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*Research Article*

# Pre-Treatment of Water by using Broken Marble and Ceramic Wastes as Up-Flow Roughing Filter Media

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***Abstract***

*The main objective of this study is to develop simple, inexpensive, efficient and chemical-free alternative pre-treatment process for water by using of up-flow roughing filter system. The raw water that used in present study was synthetic raw water. The turbid water obtained by adding kaolinite dose at specific concentration to achieve a turbidity from 20 to 418 NTU. The pilot plant unit was made from low-cost , locally and available materials. It consist of two steel filter columns with 1.5 m height and 30 cm in diameter. The marble media was installed in URFL.1 while the ceramic media was installed in URFL.2. The two filters was investigated with three filtration rates of 1, 0.75 and 0.5 m/h. The main aim of experimental work was to reduce the turbidity bellow 20 NTU that's acceptable to slow sand filter operation. The best performance filter was URFL.2 of ceramic media at filtration rate of 0.5 m/h. Where the URFL.2 could reduce the turbidity bellow of 109 NTU to value less than 20 NTU that's acceptable to slow sand filter operation.*

***Keywords:*** *Pre-Treatment, Roughing Filter, Cheep filters media*

## 1. Introduction

Water is essential for life. Basically all human communities grow up centering some kind of water source. A part from ground-water most of the people of the world depend on surface water as one of the main sources for drinking purposes. As surface water is unprotected and exposed, there is a possibility of faecal contamination (Biswajit *et al.*, 2009).

In Iraq, towns, small communities in rural areas, individed residences, cluster homes and other establishments that settle near from sources of water, suffers from the different disease such as, cholera, hepatitis, nephritic, dermatology and other caused by unavailability of acceptable drinking water. The planning, design, construction and management of conventional water treatment plants in these individual homes are impossible because need high financial sources. These problems galvanized our to find other ways that's comported with our conditions.

The roughing filter is not only a simple, inexpensive, efficient and chemical-free alternative treatment process applied mainly for solid matter separation, it also improves the microbiological water quality (Wegelin, 1996).

Three roughing filter mechanisms are distinguished: transport, attachment and transformation as shown in figure (1). The transportation mechanisms consist of four mechanisms are:

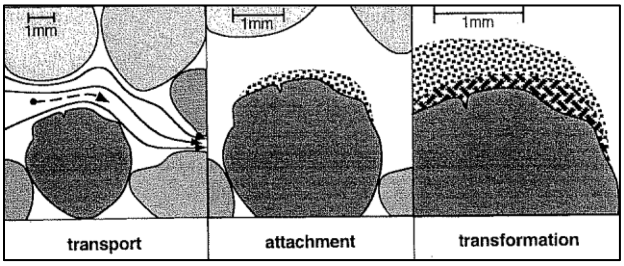


**Fig.1** Solid Separation Mechanisms in Roughing Filters **(Wegelin, 1996)**

Screening mechanisms: Removes particles larger than the pores of the filter bed. The smallest pore sizes are roughly one sixth of the gravel size (Huisman, 1989).

Sedimentation Mechanisms: The sedimentation mechanisms are separated solid by gravity. The settling velocity is influenced by mass, density, particle size and shape, as well as viscosity and hydraulic conditions of the water (Galvis *et al.*, 1993).

Interception Mechanisms: Is described as the process which enhances particle removal through gradual reduction of the pore size caused by accumulated material (Wegelin, 1996).

Hydrodynamic Forces: The flow-lines of water around gravel grains are not straight but curved. Due

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to inertial and centrifugal forces, particles within the flow-lines are forced to leave and come into contact with the gravel grains where they remain attached (Galvis *et al*., 1993). Figure (2) shows the transportation mechanisms.

