

Removal Efficiency of Solid Particles from Raw Water Using AFM Grade-2 Media: Case Study

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Abstract

This paper describes the removal efficiency of solid particles from raw water by activated crushed glass media and compares its efficiency with sand media. In this study, activated crushed glass media (AFM) grade 2 and 14/25 sand media were experimentally tested using a filtration pilot plant unit in CORA laboratory. Turbidity level of the effluent used was around 70 NTU, which has been selected from turbidity profile test of Wey River (Guildford/UK) on March 2010. Although, both of these filter media were not identical in porosity and particle size distribution, the experimental results showed that AFM media grade-2 exhibited a high capability to remove solid particles from the raw water besides of it other advantages. Also, the capability of AFM for removing solid particles was slightly poorer than those of 14/25 sand media.

Keywords: Filtration; AFM; Crushed glass media; Sand media

Introduction

The chemical and biological contamination of drinking water in addition to its scarcity is considered as one of the most significant challenges of this millennium. Statistics on the necessity of freshwater provision show that 20% of the global population, around 1.2 billion, do not have access to safe drinking water, while around 50% of the world's population do not have adequate water treatment systems. By 2025, the global population is predicted to increase by more than 30%, thus, necessitating the search for potable water supplies, for example, from desalination of seawater and brackish water, which requires much further development leading to financial viability; otherwise the freshwater accessibility is likely to considerably deteriorate [1].

Two main types of contaminants are present in raw water, very finely dispersed organic and inorganic particulate matter, and dissolved solute contaminants. One of the major challenges in treating raw water prior to further purification, using advanced techniques such as reverse osmosis (RO), is the need to remove these contaminants since without doing so, the membrane will be rapidly subject to fouling, increasing the energy consumption of the RO process leading to increased cost of the produced water. The removal of these foulants is achieved by various unit operations collectively called 'pre-treatment'.

Membrane fouling is caused by the accumulation of any substance (i.e., a foulant) in the membrane material or on membrane surface; a foulant restrict water passing across the membrane. In natural waters, foulants include inorganic particles, natural organic matter (NOM), microorganisms, mineral ions (e.g., calcium), and mixtures of all these substances due to mutual interactions [2]. In particular, the biopolymers or colloidal fractions of NOM were more closely associated with membrane fouling than other NOM fractions, such as humid substances [3-5].

The major effects of fouling are increased process downtime, increased consumption of cleaning chemicals, decreased membrane productivity and deterioration of product water quality. All these effects increase the capital and operating cost of membrane installations. Membrane fouling is broadly categorized into colloidal, organic

precipitation and biological fouling. All these types of fouling require their own specialized pre-treatment operations [6,7]. Scale formations on RO membrane may occur when sparingly soluble salts in the RO feed water are concentrated beyond their solubility. Common sea salts of concern are calcium carbonate, calcium sulphate, barium sulphate, strontium sulphate, calcium fluoride and silica in addition to salts of iron, manganese and aluminium [8]. The potential for scale formation should therefore be controlled with adequate pre-treatment and proper system design. Generally, antiscalants are designed and employed to prevent scaling. Commercial antiscalants can be used to control scaling effectively by the presence of the metal ions in the feed stream and preventing precipitation. To determine the scaling potential, the ion product (IP) of the considered salt in the concentrate stream would need to be compared with its solubility product (Ksp) [8]. Generally, the scale-control measures are not needed if $IP < Ksp$.

To assess the propensity of feed waters for colloidal fouling, several types of measurements, such as turbidity, particle counts, and particle electrophoretic mobility are employed; none of these alone is a reliable tool for fouling prediction [9-21]. The most widely accepted quality criterion which is endorsed by the membrane manufacturers for more than 30 years is silt density index (SDI) and modified fouling index (MFI). Membrane manufacturers recommend that SDI should not exceed 4 or 5 and set limits of membrane productivity depending on the SDI [19].

To increase the efficiency and to ensure the longevity of the membranes, effective pre-treatment of the feed water is required. An

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appropriate pre-treatment will maximize the efficiency of the process and increase membrane lifetime by minimizing scale formation, fouling deposition and membrane degradation. The net results of pre-treatment will be the optimization of product flow, salt rejection, product recovery as well as operating and membrane replacement cost [16]. Since sedimentation alone cannot produce the required feed water quality for the RO process, filtration is necessary. Deep bed filtration can be regarded as the heart of pre-treatment prior to the RO process.

