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Grey Water Treatment Using Sand Filtration

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Abstract— *Conventional sand filtration is a clean, green and renowned technology that can be applied for the treatment of grey water. It requires a small footprint area, cost effective for both construction and operation with no skilled manpower. The current research work was conducted at The British University in Egypt to determine the efficiency of sand filtration in treating grey water using the model CE 579 pilot plant. The pilot plant was operated using grey water produced from administrative buildings and students hostels in the University at a fixed water head of 80 cms and effective sand size of 2.38 mm. Three different flux rates and sand media depths were experimented. The optimum removal efficiency was recorded for flux rate of 555 lit/m^2/hrs and sand depth of 80 cms; values recorded were 80.03 % and 78.65 % for TSS and COD respectively.*

Keywords— *Grey water, treatment system, sand filtration, total suspended solids, chemical oxygen demand.*

I. INTRODUCTION

Egypt depends mainly on the River Nile as a source of raw fresh water for different uses; domestic, agricultural, commercial and industrial. Due to the growth of population, agricultural expansion, industrialization and urbanization coupled with the fixed flow of raw water from the River Nile which is estimated to be 55.50 billion cubic meters (bcm) per year. Thus; it is very important to find other secondary sources of raw water. Separation of domestic sewage into grey/black and further reuse of the treated grey water provides a promising potential source of water as it represents about (65-75) % of the total domestic sewage (1).

Grey water separation and characterization has been thoroughly documented in literature (2, 3, 4). The flow rates and composition depends mainly on in-house life style, attitudes, social habits, economic status and usage with high discrepancy reported in the values documented in literature (5, 6, 7). Average values recorded for some parameters include a pH range of (7.2-8.0), total suspended solids (TSS) value of (88-100) mg/lit, biological oxygen demand (BOD) value of (155-411) mg/lit and, finally, chemical oxygen demand (COD) value of (370-806) mg/lit (6, 7).

Filtration is the removal of suspended particles from wastewater by allowing the wastewater to pass through a porous, inactive and clean media. This porous media can be naturally made, such as sand, gravel, crashed stone, and clay, or it can be a membrane synthetically made of various materials (8). In some cases, if raw wastewater is used, large particles and solids are settled prior to filtration in settling basins; to reduce the solids in the influent wastewater. Size of particles retained during filtration depends on the pore size of the filter media used. Figure 1 below gives a summary of the filtration spectrum according to pore size from which we deduce that sand filtration is the first step in the filtration train (9).

Sand filtration removes particles of size bigger than 10 microns and removes some portion of the algae and bacteria. The efficiency of sand filtration for the removal of dissolved particles in wastewater is practically nil as they pass within the sand media pores (10). Grey water treated using a slow sand filter using sand with effective size of 0.3 mm and depth of 400 mm attained removal efficiencies of 89 % and 71.85% for BOD and COD respectively and by using slate waste as media the percentage removal dropped to 51% and 60% for both parameters respectively; and by further changing the media to volcanic turf the removal rates raised to 73% and 65% respectively (10). Using gravel, sand and carbon filter grey water was treated and the removal efficiencies obtained for the parameters under study were 95 %, 52 %, 88 %, 100 % and 100 % for colour, TDS, turbidity, total coliform and E. coli, respectively (11).

Sedimentation followed by filtration and then adsorption was tested for treating grey water and the parameters monitored were TSS, BOD and COD and they gained removal efficiencies of 70.74 %, 85.65 %, and 57.09 % respectively (12). In another study in Egypt, a plain sedimentation tank followed by four sand gravity filters was tested to determine the extent of grey water treatment. The operational range was from 86.5 m^3/m^2/day to 173 m^3/m^2/day and the removal efficiencies obtained were in the range of (40-80) %, (45-82) % and (50-93) % for COD, BOD and TSS respectively (13). Grey water from students hostels in a University in Iran was treated using horizontal filters in series consisting of different types of media starting with sand and ending with granular activated carbon and the elements tested include COD, BOD_5, TSS and turbidity. The set-up was operated at a flux rate of 2.94 m^3/m^2/day. Results from the filtration tests showed that the best filtration performance for the removal of COD, BOD_5, TSS and turbidity with efficiencies obtained reaching 90.42 %, 91.43 %, 82.95 %, and 90.27 %, respectively (14). A filter using nonwoven textile media was used for treating grey water with an average capacity of (1.0-1.4) cm/day. The overall removal efficiencies of COD, BOD_5 and TSS were in the range of (58.80-71.60) %, (56.70-79.80) and (67.00-88.40) %, respectively (15). Sand filter media both alone and mixed with other media was used in the treatment of agriculture drain water and COD removal efficiency was in the range between (77.74-89.00) % (16).