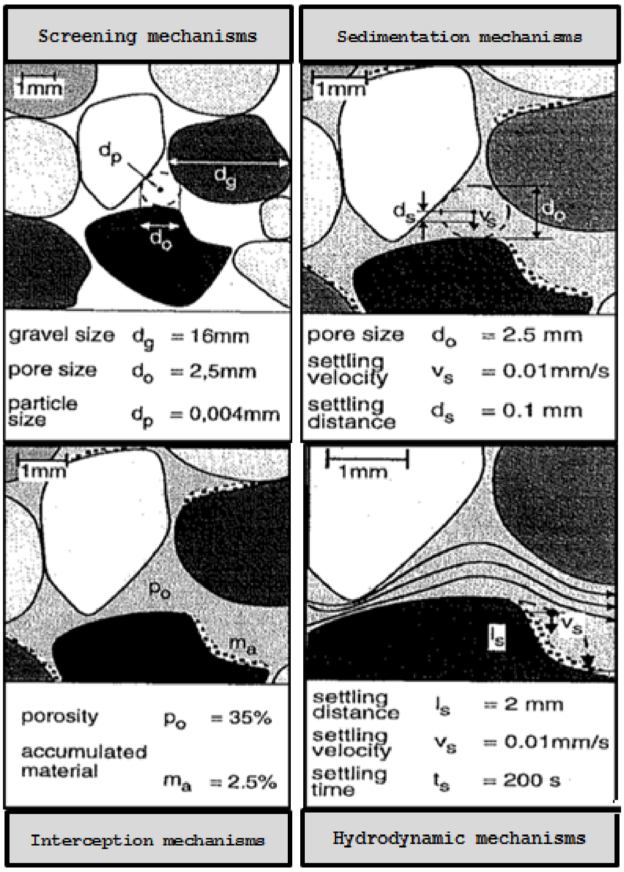


**Fig. 2** Transportation Mechanisms of Roughing Filter (Wegeline, 1996)

The attachment mechanisms is considered to be the most important purification process of removal suspended and colloidal particles by electrostatic and mass attraction forces (Galvis *et al*., 1993; Wegelin, 1996).

The transformation mechanisms consist of two main mechanisms are bio-chemical processes and micro-biological processes. The bio-chemical processes is the processes of oxidation of bio-degradable organic matter that accumulated on the sides of gravel grains. While the micro-biological processes used for removing pathogenic micro-organisms. Where the microorganisms produce antagonistic actions, such as killing or at least weakening intestinal bacteria with chemical (antibiotics) or biological poisons (Viruses) (Huisman, 1989).

The main objective of roughing filtration is to remove suspended matter from raw water to a level acceptable for effective SSF. Pre-treated raw water with turbidity values about (10-20 NTU) and total suspended solids less than 5 mg/L is generally suitable for SSF.

Roughing filter design parameters include operation period, number of filter units and size, flow control and filtration rates, gravel size, number/depth of gravel layers, and under-drain systems (Wegelin, 1996).

Roughing filters should run continuously because intermittent operation may disturb the biochemical and micro-biological activities. A minimum of two filters operating in parallel is required to maintain desired plant output and during maintenance. Dimensions of a roughing filter are different depending on the type chosen (Galvis *et al*., 1996).

In roughing filters, the filtration rates generally vary between (0.3-1.0 m/h). The filtration rates can occasionally be increased to (1.5- 2 m/h) if one of the filters is out of operation for maintenance (Wegelin, 1996). With increasing filtration rates, the performance is expected to decrease since more solids would penetrate and eventually breakthrough. Studies by ( Galvis et at 1993) on filtration rates of (0.30-0.60 m/h) show that the removal efficiency did not vary more. Although filtration rates are reported to affect removal efficiencies, the removal efficiency for a given filtration rate will significantly be affected by the quality of raw water. It is easier to reduce high turbidity (say 1000 NTU to 100 NTU) than low turbidity (10 NTU to 1 NTU). Raw water originating from clay bearing areas is more difficult to treat because clay forms colloidal suspensions which do not easily settle.

Size (dg) of the filter material usually ranges between (4 - 20 mm). The gravel should be rather uniform to achieve large porosity. Filter resistance increases with progressive filter operation.

The headloss in a roughing filter is usually small a bout (10 – 30 cm) at the most, headloss variation in the filter can be recorded by water level in the inlet filter compartment. As filtration progresses, accumulated solids reduce the gravel bed porosity, and eventually lower the efficiency in terms of filtrate quality, output and filter resistance (CINARA, 1990).

The draining the filter unit dislodges retained matter from the filter media and flushes it out through the drainage systems. This is an easier option used in roughing filtration. For drainage systems in roughing filtration, Wegelin, (1996) recommends false filter bottoms for up or down-flow roughing filters and perforated pipes or prefabricated culverts for horizontal roughing filters as shown in figure (3).