In filters, Particles are removed from raw water through a variety of mechanisms [22,23]. When particles are larger than the void spaces in the filter, they are removed by straining, which is the dominant mechanism in precoat filtration and slow sand. Then when the particles are smaller than the voids, they can be removed only if they contact and stick to the grains of the media. Transport to media surface done by interception, diffusion, inertial force, and gravitational force and attachment occurs by attractive close-range molecular forces such as London and van der Waals forces. Straining forms cake at the surface of the filter bed, can cause improvement in particles capturing but increase the head loss across the filter media. In slow sand filters the minimizing of the head loss can cause by operating at low filtration rate. Using a low filtration rate is encouraging microorganism growth, which degrades some of the accumulated particulate matters. While, in rapid filters, head loss builds up quickly to unacceptable levels if significant cake layers forms and filtration at the surface leaves the bulk of the rapid filter bed unused. Thus, rapid filters are designed to minimize straining and encourage filtration by transport and attachment. The bed of granular media can strain the particles smaller than the grain size. However, a close-packed arrangement of spherical media will cause straining when the ratio of particle diameter to grain diameter is greater than 0.15 as presented in Figure 1. Particle removal within filter bed has been experimentally observed to be dependent on particle concentration similar to a first order rate equation 1 [22,23].

$$\frac{\partial C}{\partial Z} = -\lambda C \quad (1)$$

Where; λ : Filtration coefficient, m^{-1} , includes all the mechanism mentioned above (interception, diffusion, inertial and gravitational forces); C: Mass or number concentration of particles, mg/l; Z: depth of filter bed, m.

Then, for successful filtration the coagulation, flocculation, mixing process, filtration velocity, appropriate sizes, depths and size distribution of filter media need to be optimized. The media size and their size distribution will determine the length of the filter run-time and backwash velocity required. Generally, the filter types used in water treatment are categorized based on the driving force, the direction of flow, and the filtration rate (slow sand filters and rapid sand filters) [12]. Sand filtration is frequently used as a cheap, easy and robust technique to capture suspended solids from raw water. The method has a broad application in the water treatment field, where it has proved its efficacy [9,21]. In bed filtration, suspension containing particles is flowed into a filter bed packed with filter media. During the operation, the suspended particles will be deposited on the surface of filter media and then separated from liquid. The phenomena in the filter bed would be unsteady state due to the deposited particles will change the surface properties of filter media and also, the structure of void space in the filter bed. These changes are negatively reflected on filtration process through decrease the particle capturing efficiency and increase the pressure drop in filter as well. In order to continue the operation the

accumulated particles should be removed from filter media. One of the best ways to clean filters is backwashing. In general, the filtration and backwashing steps are conducted mutually [24-26].

The backwashing process involves reversing the flow through filter bed by using clean water from the clean water storage tank. Excessive backwash velocities can result in loss of filter media, whereas insufficient velocities can cause mud ball formation, leading to filter channelling and eventually filter media solidification [12]. It is impossible to prevent bacteria from growing on sand because it is an excellent substrate for their growth. However, the sand bed is continually fluidized by a 50% expansion. It becomes a very effective biofilter, then, no amount of air scouring, or backwashing will remove the biofilms because the alginates excreted by bacteria, glue the bacteria on to the sand. The alginates also glue the sand grains together as well, to form channels and become harder and more stable over periods of few months to several years depending on water temperature and water quality. At temperature of water over 15°C, the growth rate of heterotrophic bacteria can be as short as 15 min. Both the production of alginates and the exponential growth rate will form stable channels through the sand bed or cause a rapid increase in pressure differential across the filter. The consequent effects are either deterioration in water quality or an increase in backwash frequency or more likely a combination of both. Bacteria are required in slow sand filters, but they are the main reason for poor quality and filter failure in rapid gravity and pressure sand filters. AFM is one of the alternatives designed to replace sand in all types of sand filters. This type of media has active surface properties preventing colonization by bacteria and due to this, bacteria induced bed channelling is essentially eliminated [11].

