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Research Article

Treatment of Water and Wastewater by using Roughing Filter Technology of Local Materials

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Abstract

This study investigated the ability of up-flow roughing filter to pre-treatment of water and wastewater by using local filters media such as gravel and plastic waste. The pilot plant consists of two steel filters columns with 30 cm diameter and 150 cm length attached with two piezometer for head loss reading. Each column contains filter media divided into three layers: the bottom layer of (50 cm) depth, it was graded from (9.52 to 19 mm), the middle layer of (30 cm) depth, it was graded from (4.75 to 9.52 mm) and the top layer of (20 cm) depth, it was graded from (2.36 to 4.75 mm). The gravel media was installed in URFL.1, the plastic media was installed in URFL.2. The two filters was studied with three filtration rates of 1, 0.75 and 0.5 m/h. The water results investigated that the turbidity and TSS removal efficiencies of UFRL.1 and URFL.2 have been ranged from [(68 – 93 %) & (73 – 94%)] and [(71 – 94 %) & (75 – 96)] respectively. The plastic filter at filtration rate of 0.5 m/h could reduce the turbidities below 234 NTU to values less than of 20 NTU and These values are acceptable to slow sand filter operation. The plastic media was installed in URFL.3 for domestic wastewater filtration. The BOD_5 and TSS removal efficiencies at filtration rate of 0.5 m/h have been ranged from [(31 – 44 %) & (86 – 96%)] respectively.

Keywords: *Enhance water quality, Roughing filter, local materials*

1. Introduction

In Iraq, the quality and quantity of surface water is annually decreasing because of many reasons; first, the neighboring countries constructed many numbers of developing projects such as, dams and reservoirs without the coordination with Iraqi side; second, disposal of domestic and industrial wastewater from 250 to 300 ton annually in surface water without actually treatment, that lead to increase the turbidity and salinity to high level; third, decreasing the amount of precipitation in Iraq caused an increase in salinity content. These factors lead to the problems in conventional water treatment plants for treating surface water to acceptable quality that's made deficit in drinking water of 35 percent **(Huda M., 2007)**.

The chemical pre-treatment stage (coagulation, rapid mixing, flocculation, sedimentation) improves raw water to quality suitable for effective performance of the main treatment (slow or rapid sand filtration). Chemical pre-treatment combined with rapid sand filtration has disadvantages, particularly pronounced in poor developing countries **(Wegelin *et. al.*, 1991)**. These disadvantages include high capital and operating cost, unavailability of chemicals, inadequate dosing equipment, difficult operation and maintenance procedures, lack of local technical skills and trained operators and the need for expert supervision for the complex operation and maintenance. 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. Media types commonly used in roughing filtration are gravel, broken stones or rocks, broken burnt clay bricks, plastic material, burnt charcoal and coconut fiber, but can be replaced by any clean, insoluble and mechanically resistant material **(Graham, 1988)**. The media size for roughing filter ranging from (4– 20 mm). The roughing filter classified according to direction of flow to, vertical and horizontal flow roughing filter where the vertical flow roughing filter classified to downflow roughing filter and upflow roughing filter. The roughing filter work at filtration rate ranging between (0.3 – 1 m/h), **(Wegelin, 1996)**.

The acceptable performance of slow sand filter when influent turbidity between (10 – 30 NTU) or less **(Wegelin, 1996)**. One of the early mistakes in the using of slow sand filtration was to subject it to highly turbid raw water **(Graham *et. al.*, 1994)**. The roughing filter is an attempt to pre-treat the raw water to quality acceptable for slow sand filtration. The roughing filter is a low cost treatment technology based on physical process to treat water and wastewater by removing contaminant like, turbidity, suspended solids, COD and

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BOD also improves the microbiological water quality. The using of roughing filter of cheap materials, it will provide an alternatives to the current conventional systems, because it has good operation and low maintenance costs. In addition, the system is most suitable for small and medium water supply. So for these mentioned reasons, the justifications of study came.

The objectives of present study were investigating the ability of pre-treatment up-flow roughing filter to reduce the high turbidity of water without chemical additions to a values are suitable for slow sand filter operation, investigating the ability of upflow roughing filter to treatment of wastewater by removal of BOD_5 and TSS and comparing the performance of the local filters media of plastic waste with that of conventional filters media of gravel media.