More studies done in Colombia by CINARA explained the efficiencies of different pilot roughing filters with similar gravel fractions. In this study CINARA used five types of roughing filters pilot plants, these types are HFR, URFS, DRFS, UFRL and MHFR as shown in figure (4). The infiltrate of each roughing filter in figure (4) was fed to a slow sand filter. CINARA explained that the reduce in filter length in URFL, compared to all other filters can be attributed to its lower removal efficiency since the retention time (which directly influences filtration mechanisms) is reduced. The effect of reducing filter length is also evident when you compare HRF (7.10 m) and MHRF (4.4 m), the former show a higher removal efficiency. The layout of the filter media and direction of flow may affect the efficiency of RF to some extent. URFS, DRFS and MHRF have the same filter-bed lengths but different efficiencies. The effect of the direction off low is seen when URFS is compared to DRFS.

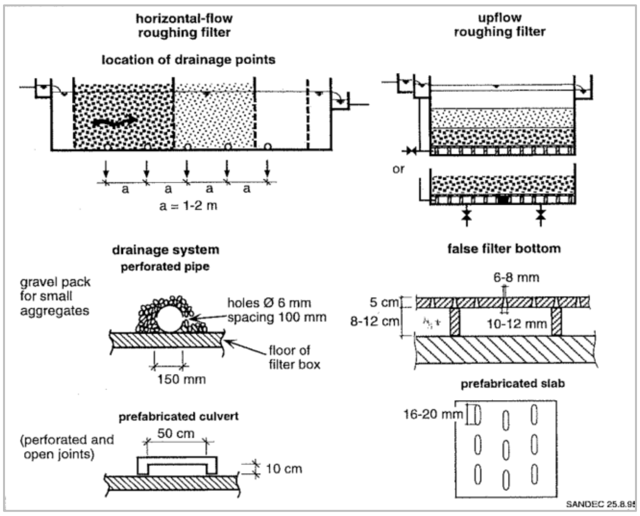


**Fig.3** Drainage System of Roughing Filters (Wegelin, 1996)

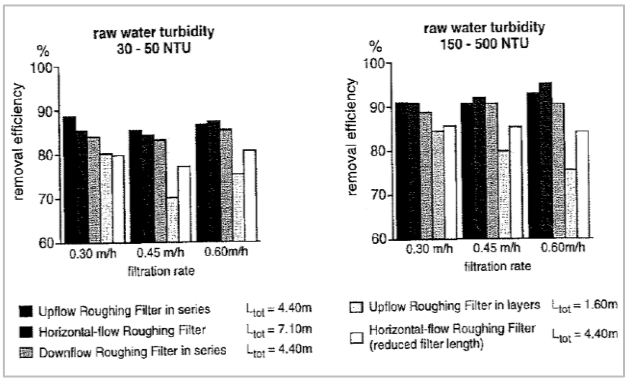


**Fig.4** Turbidity Removal by Different Roughing Filters in Call, Colombia (Mwinga, 1998)

## 2. Materials and Methods

### *2.1 The pilot plant and filter media used*

The experimental work investigated the ability of marble and ceramic wastes to reduce the turbidity to value acceptable to slow sand filtration. The reasons of using marble waste and ceramic waste as a filter media are; local, available and low cost materials, clean, insoluble and mechanically resistant materials, and implementation of sustainability concepts to conservation of natural resources by reuse of solid waste and reduce using of natural gravel as conventional filter media.

The upflow roughing filter pilot plant unit was made from low-cost, locally and available materials as shown in figure (5) and figure (6).

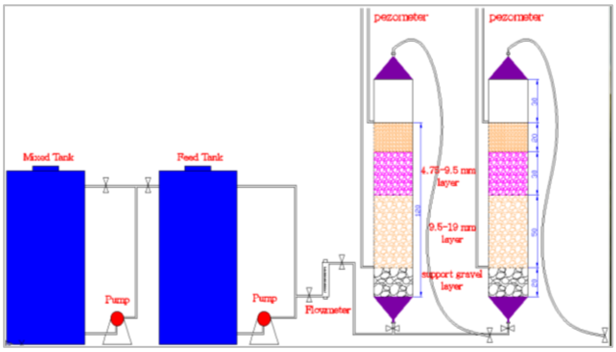


**Fig. 5** Diagram of Pilot Plant Used

**Fig. 6** Photo of the UREL pilot plant

Marble is a rock that forms when limestone is subjected to heat and pressure. It is composed primarily of the mineral calcite (CaCO3), and contain other minerals such as: clay minerals, micas, quartz and graphite. One hundred percent of the marble and ceramic materials that used as filter media in present study is considered to be unwanted solid wastes produced by broking the marble tile and ceramic during buildings construction and demolition. The marble and ceramic materials are clean, insoluble and mechanically resistant so that they can be used as filters media. These materials were collected, cleaned and then crushed as shown in figures (7 and 8).