The observations and researches which have been conducted by two UK water companies prove that AFM removed at least 30% more particles from the water than sand media. In backwashing, more waste is removed from the AFM filter compared with the identical filter bed containing sand. The backwash profile of AFM is also reproducible which indicates stable steady state conditions. In comparison, the backwash performance of sand is not stable, and AFM emerged up to 30% less waste is eluted from the sand [20]. In sand filters, aggressive air scouring, and extended backwash times are required, to keep the media clean because a proportion of particles are glued to the sand. In AFM where the solids are only held by weak electrical charge that is broken during backwash to release all of the particles, due to this less water is required to backwash AFM. The surface of AFM exhibits catalytic activity in the presence of oxygen and a proportion of dissolved oxygen molecules are dissociated on the surface of AFM, which increases the

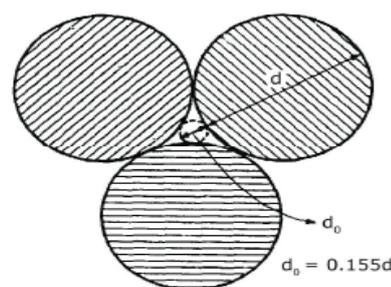


Figure 1: Capture of spherical particle by spherical media grain (Crittenden et al.).

oxidation potential of the media. The surface of AFM is therefore, self-sterilizing [13,14,20].

The zeta potential generates a high charge density which attracts the positively charged particles, but at the same time the slip zone prevents the particles from reaching the surface of the media thus, AFM attracts the particles and holds on to them but they are prevented from bonding to the surface. Usually, chlorine is added after the sand filters while in double filtration systems, chlorine may be added before the second sand filter. Under these conditions, Tri-chloramines will be produced. Tri-chloramines are produced by the reaction between ammonia and chlorine at pH less than 5. The biofilms on sand grains is acidic and is the principal location for tri-chloramine production. In AFM, which has no biofilms and the surface is not acidic; tri-chloramines can be produced as shown in the following reactions [11,16].



Using the chlorine levels before sand filters will not kill the biofilms, it can actually promote the growth of bacteria species. Bacteria will produce copious quantities of alginates such as *Pseudomonas* spp, as a defence mechanism. Generally, the research shows, the performance of recycled glass media compared to conventional sand media can:

- Improve water clarity shown by a 25% reduction in NTU.
- Increased backwash efficiency shown by a 23% reduction in water used for backwashing.
- Lead to approximately 20% less glass than sand (by weight) required for filtration.

The main aim of the present study is to investigate the effectiveness of crushed glass media grade-2 for capturing solid particles as a step in the pre-treatment for desalination processes and compare the results with that of sand media. Two types of available media were tested such as; crushed glass grade-2 and 14/25 sand media using a filtration pilot plant unit (FPP). This unit was designed and manufactured in the Faculty of Engineering and Physical Sciences workshop at University of Surrey.

Experimental Work

The equipment

A filtration pilot plant (FPP), as illustrated in Figure 2, consists of a cylindrical filter column with a height of one meter and 0.2 m diameter is made from two compartments of Perspex. The filter column receives the influent from the top and the effluent out from bottom. At the bottom of the column, there is under drain system, which is designed and manufactured as a perforated plate with uniform holes, used for distributing the backwash water through the media, evenly works as support for the gravel and media layer.

The filter column is equipped with two transparent tubes for measuring pressure drops during operation of the filter. Additionally, this pilot plant has two flow distributors, manufactured from

transparent (Perspex) material. These distributors give the pilot plant good flexibility in transporting the solutions and air flow in both filtration and backwashing processes. Also, it consists of two polypropylene storage tanks with capacity (64 L); the first elevated tank (TK-1) is used as influent storage tank, while the second ground tank (TK-2) is used for gathering the effluent. Each tank is equipped with a centrifugal pump supplied by Lowra company, (P-1 and P-2), P-1, is used for circulating the influent and pumping it to the filter column. However, the P-2, is used for pumping effluent into the filter column during the backwash process or out the pilot plant unit.

All connections and tubes used in the pilot plant are made of polyethylene and the ball-type valves are made of stainless steel. The flow rate is measured using three flow meters; the first one is a Rotameter type (FI-1) connected on influent line prior to the filter column, the second one is a digital type (FI-2), connected to the effluent water line, while the third flow meter (Rotameter type) is connected to the water backwash line. There are also two pressure gauges connected in the pilot plant, one is fitted to the air feed line, and the other to the feed backwash water line. All instruments work with single phase electricity current.

The filter column is loaded with two layers of gravel; the bottom layer is the coarse gravels with a height of 10 mm and the top layer is fine gravel with a height of 6mm. The gravel layers are covered with a stainless-steel mesh to prevent the transportation of gravels to the media layer during the backwash process. However, on the top of the stainless-steel mesh, two types of media are placed separately, with different grades such as, 14/25 sand media and crushed glass grade-2 media. Additionally, turbidity meter instrument model 6035 manufactured by Jenway Company in the UK was used to determine the turbidity values in NTU for the influents and effluents.