The basic components of a roughing filter include a filter box, filter media, inlet and outlet structures, raw water distribution, collection of the treated water and filter drainage facilities as shown in figure (1), **(Mwinga, 1998)**.

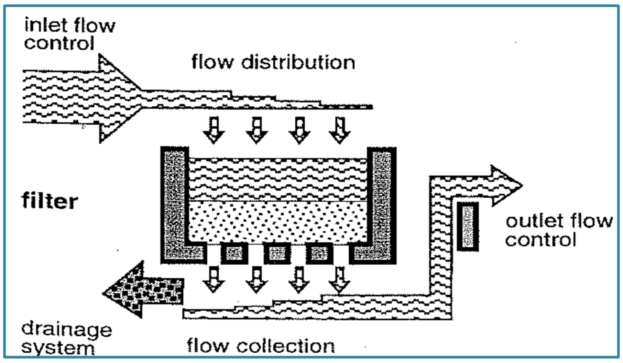

Fig. 1 The Components of Roughing Filter **(Wegelin, 1996)**

The types of roughing filters are; intake and dynamic filters and roughing filters prior to slow sand filter (SSF).

Intake and dynamic filters are usually located at the raw water intake site. They are applied to abstract raw water, and pre-filter it to protect the main treatment plant against heavy suspended solids common after heavy rains. The filter media size increases in the direction of flow. Therefore, most of the solids are retained on top of the filter-bed, and cleaning is simply achieved by manually scouring the top fine filter media with a rake or shovel **(Collins,M.R, 1994)**.

The roughing filters are located within the main treatment plant site before slow sand filter to improve raw water quality. They are operated as either up-flow, down-flow or horizontal-flow filters. The flow direction identifies four main types: horizontal-flow roughing filters (in series) (HRF), up-flow roughing filters in series (URFS), down flow roughing filters in series(DRFS) and up-flow roughing filters in layers (URFL) **(Wegelin ,1996)**.

The main principle in roughing filtration is to filter raw water through gravel layers decreasing in size in the direction of flow. Hence, for down-flow roughing filters in layers, most suspended solids would be retained at the bottom where the finest gravel layer is resulting in deteriorated filtrate quality and frequent hydraulic cleaning by draining. Therefore, it would not be effective to have DRFL **(Del Mundo, 1987)**.

In HRF, URFS and DRFS, each gravel layer is installed in separate compartments or boxes in series, while in URFL all the gravel layers are placed in one filter box. HRF, DRFS, URFS and URFL are deep bed filters which allow deep penetration of suspended solids into the filter-beds because of the coarse filter media compared to either RSF or SSF. These solids are only removed hydraulically by periodic draining or flushing of the filter-beds **(Wegelin, 1996)** .

2. Materials and Methods

The upflow roughing filter pilot plant unit was made from low-cost, locally and available materials to study the performance of URFL for treatment of water and wastewater.

Figure (2), shows a schematic representation of the URFL pilot plant unit. Figure (3), shows a photo of the pilot plant.

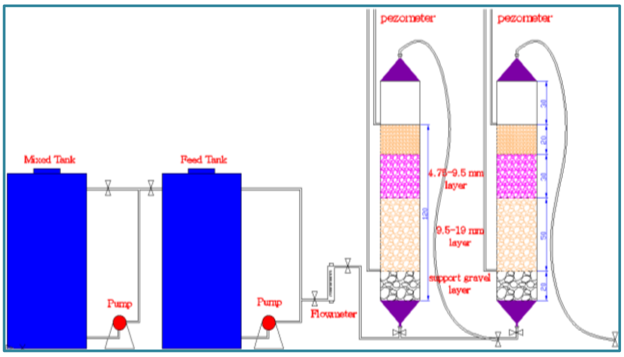

Fig. 2 Schematic diagram of the pilot plant

Fig. 3 Photo of the UREL pilot plant

2.1 Components of Pilot Plant

1. Mixing tank: The mixing tank is a galvanized steel cylindrical tank of about 443 liters capacity, with dimensions of 0.68 m in diameter and height of 1.22 m.