**Fig.7** Photos of Graded Marble Media Used

The selected marble and ceramic sizes for URFL are ranged from (2.36 to 19 mm), and it was divided into three layers; the bottom layer was (50 cm) depth which graded from (9.52 to 19 mm), the middle layer was (30 cm) depth which graded from (4.75 to 9.52

mm), and the top layer was(20 cm) depth which graded from (2.36 to 4.75 mm). Sieve analysis as shown in figures (9 and 10) gave uniformity coefficients of (UC = $d_{60}/d_{10}$) which was less than two, therefore it considered acceptable as mentioned by Wegelin, 1996.

**Fig. 8** Photos of Graded Ceramic Media used

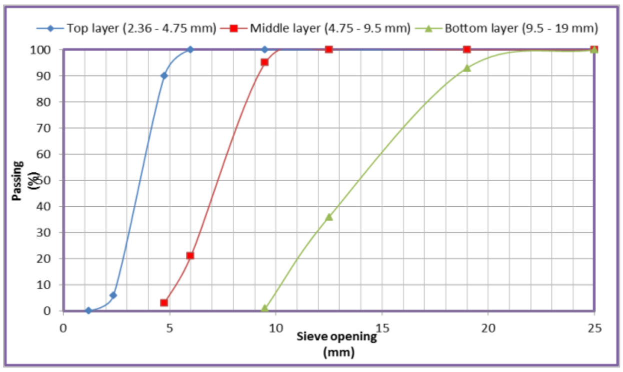


**Fig. 9** Sieve Analysis of URFL.1 Marble Media Used

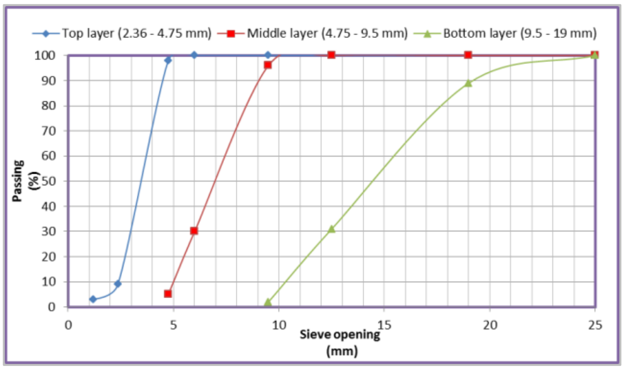


**Fig. 10** Sieve Analysis of URFL.2 Ceramic Media Used

*2.2 water filtration procedures*

The media of filter has been washed with warm water out the filter column then dried and installed for each run. The marble media was installed in URFL.1 while the ceramic media was installed in URFL.2. The procedures of the operation runs are as follows:

1) Filled up the tank with water, then adding the kaolinite dose with the help of figure (11). The mixing was done manually as well as by water recycling from the bottom to the top of mixing tank. The purpose of mixing the tank is to obtain turbid water and also to prevent the settling of suspended solid. The turbidity has been tested in the field. The required level of water turbidity have been satisfied through adding kaolinite or by dilution with clean water.