Materials

Analytical grade of hydrochloric acid (36%) supplied by Fisher Scientific Co. in the UK was used. Two types of media, such as 14/25 sand and AFM grade-2 supplied by Dryden Aqua Company in the UK were also used. In addition, the specifications of the gravel and media, used in this work are displayed in Tables 1-3. Moreover, the clay and tap water used in the present study were taken from the University of Surrey workshop.

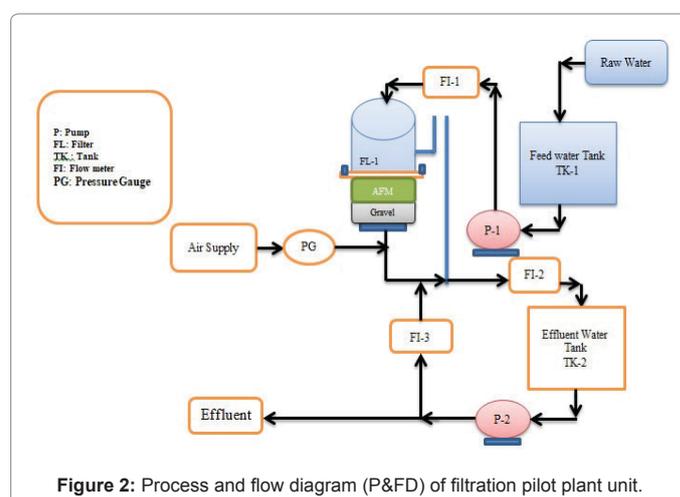


Figure 2: Process and flow diagram (P&FD) of filtration pilot plant unit.

Experimental Procedure

Filtration Pilot Plant (FPP) set up

The first step in the FPP set up process started in checking the instruments and connections according to those described in the process flow diagram presented in Figure 2. All leakage tests were carried out physically by filling tanks and filter column with demineralised water (DW), then pumping and transporting the water in and outside the pilot plant using the existing two centrifugal pumps.

Initially, the digital flow meter (FI-2) on the effluent line was found not to be accurate. It was then calibrated to obtain accurate flow rate values as shown in Figure 3. Gravel, 14/15 sand and crushed glass grade-2 media were repeatedly washed with DW to clean them thoroughly before being loaded to the pilot plant. It was observed that, the sand was dirtier than the AFM grade-2 media, and a yellow colour was produced even after more than ten washings times. This problem was solved by treating the sand media with 5% dilute hydrochloric acid for 10 minutes, with a gentle mixing. The treated media was loaded into the FPP, on the top of the two gravel layers (6.0 cm thickness for each). After that, the media were backwashed with clean water until the turbidity and the yellow colour from discharging water disappeared as shown in Figures 4 and 5.

Description of Experiments

To evaluate the performance and feasibility of the media in treating different types of influent, several experiments were conducted in the filtration pilot plant using 14/25 sand and crushed glass media grade-2.

Media head loss measurements

Initially, the head loss measurements for gravel layer alone, gravel with 14/25 sand media and gravel with AFM grade-2 media were separately conducted. Deionised water (DW) produced in the university lab was used as an influent solution at ambient temperature. In these experiments, the head loss values were taken at different influent flow rates while the bed depth of media over the gravel layer, was kept constant at 17 cm during the test. The results of this test are presented in Figure 6.

Filtration efficiency test

Several experiments were carried out to investigate the efficiency of each media type in capturing the suspended solids from the raw feed water. It was important to select the turbidity level of the raw water that could be used in this study. Thus, water from the Wey River in Guildford in the UK was chosen to be the raw water in this trial. However, to determine the turbidity profile of river, several samples were collected from this river during March 2010. Samples were taken daily over one week, and the turbidity was measured by a turbidity meter. The turbidity profile is presented in Table 4, and as it can be seen, the maximum level of turbidity was 48 NTU on 28th February 2010 which indicates that, the turbidity levels in the summer would be even higher and could be around or more than 70 NTU. The experiments were therefore designed to treat raw water around or more than this level of turbidity.