The main objectives of mixing tank is to store and mix of the raw water with kaolinite dose to obtain synthetic turbid raw water and also to give constant flow rate for feeding tank in order to maintain constant head in the feeding tank.

2. Feeding tank: The feeding tank is a galvanized steel cylindrical tank of about 443 liters capacity, with dimensions of 0.68 m in diameter and height of 1.22 m. The main objective of the feeding tank to supply the URFL columns by water and wastewater.

3. The pumps: Two pumps were used here. The main objective of the first pump is to obtain a constant head in feeding tank, so that it could supply the water to filters with constant flow rate. It also used to agitate the turbid raw water and thus lead to prevent the settling in the mixing tank. The second pump was used to agitate the raw water or wastewater in the feeding tank and then pump it to URFL columns.

4. Flow meter: The main objective of using flow meter is to measure the flow rate of the water and wastewater that inters the columns filters.

5. Pipes and valves: PVC pipes of 0.5 in, in diameter being used. The PVC pipes are reliable with respect to leakage, non-corrosion, and easily fabricated as desired. PVC valves are used to control the flow rate that inters the filter columns and helps to take samples for testing .

6. Filter columns: The pilot unit consists of two steel filters columns. Each column is 30 cm in diameter and length of 150 cm. The filters are designed and built to run in parallel system with up-flow direction. Each filter column connected with two plastic tubes each of 0.5 in, in diameter. The tubes are parallel to the column filter and they works as piezometers. The main objective of installing piezometers is to read the head loss H, (m) during filter running period. A perforated stainless steel disc is used at the bottom of each column to support the filter media, evenly distributes the influent raw water and to back washing drainage facilities. It is of 2 mm in its thickness and it has holes of 10 mm in diameter. The holes are distributed on the entire plate area.

2.2 Filter media

Gravel, plastic waste, marble waste and ceramic waste are used as filter media in this study. The gravel is the conventional filter media in roughing filtration, but can be replaced by any clean, insoluble and mechanically resistant material **(Graham, 1988).** In this study the gravel media is regarded as a reference for other materials that used as a filter media. In this study it was tried to find alternative local filter media for gravel. The gravel material was not suitable for direct use from its sources. It must be washed and graded to ensure good performance, as shown in figure (4). The selected gravel size for URFL 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 figure (5) of the gravel revealed that the uniformity coefficients of ($UC = d_{60}/d_{10}$) which was less than two, so it was considered within the acceptable limits as mentioned by Wegelin, 1996.

Fig. 4 Two photos of graded gravel media used

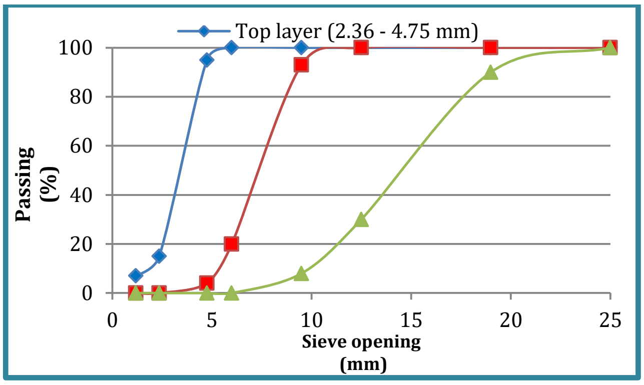

Fig. 5 Sieve analysis of URFL.1 gravel media used

The plastic used in the filter columns of the pilot plant unit was 100% recycled from solid wastes, the most these materials were polypropylene (PP) and Polyvinylchloride (PVC). It was collected, cleaned and then crushed as shown in figure (6).

Fig. 6 Two photos of graded plastic media used

The selected plastic size for URFL 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 figure (7) gave uniformity coefficients of (UC= d_{60}/d_{10}) which was less than two, therefore it considered acceptable as mentioned by Wegelin, 1996 .