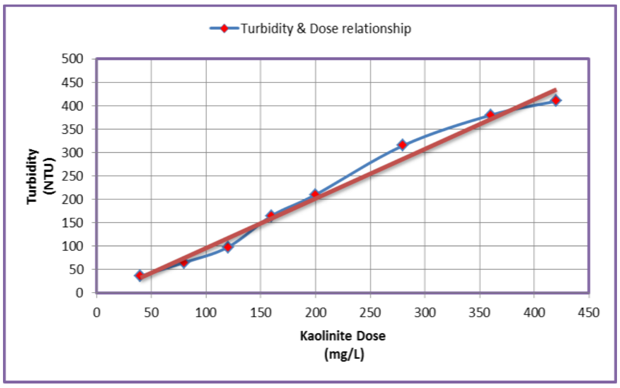


**Fig. 11** The Relationship Between Turbidity and Kaolinite Dose

2) Pump the synthetic turbid water to feeding tank continuously. A float valve in each raw water tanks was installed to maintain constant water level. The hydraulic head that delivering water to the filter units was constant value, and thus means constant flows. The fluctuations of water level leads to change the flow readings.
3) Pump the raw water to URFL unit columns at filtration rates of 0.5, 0.75 and 1m/h or flow rates of 35.4, 53 and 70.7 L/h for each column for running times of 8, 6 and 4 hr/day, respectively. To control the influent flow rate it was used flow meter. Also, the effluent flow rate has been measured to ensure the accuracy of the flow meter.
4) Taking samples of the influent and effluent for each filtration rate and for each column.
5) The collected samples have been tested according to manner as shown in table (1).

**Table 1** Samples Duration for Laboratory Tests

| Test Type | Duration |
|---|---|
| Turbidity | Every day |
| TSS | 2 – 3 day |
| Conductivity | 2 – 3 day |
| TDS | 2 – 3 day |

6) The filtration run continued until clogging has been happened, and also the head loss reaches of 16 cm. After clogging, it was observed of low effluent quality and low flow rate.
7) When the filter clogged, it was cleaned by pumping the clean water in downflow direction at high flow rate until the effluent water become clean.
8) The schedule of pilot plant operation is shown in table (2).

**Table 2** Pilot Plant Monitoring Schedule

| Duration | Activity |
|---|---|
| Hourly | - Check the hydraulic level in feeding tank<br>- Check the flow meter records<br>- Check the filtration rate |
| Daily | - Check raw water quality<br>- Check headloss in filter column<br>- measure turbidity levels in both influents and effluents of each filter unit |
| Weekly | - Clean the pilot plant<br>- Maintenance of damaged parts |
| From 20 to 25 day | - Hydraulic cleaning of filter media<br>- Replacing other type of filter media |

## 3. Results and Discussion

The filtration rates that used in the present study were 1, 0.75 and 0.5 m/h. The present study investigated the ability of URFL to reduce the turbidity to value below 20 NTU which make the effluent water suitable for slow sand filter operation as referred in Wegelin, 1996.

### *3.1 The First Run at Filtration Rate of $V_F$ = 1 m/h*

The turbidity removal efficiencies of UFRL.1 and URFL.2 have been ranged from (59–82 %) and (63–86 %) respectively, as shown in figure (12). The TSS removal efficiencies of UFRL.3 and URFL.4 have been ranged from (63 – 86%) and (71 – 90%) respectively, as shown in figure (13).

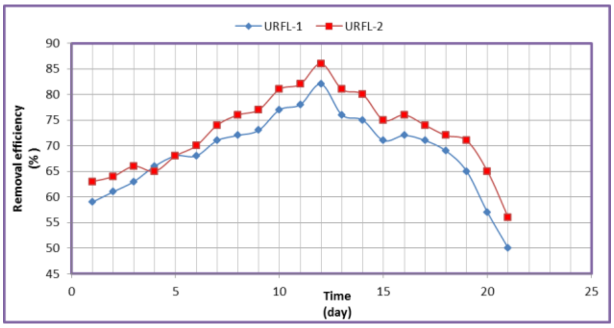


**Fig.12** Variation of Turbidity Removal Efficiency with Time for URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 1 m/h

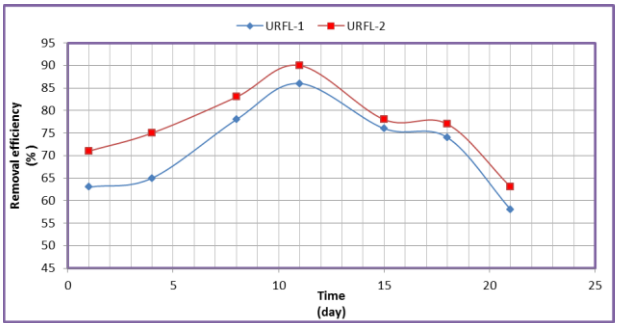


**Fig. 13** Variation of TSS Removal Efficiency with Time for URFL.1 (Marble) and URFL.2(Ceramic) at $V_F$ = 1 m/h

The turbidity values below of (60 NTU & 68 NTU) were reduced below of 20 NTU by URFL.1 and URFL.2 respectively and these values were acceptable to S.S.F operation.