In this work, the bed depth (17 cm) and the height of water over the media were maintained constant. Raw water with 66.7 NTU turbidity value was prepared by mixing 400 g of clay in 100 L of tap water. The prepared influent was pumped at 2.0 L/min flow rate using a small centrifugal pump which is placed underneath the feed elevated tank. Meanwhile both the outlet valve and one of the side valves in

the filter column were left open in order to keep the level of raw water in filter column constant at 56 cm throughout the filtration process (head loss equal to 36 cm). After 90 minutes, the effluent flow rate was disconnected to give an indication that the first run was ceased. In this experiment, the effluent samples and head loss reading values were taken at constant intervals of 10 minutes. Then, the loaded media was backwashed for 1 minute with 40.0 L/min flow rate of tap water. The backwashing was also preceded with intermittent pulses of compressed air. All the turbidity of samples are measured by turbidity meter.

The Second run was carried out similarly to the first run with using a new influent quantity with turbidity value of 76 NTU. Both runs were performed at ambient temperature and the raw water pH was seven. The experimental results of these two runs are displayed in Figures 7 and 8.

To investigate the performance of AFM media grade-2 for removing suspended solids from the influent, two runs were conducted. The first one was carried out by filtering influent with turbidity 71.3 NTU which was prepared by mixing 400 g of clay with 100 L of tap water. Similar to that conducted when using 14/25 sand media, the head loss was maintained at a constant of 36 cm throughout the experiment. Initially, the run time was planned to be 90 minutes, but because the effluent still coming on from the filter column, the run time was extended to

App. particle density	2.65 mg/cm ³
10% Fine (Soaked)	340 kN
Sulphate content water extract	<0.1 g/L
Chloride ion content	0.01%

Table 1: Gravel specifications used in this work.

Size range	1.18-0.60 mm
Colour	Brown
Specific gravity	2.65
Incompatible bulk density	1.56 kg/m ³
Nominal effective size	0.63-0.85
Uniformity coefficient	<1.4

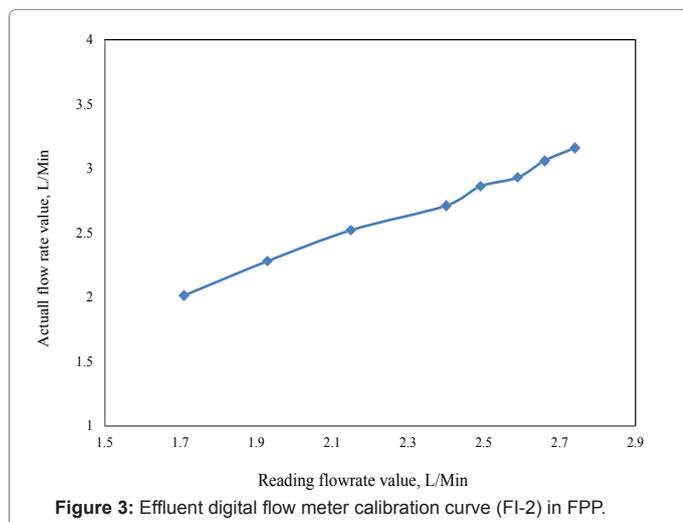
Table 2: Sand medium grade 14/25 specifications.

Colour and shape	Brown or green sub-angular granules
Dust content	<0.1% m/m below 160 micron
Grain effective specific gravity	2.5 g/cm ³
Effective size	1.2-1.8 mm
Uniformity coefficient	1.5 or less
Bulk density	Loss: 1230 kg/m ³
	Packed: 1450 kg/m ³
Abrasion resistance(water only)	<3% loss after 100 hr backwash
Poured voidage	0.51-0.54
Packed voidage	0.44-0.48
Acid solubility 20% HCl/24	5%

Table 3: AFM medium grade-2 Specifications.

Date	Turbidity value NTU	Weather condition
28-02-2010	48.0	Rain
01-03-2010	35.0	Rain
02-03-2010	17.2	Sunny
03-03-2010	12.0	Sunny
04-03-2010	7.3	Sunny
05-03-2010	6.0	Sunny
06-03-2010	4.3	Sunny

Table 4: Wye river turbidity values profile from 28 Feb-06 Mar 2010.



be 240 min. The loaded media was then backwashed with effluent for one minute at 40.0 L/min flow rate. Also, the backwashing process was preceded with a series of compressed air pulses. However, the second run conducted using influent with 72.9 NTU turbidity and flow rate of 2 L/min. The second run was allowed to continue up to 240 minutes. Similarly, this run was conducted at constant head loss of 36 cm. All runs were carried out at an ambient temperature of 22°C and pH of seven. The effluent samples were gathered during run time and the turbidity was then measured. The results of the two runs are presented in Figures 9 and 10 and the turbidity removal efficiencies are demonstrated in Figure 11.