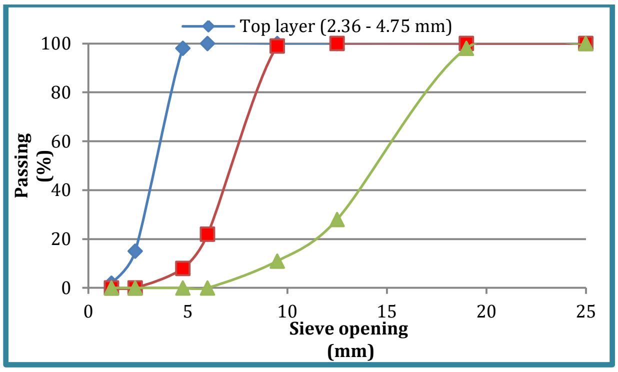

Fig. 7 Sieve analysis of URFL.2 plastic media used

3. Results and Discussion

In the present study, synthetic turbid water was used by adding kaolinite clay to tap water. The range of turbid water was of 20 to 450 NTU. Domestic wastewater used with BOD_5 from 250 to 450 mg/L. The filtration rates that used in the present study were 1, 0.75 and 0.5 m/h. The effects of filtration rate on the filters efficiency have been extensively investigated.

3.1 Experimental Water Results

The gravel and crushed plastic waste are tested here. The gravel was used in URFL.1 while the plastic was used in URFL.2. The two filters subjected to the same parameters and the same influent water quality, filtration rate, running time and filter unit design criteria.

1. The First Run, Filtration Rate of V_F = 1 m/h

The value of filtration rate used was 1 m/h. It was found that the URFL.2 of plastic filter had higher turbidity and TSS removal efficiencies than URFL.1 of gravel filter.

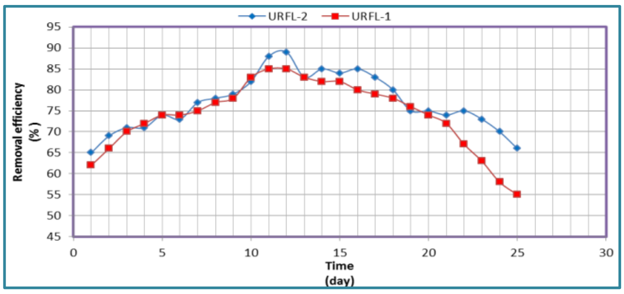

Fig. 8 Variation of Turbidity Removal Efficiency with Time for URFL.1 (Gravel) & URFL.2 (Plastic) at V_F = 1 m/h

The turbidity removal efficiencies of UFRL.1 and URFL.2 have been ranged from (62 - 85 %) and (65 – 89 %) respectively, as shown in figure (8). The TSS removal efficiencies of UFRL.1 and URFL.2 have been ranged from (67 – 89 %) and (71 – 92 %) respectively, as shown in figure (9).

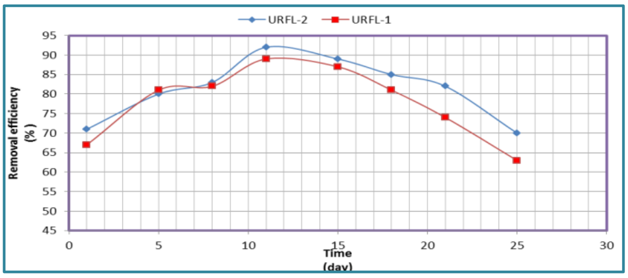

Fig. 9 Variation of TSS Removal Efficiency with Time for URFL.1 (Gravel) & URFL.2 (Plastic) at V_F = 1m/h

The main objective of roughing filter is to reduce the turbidity to an acceptable value for S.S.F operation. Reasonable S.S.F operation can only be expected with inlet water turbidities below 20 to 30 NTU, (Wegelin, 1996). At filtration rate of (V_F = 1m/h), the turbidity values that are below of (83 NTU & 100 NTU) reduced to values below of 20 NTU. While the turbidity values below of (212 NTU & 240 NTU) have been reduced to values below of 30 NTU by URFL.1 and URFL.2 respectively and these values were acceptable to S.S.F operation. Table (1) shows the experimental results of filtration rate of (1 m/hr).