Conventional sand filtration has a main advantage of its low cost and easy operational requirements and can be easily fixed and operated on-site thus reducing the sewage collection works and returning back the treated grey water for reuse for non-

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potable purposes. Its main drawback is its clogging and in some cases the quality of the output effluent treated grey water doesn't meet the required standards (17).

Research Significance

The separation of domestic sewage into grey and black water on the household level and further treatment of the grey water on-site for reuse is gradually becoming a necessity and gaining grounds in many parts of the world.

Consequently, the main objectives of this research study is to determine the efficiency of conventional sand filtration for the treatment of grey water. Optimum operating conditions were also obtained by operating a standard pilot sand filtration plant.

II. Materials and Methods

The experimental work was conducted on model pilot plant CE 579 filtration unit in the Sanitary Engineering laboratories, Faculty of Engineering, The British University in Egypt. The grey water was collected from the administrative buildings and the students hostels in the university; table 1 shows the average influent values to the pilot plant during the operation of the pilot plant.

The CE 579 pilot plant is a standard physical treatment system using sand filtration. The plant consists of a series of tanks and valves and a transparent Plexiglas filter unit and the plant operation is controlled by a special software via a computer connected to the system, figure 2. The plant was operated at three different flux rates 555 lit/m^2/hrs, 1390 lit/m^2/hrs and 2780 lit/m^2/hrs with varying the sand media depth at 40 cms, 60 cms and 80 cms. The sand filter was operated at a constant water head of 80 cms while effective size of the sand media was 2.38 mm. A number of nine runs were conducted for each flux rate for each of the sand media depths mentioned above; the duration of each run was 8 hours.

The filter passage ratio was calculated during the duration of each run to determine the filter clogging percentage. The last run with flux rate of 2780 lit/m^2/hrs and sand media depth of 80 cms was terminated after 6 hrs of operation only as the filter passage dropped to below 50 % recording a value of 39.60 %.

One extra tenth run was conducted for the run with optimum effluent values. This run was a continuous extended run for a period of 18 hours with backwashing every 6 hours after reaching a filter passage ratio of about 57.33 % in average. Backwashing time was 20 minutes at a rate 5 times the flux rate using filtered grey water.

TABLE 1. Values of the collected grey water for the parameters monitored

Parameter	Minimum value	Maximum value	Average value
pH	6.0	8.5	7.25
Total Suspended Solids (TSS) (mg/lit)	121	215	185
Total Chemical Oxygen Demand (CODt) (mg/lit)	194	429	325
Soluble Chemical Oxygen Demand (CODs) (mg/lit)	46	143	105