Results and Discussion

As shown earlier in Figure 6, the heights of water over the media are plotted against the head loss values for gravel alone, gravel with 14/25 sand media and gravel with AFM grade-2 media. The results showed that, the gravel with 14/25 sand media produced greater head loss compared with the gravel alone and gravel with AFM. This could be attributed to the fact that AFM grade-2 media has a greater porosity compared to that of 14/25 sand media. Figure 7 shows that the ripening stage could take a shorter time in the second run compared with that in the first run. This may be attributed to the fact that the media in the second run has a proportion of solid particles after backwashing, while the media in the first run was virgin.

In Figure 8, the breakthrough points for both runs did not appear because the runs were stopped in 90 minutes since it was difficult to make them running longer because the media seems entirely loaded with suspended solids at this period of time. Due to the difference in feed water turbidity values in both runs, the head loss in the second run could be increased slightly. But, in reality, the first and second runs have nearly the same head loss of 36 cm during the run times. This discrepancy may be attributed to the fact that a proportion of the suspended solids in the elevated feed tank were settled during the second run, which subsequently cause decreasing in turbidity level of the raw water that was pumped to the filter media.

Figure 9 demonstrates that when using AFM media, the effluent turbidity value in the ripening stage of the first run was increased moderately from 30 to 38 NTU within the first 40 minutes. After that, this value was fluctuating within a short period and then stabilised around 40 NTU for the remaining run time. This may be attributed to the accumulation rate of solid particles inside the media. In the second run, the effluent turbidity value was higher (about 43 NTU) than those in first run for the first 30 minutes. This may be due to the retention of some solid particles inside media after the first run backwashing. Because the crushed glass media (AFM) has a higher porosity compared with 14/25 sand media, the filtration process took more time before realizing the breakthrough points.

However, from Figure 9, the repining and the effective filtration stages can be recognised. Moreover, this Figure shows that the efficiency in the first run increased moderately up to 100th minute and then decreased slightly to be maintained at nearly constant value (43 NTU) for the remaining run time. In the second run, turbidity removal decreased moderately from 43 to 39.8 NTU at 45 minutes and then maintained to be nearly constant at 40 NTU. This behaviour may be due to the settling of a proportion of the influent particles in the feed tank which affects the influent turbidity values, or it could be attributed to the rate of solids capturing in media, or due to both. Figure 10 shows that, the breakthrough points for these two runs did not appear in breakthrough curves up to 240 minutes. This indicates that, this

media has capability to work for longer than 240 minutes under these conditions before breakthrough point is realized.

From Figure 11, it appears that in first run of 14/25 sand media the turbidity removal percentage reached about 71%, for the first 30 minutes of the run time and then it slightly increased to about 73%. The increase could be due to the accumulation of suspended solids inside and on surface of this media. While in the second run, this percentage was around 70% for the first 30 minutes, then slowly increased to reach up to 76%, and eventually decreased to 74.6%. This may be due to increase the captured solids amount by media with run time progressing or accumulation of solid particles resulted from the first run after the backwashing process.

When using AFM media, the turbidity removal percentage in first run decreased moderately from 53.57 to 44.18% at the 50th minute, then sharply increased to 49.79% at the 60th minute and eventually decreased to 38% at the 240th minute. This behaviour may be due to settling a proportion of influent particles in feed tank which affected on influent turbidity values, or it could be attributed to the rate of solids capturing in media, or due to both. In the second run using AFM media, this percentage increased moderately to reach peak value of 47% at the 40th minute, then decreased moderately to 42% at the 85th minute before slightly increasing to 45% for the remaining run time. It can be seen clearly from Figure 11 that the 14/25 sand media offered higher efficiency for removing the turbidity of influent at a short run time as compared with AFM technology. This disparity in removal efficiency between these two mediums could be attributed to the difference in the porosity. However, the crushed glass media also exhibited a capability to remove the suspended solids from influent with sand media even though both media were not identical in porosity and particle size distribution. The fluctuations in the removal efficiency values when using crushed glass media can be referred to precipitate some of solid particles in feed tank, which can cause instability in turbidity values of influent with time.