However on the first day, URFL.1 of marble media and URFL.2 of ceramic media were recorded lowest turbidity and TSS removal efficiencies which are (59% & 63%) and (63% & 71%) respectively. These initial low removal efficiencies can be attributed to the fact that the filter-media were still undergoing of cleaning since the filters were run for the first time. It was impossible to use filters-media with fully clean.

Figures (14) & (15) show the turbidity and TSS levels in raw water, URFL.1 and URFL.2.

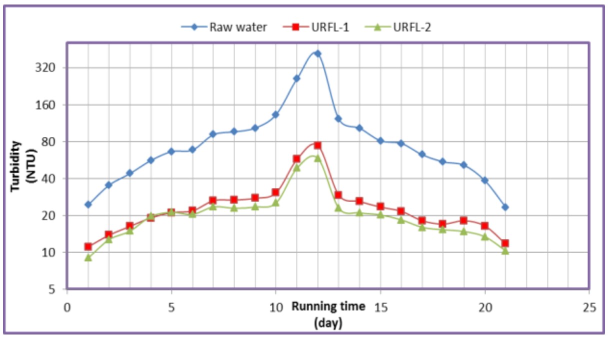


**Fig. 14** Turbidity Level in Raw Water, URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 1 m/h

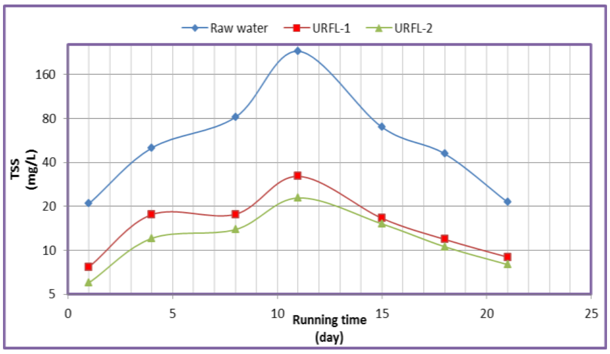


**Fig. 15** TSS Level in Raw Water, URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 1 m/h

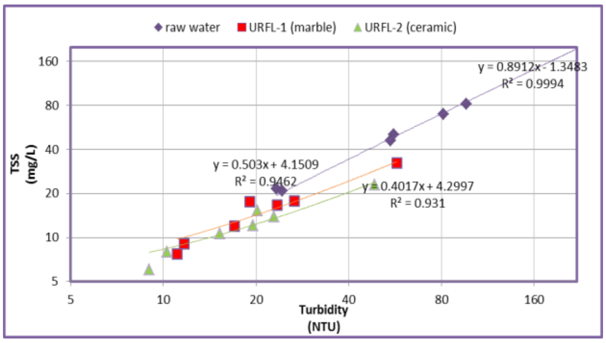


**Fig. 16** Correlation between Turbidity and TSS at $V_F$ = 1 m/h

Figure (16) shows the relationships between turbidity (NTU) and total suspended solid (TSS) for raw water before filtration, filtered water by URFL.1 and filtered water by URFL.2 at filtration rate of 1 m/h. The relationships between turbidity and TSS were:

1) For synthetic raw water: TSS = 0.8912 NTU–1.3483 ......... Eq (1), $R^2 = 0.99$
2) For URFL.1 of marble media: TSS = 0.503 NTU + 4.1509......... Eq (2), $R^2 = 0.9462$
3) For URFL.2 of ceramic media: TSS = 0.40171 NTU+4.2997......... Eq (3) , $R^2 = 0.931$

*3.2 The second Run at Filtration Rate of $V_F$ = 0.75 m/h*

The turbidity removal efficiencies of UFRL.1 and URFL.2 have been ranged from (60 – 83 %) and (65 – 88 %) respectively, as shown in figure (17). The TSS removal efficiencies of UFRL.1 and URFL.2 have been ranged from (65 – 88) and (73 – 92) respectively, as shown in figure (18).