Table 1 Experimental results of the first run (V_F = 1 m/hr)

Parameters	UFRL.1	UFRL.2
Max turbidity removal efficiency, (%)	85	89
Max TSS removal efficiency, (%)	89	92
Running time, (day)	23	25
Headloss, (cm)	15	15
Reduced Turbidity below 20 NTU	83	100
Reduced Turbidity below 30 NTU	212	240

2. The Second Run, Filtration Rate of V_F = 0.75 m/h

The value of filtration rate used was 0.75 m/h. It was found that the URFL.2 of plastic filter had higher turbidity and TSS removal efficiencies than URFL.1 of gravel filter. The turbidity removal efficiencies of UFRL.1 and URFL.2 have been ranged from (64 – 89 %) and (66 – 92 %) respectively, as shown in figure (10). The TSS removal efficiencies of UFRL.1 and URFL.2 have been ranged from (70 – 93) and (71 – 94%) respectively, as shown in figure (11). The URFL.1 and URFL.2 have best performance at (V_F = 0.75 m/h) than that of (V_F = 1m/h). It can be noted that the turbidity below (93 NTU & 160 NTU) reduced to a values below of 20 NTU, and the turbidity below of (226 NTU & 300 NTU) reduced to a values below of 30 NTU by URFL.1 and URFL.2 respectively and these values were acceptable to S.S.F operation. Table (2) shows the experimental results of filtration rate of (0.75 m/hr).

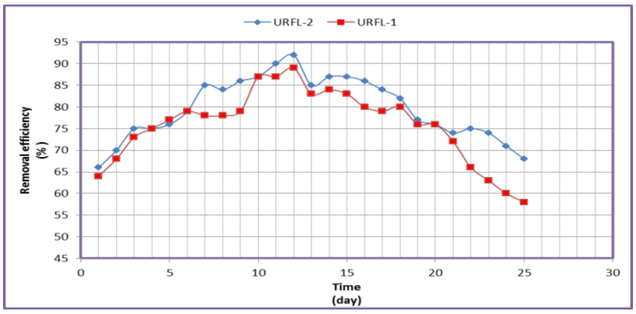

Fig. 10 Variation of Turbidity Removal Efficiency With Time for URFL.1 (Gravel) & URFL.2 (Plastic) at V_F = 0.75 m/h

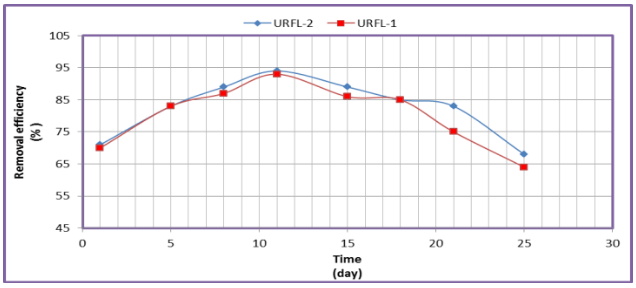

Fig.11 Variation of TSS Removal Efficiency With Time for URFL.1 (Gravel) & URFL.2 (Plastic) at V_F = 0.75 m/h

Table 2 Experimental results of the second run (V_F = 0.75 m/hr)

Parameters	UFRL.1	UFRL.2
Max turbidity removal efficiency, (%)	89	93
Max TSS removal efficiency (%)	93	94
Running time, (day)	23	25
Headloss, (cm)	15	15
Reduced Turbidity below 20 NTU	93	160
Reduced Turbidity below 30 NTU	160	300

3. The Third Run, Filtration Rate of V_F = 0.5 m/h

This run at filtration rate of 0.5 m/h. It was found that the URFL.2 of plastic filter had higher turbidity and TSS removal efficiencies than URFL.1 of gravel filter.

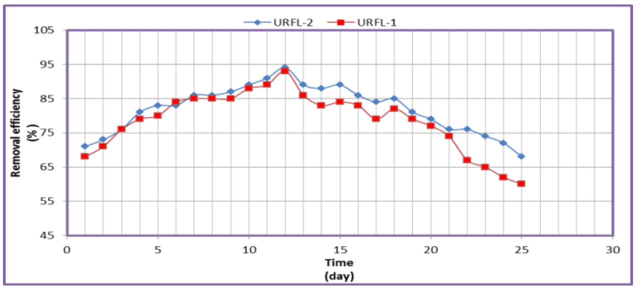

Fig. 12 Variation of Turbidity Removal Efficiency With Time for URFL.1 (Gravel) & URFL.2 (Plastic) at V_F = 0.5 m/h

The turbidity removal efficiencies of UFRL.1 and URFL.2 have been ranged from (68 – 93 %) and (71 – 94 %) respectively, as shown in figure (12). The TSS removal efficiencies of UFRL.1 and URFL.2 have been ranged from (73 – 94 %) and (75 – 96%) respectively, as shown in figure (13).