Conclusions and Recommendations

The results of this experimental study have led to the following conclusions:

- Activated Crushed glass media is new media, which is used for the first time in the water filtration technology. It is different from the sand media which is nearly using in all water filtration process. This new (AFM) media is negatively charged which make it have potential to attract the undesirable elements from the contaminated water. The plan of this case study is to investigate all this media aspects started in capturing the suspended solid and then will extend to exam other it aspects.
- The 14/25 sand medium creates a greater head loss compared with that of AFM grade-2 media; this is due to low porosity of the sand media.
- Although the AFM grade-2 media showed lower efficiency than sand media in filtration, it demonstrated capability in capturing suspended solids from raw water. This may encourage researchers to use several grades of crushed glass media in filtration process.
- To make particles removal efficiency comparison between these two media more accurately, it is recommended to use them at same particle size distribution which could be conducted by crushing and sieving processes. Depending on Zeta Potential charge between crushed glass media and particles, this study could be extended to

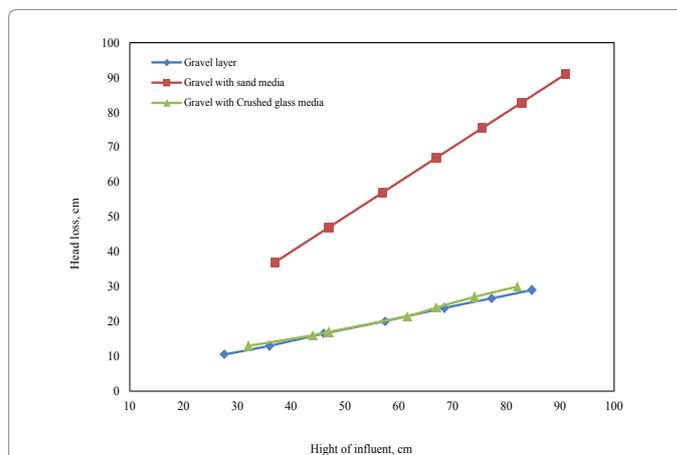


Figure 6: Head loss variation in filter column with the influent height for gravel, gravel with 14/25 sand media and gravel with AFM grade-2 media.

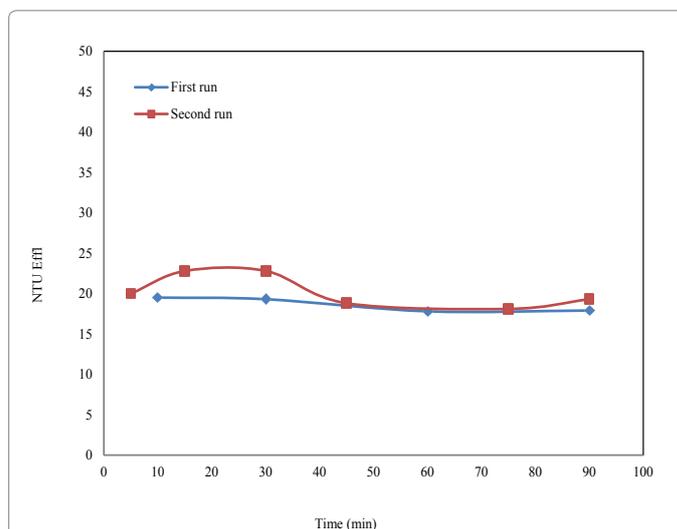


Figure 7: Turbidity profile of first and second runs using 14/25 sand media in filtration pilot plant.