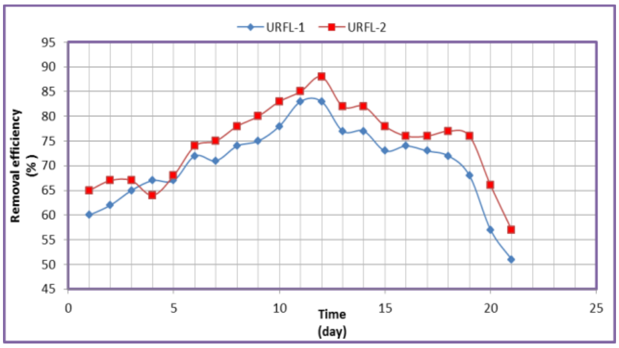


**Fig. 17** Variation of Turbidity Removal Efficiency with Time for URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 0.75 m/h

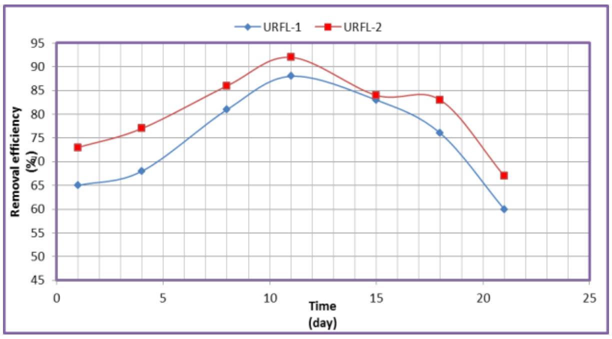


**Fig. 18** Variation of TSS Removal Efficiency with Time for URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 0.75 m/h

The URFL.1 and URFL.2 have best performance at ($V_F$ = 0.75 m/h) than of that of ($V_F$ = 1m/h). Where the turbidity below of (73 NTU & 85 NTU) were reduced to values below of 20 NTU by URFL.1 and URFL.2 respectively. The high turbidity and TSS removal efficiencies at day no.12 were not better filtrate quality. The raw water turbidity at day no.12 was the higher. The filtrated turbidities at day no.12 were (68.5 NTU & 47.9 NTU) While at day no.13 were (26.9 NTU & 21.1 NTU) for URFL.3 & URFL.4 respectively as shown in figures (19) & (20).

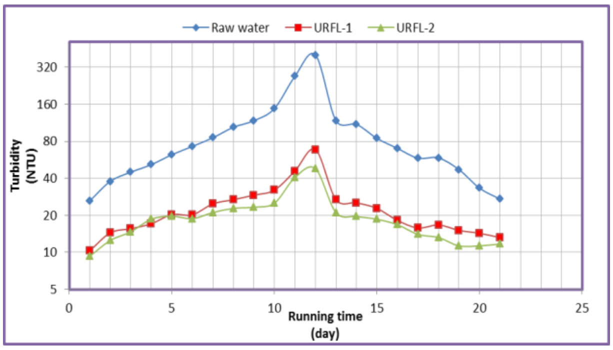


**Fig. 19** Turbidity Level in Raw Water, URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 0.75 m/h

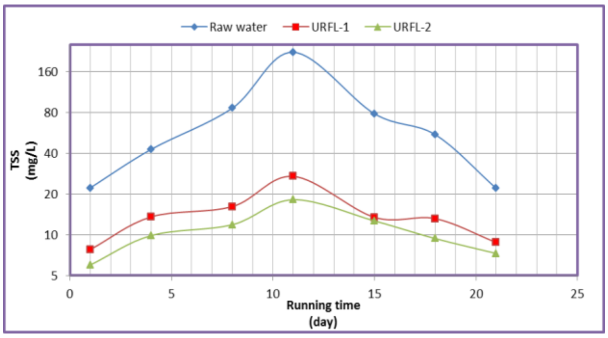


**Fig. 20** TSS Level in Raw Water, URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 0.75 m/h

*3.3 The Third Run at Filtration Rate of $V_F$ = 0.5 m/h*

The turbidity removal efficiencies of UFRL.1 and URFL.2 ranged from (68 – 86 %) and (70 – 91 %) respectively, as shown in figure (21). The TSS removal efficiencies of UFRL.1 and URFL.2 have been ranged from (73 – 91%) and (76 – 93%) respectively, as shown in figure (22).