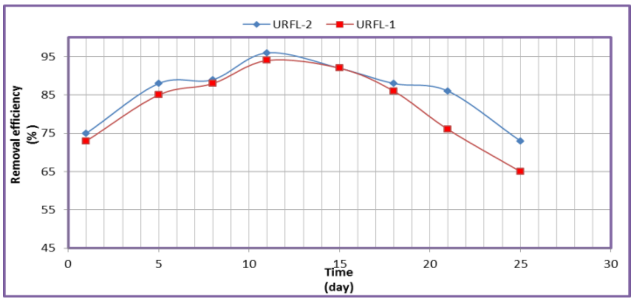

Fig. 13 Variation of TSS Removal Efficiency With Time for URFL.1 (Gravel) & URFL.2 (Plastic) at V_F = 0.5 m/h

The URFL.1 and URFL.2 have higher turbidity and TSS removal efficiencies at V_F = 0.5m/h than that of 0.75 & 1 m/h. Where the turbidity below (160 NTU & 234 NTU) were reduced to value below of 20 NTU, and the turbidity less than (410 NTU & 410 NTU) were reduced to value below of 30 NTU by URFL.1 and URFL.2 respectively. Where these values were acceptable to S.S.F operation.

The turbidity and TSS removal efficiencies were increased with running time because the screening mechanisms become more efficient with a decreasing the pore size of the filter bed with time. Where at day no.1, the influent turbidity and TSS were (23.8 NTU & 20.7 mg/L) which made the removal efficiencies of (68% & 71 %) and (73% & 75%) for URFL.1 and URFL.2 respectively. While at day no.21, the influent turbidity and TSS were (20.2 NTU & 19.2 mg/L) witch made the removal efficiencies of (74 % & 76 %) and (76% & 86%) for URFL.1 and URFL.2 respectively. Table (3) shows the experimental results of filtration rate of (0.5 m/hr).

Table 3 Experimental results of the third run (V_F = 0.75 m/hr)

Parameters	UFRL.1	UFRL.2
Max turbidity removal efficiency, (%)	93	94
Max TSS removal efficiency, (%)	94	96
Running time, (day)	23	25
Headloss, (cm)	15	15
Reduced Turbidity below 20 NTU	160	234
Reduced Turbidity below 30 NTU	410	410

3.2 Experimental Wastewater Results

The best performance of up flow roughing filter was by using of plastic media at filtration rate of 0.5 m/h. Therefore it was decided to use plastic media in wastewater treatment under best operation parameters. The plastic media used in URFL.3 at filtration rate of 0.5 m/h.

The main aims of wastewater treatment are to remove of BOD_5 and TSS by URFL.3. The BOD_5 and TSS removal efficiencies of URFL.5 have been ranged from (31 – 44 %) & (86 – 96%) respectively, as shown in figure (14). It was found that the removal efficiency of BOD_5 was lower than TSS removal efficiency, and this finding can be attributed to two reasons. The first reason is that the Roughing filter works at physical mechanisms that are satisfactory to remove TSS and it cannot remove TDS at high efficiency. While the second reason get back to biological treatment facilities, where the bacteria need continuous dissolved oxygen and enough detention time to stabilize dissolved organic matter in wastewater and it was impossible to provide this condition at significant amount.