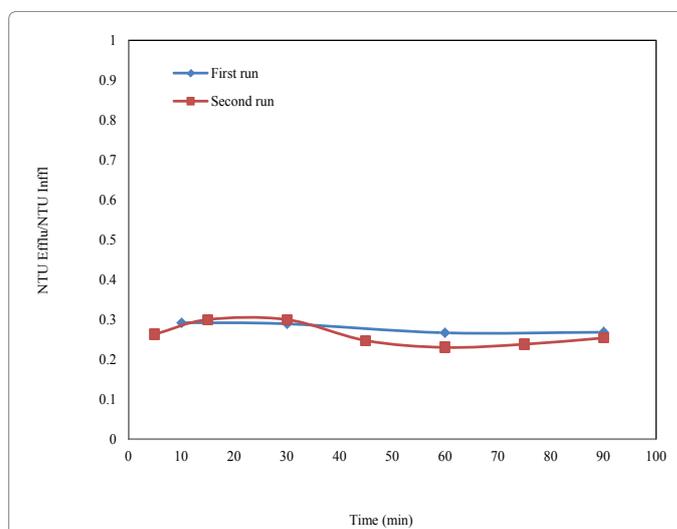
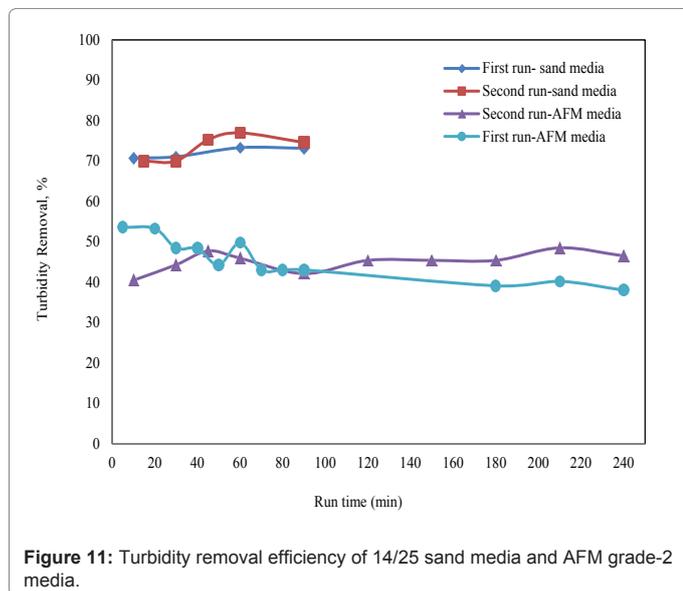
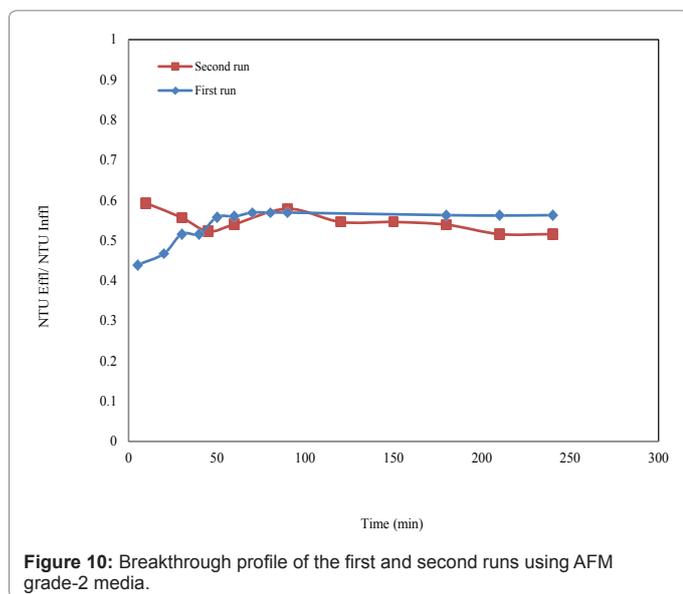
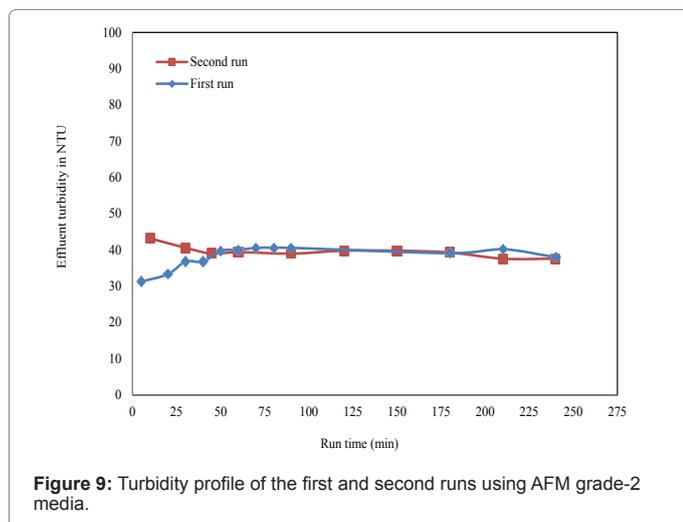


Figure 8: Breakthrough profile of first and second runs using 14/25 sand media.



investigate its capability for removing other raw water impurities such as organic matter and heavy toxic metals (Arsenic and Cadmium) at different operating conditions. It would be very useful to construct the pilot plant near the influent source, so as to test the media efficacy at a wide range of operating conditions and for longer time. Also, in future works, modifications can be done in the filtration pilot plant as well to make it work by self-backwashing mode when it loaded with particles, which will create gain in energy consumption. Then to make this study includes more in filtration area, a different grade of AFM media can be used for pre-treating the waste water and comparing the results with existing media used.

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