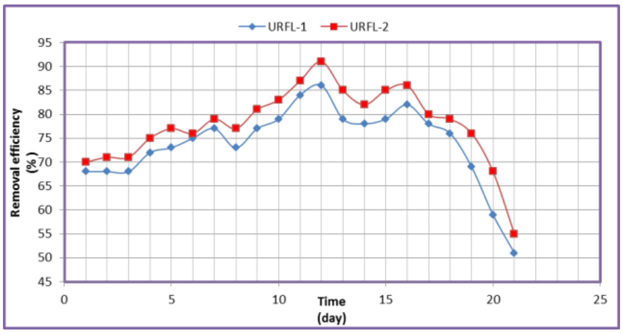


**Fig. 21** Variation of Turbidity Removal Efficiency with Time for URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 0.5 m/h

The URFL.1 and URFL.2 have higher turbidity and TSS removal efficiencies at $V_F$ = 0.5m/h than at 0.75 & 1 m/h. The turbidity values below (85 NTU & 109 NTU) were reduced to values below of 20 NTU by URFL.1 and URFL.2 respectively.

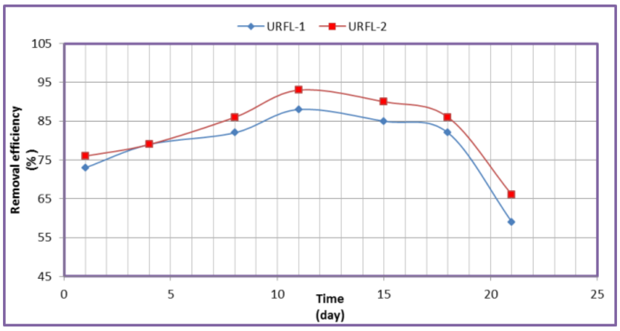


**Fig. 22** Variation of TSS Removal Efficiency with Time for URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 0.5 m/h

The filtrated turbidity increased with the influent turbidity increasing while the removal efficiencies increased with influent turbidity and running time increase as shown in figures (23) & (24).

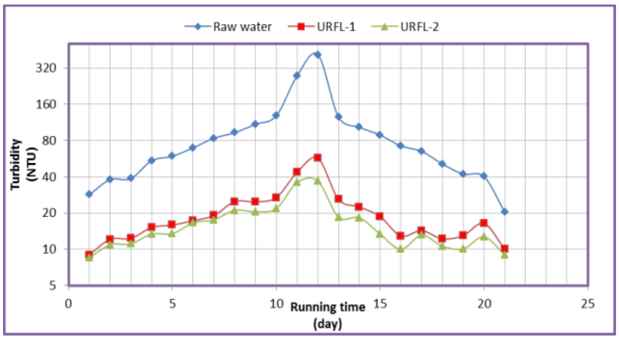


**Fig. 23** Turbidity Level in Raw Water, URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 0.5 m/h

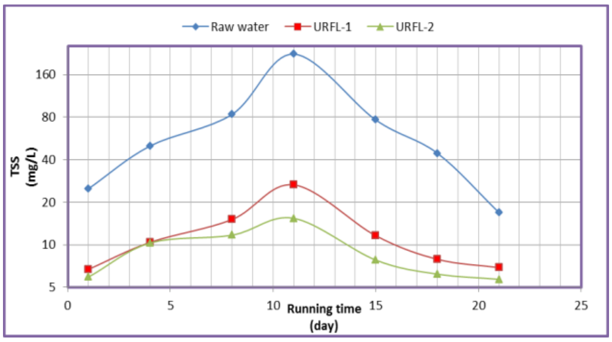


**Fig. 24** TSS Level in Raw Water, URFL.1 (Marble) and URFL.2 (Ceramic) at $V_F$ = 0.5 m/h

The time of breakthrough points of URFL.3 and URFL.4 were 19 and 21 day respectively and these results happened because the ceramic media has greater porosity than marble media.

## Conclusions

It was concluded that URFL of marble and ceramic media able to reduce the turbidity to value acceptable to slow sand filtration.

1) The URFL.2 of ceramic media has best performance in removal of turbidity and TSS than that of URFL.1 of marble media.
2) The URFL has better performance to treat the raw water at filtration rate of 0.5 m/h than both filtration rates of 0.75 and 1 m/h.
3) The URFL2 of ceramic media has running time greater than URFL.1 of marble media because it has higher porosity.
4) It was concluded that the ceramic and marble wastes can used as URFL media instead of conventional gravel media if the second is unavailable.

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