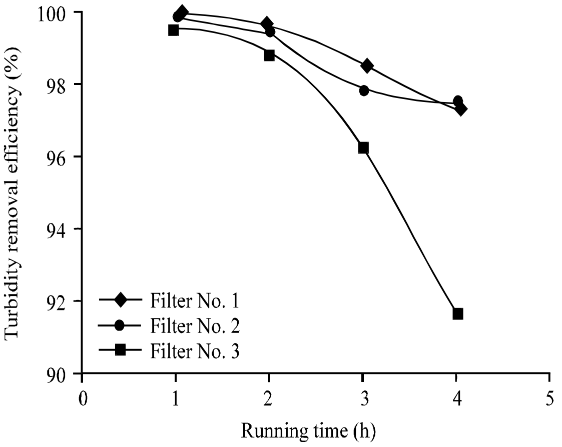

Fig. 15: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 200 NTU, alum dosage = 20 mg/L

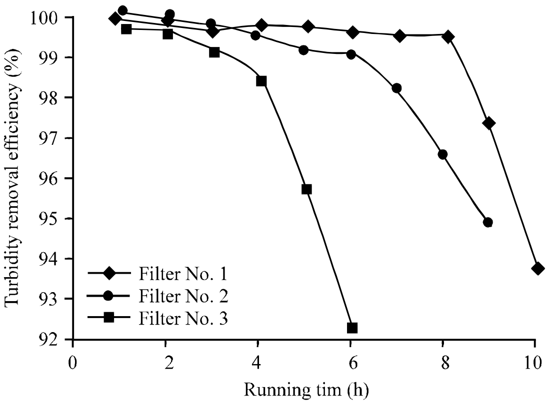

Fig. 13: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 100 NTU, alum dosage = 15 mg/L

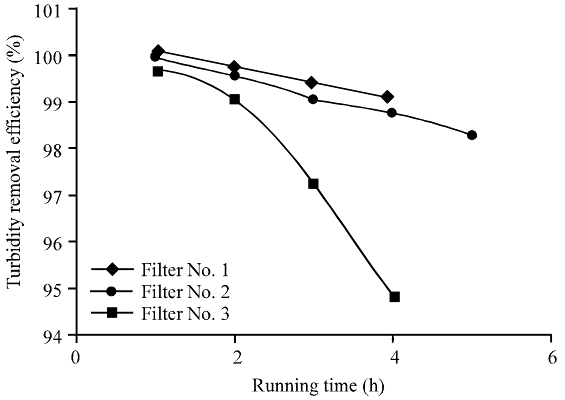

Fig. 16: The turbidity removal efficiency with time of filters (No. 1-3) influent turbidity = 200 NTU, alum dosage = 15 mg/L

alum dosages. it is apparent from these figures as the influent turbidity increased the run time to reach the maximum allowable turbidity is decreased. The removal efficiency and running time to reach turbidity breakthrough in the three filters increased as the alum dosage decreased because low alum dosage that will form pinpoint floc penetrated deeper into the filter media thus avoiding surface clogging and this is in a good agreement with Culp (1977) who stated that the direct filtration may be saving of 10-30% in chemical costs because of generally less alum dose is required to produce a filterable floc than to produce a settleable floc.

The most successful configuration of the used porcelanite dual filter media was filter No. 2 which is characterized by 50 cm of sand in the bottom and 50 cm of the porcelanite on the top where it could be treated raw water with maximum turbidity of 100 NTU and running time of 9 h.

CONCLUSION

Filter No. 2, in this study was the best porcilanite dual filter media configurations where it could be treated raw water with maximum turbidity of 100 NTU and running time of 9 h.

It was seen clearly that direct filtration treatment technique is required less alum dosage than conventional treatment because of generally less alum dose is required to produce a filterable floc than to produce a settleable floc and this feature may save chemical cost.

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