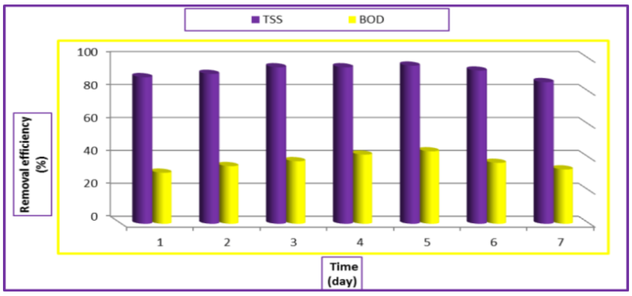

Fig. 14 Variation of BOD_5 &TSS Removal Efficiency with Time for URFL.3 (Plastic) at V_F = 0.5 m/h

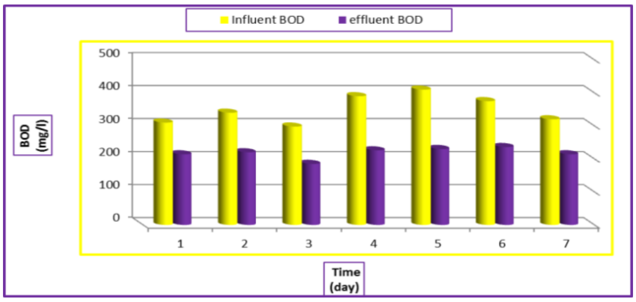

Fig. 15 BOD_5 Level in Influent and URFL.3 (Plastic Media) at V_F = 0.5 m/h

At day no.6, the concentrations of BOD_5 and TSS of filtered wastewater are began to increase to values of 236 mg/l and 40 mg/l respectively as shown in figures (16 & 17).

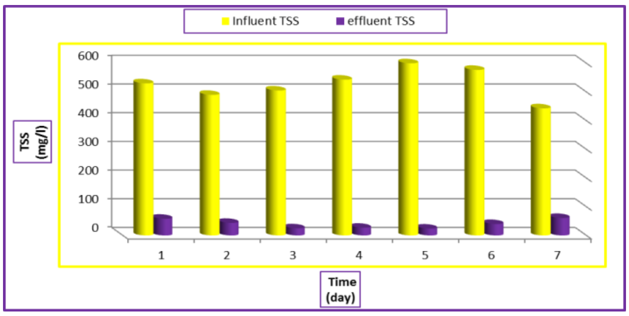

Fig. 16 TSS Level in Influent and URFL.3 (Plastic Media) at V_F = 0.5 m/h

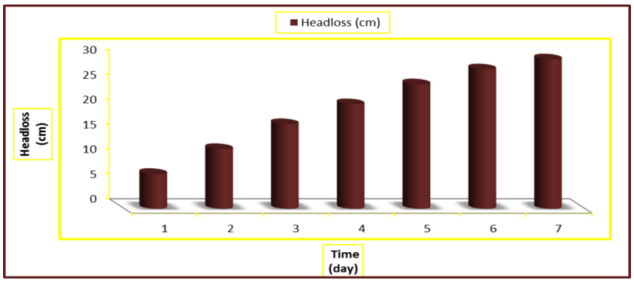

Fig. 17 Variation of Headloss With Time for URFL.3 (Plastic) at V_F = 0.5 m/h

The results obtained because the URFL.3 was started to be clogged and thus would lead to increase the headloss to value more than 28 cm. The accumulation of organic matter in pores of filter grains was contributed to depletion of dissolved oxygen into the filter media. To complete its activities, the bacteria was entered in anaerated condition causing low filtrated wastewater quality at seventh day .

The running time of URFL.3 was seven days, and the maximum headloss at the last day was reached to value of 30 cm. This results can be attributed to high TSS concentration of wastewater as compared to that of water.

Conclusions

1) It is found that URFL able to do pretreatment of the turbid raw water to quality levels are acceptable to slow sand filter operation.
2) The URFL.2 of plastic filter has better turbidity and TSS removal efficiency than that of URFL.1 of gravel media.
3) 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. The ability of URFL to remove the suspended solid increase with decreasing of filtration rate.
4) The URFL2 of plastic filter has running time greater than other filters because it has higher porosity than other filters used.
5) The maximum BOD_5 and TSS removal efficiencies of domestic wastewater were 44% and 96% by URFL.3 of plastic media. Based on these results, it can be concluded that the biological mechanisms of roughing filters have not enough ability to remove of TDS as compared to that of physical mechanisms.

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