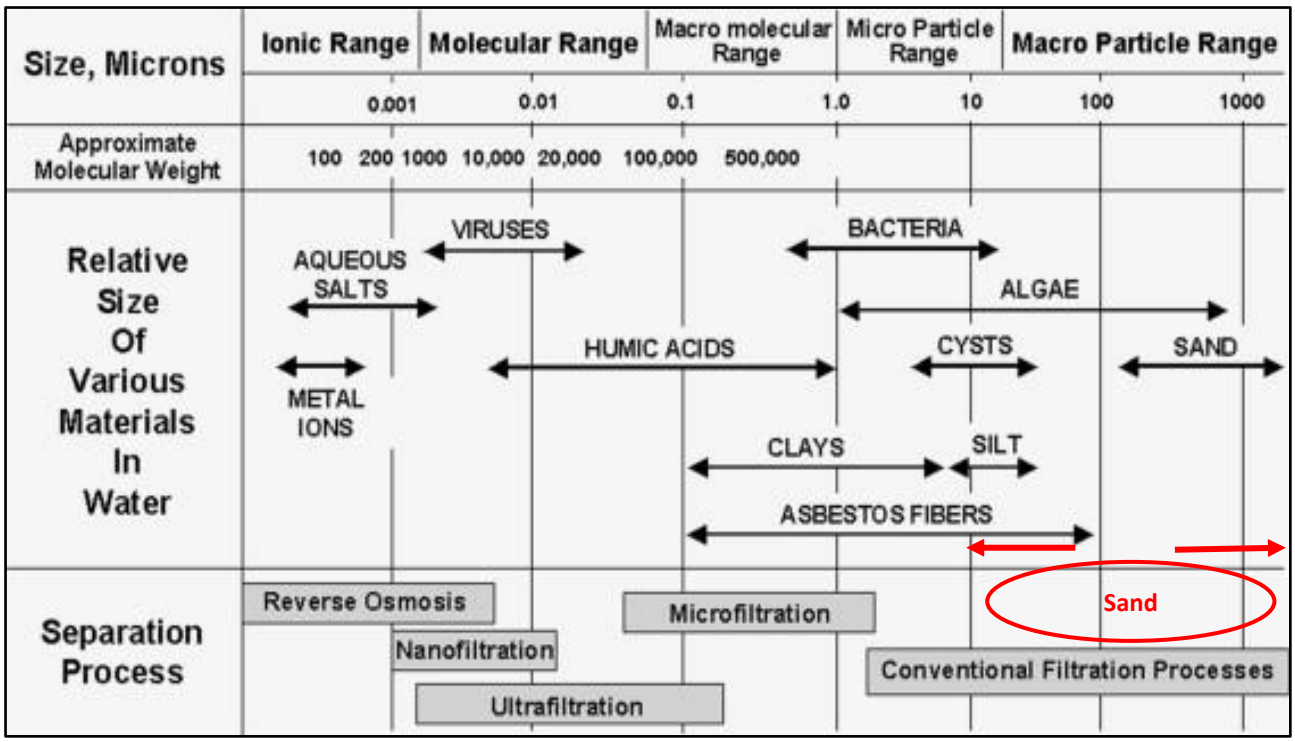

Fig. 1. Filtration spectrum for different separation processes (9)

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No.	Name
1	Raw water pump (P1)
2	Raw water tank (B1)
3	Switch board cabinet
4	Backwash pump (P2)
5	Flow rate sensor (FIR)
6	Temperature sensor (TIR)

No.	Name
7	Valves (V1-V4)
8	Differential pressure sensor (PDIR)
9	Sand filter (F)
10	Pressure relief valve (V5)
11	Bleeder
12	Treated water tank (B2)

Fig. 2. CE 579 pilot plant general view and filter close view

The parameters monitored during the experimental phase of this research work include pH, Total Suspended Solids (TSS), Total Chemical Oxygen Demand (CODt) and Soluble Chemical Oxygen Demand (CODs). All the parameters analyses were done as per Standard Methods (18).

III. Results

Results obtained from the operation of the pilot unit indicated that lower flux rates and deeper sand media gave better removal. The increase in flux rates and media depth accelerated the filter clogging. Figures 3 to 8 show the output results from the operation of the pilot plant. Influent and effluent pH values were almost constant and no any removal was recorded for COD soluble.

The best TSS and COD total removal was recorded at a flux rate of 555 lit/m^2/hrs and sand depth of 80 cms. The removal efficiencies recorded were 81.08 % and 78.75 % for TSS and COD total respectively. This values were for influent TSS and COD total of 202 mg/lit and 410 mg/lit and average effluent of 39.25 mg/lit and 92.25 mg/lit respectively. The run was operated for 8 hrs and the filter passage dropped to 51.80 % at the end of the run. Initial effluent values were above the requirements of the Egyptian Standards; for TSS the effluent values dropped below the standard value of 50 mg/lit after the first hour of operation coinciding with a filter passage of 80.40 % while for COD total it dropped below the standard value of 80 mg/lit after the fourth hour of operation coinciding with a filter passage of 59.20 %. Other flux rates gave moderate removal rates rapid filter clogging especially for deeper sand media depth.

For the extended run for 18 hours with backwashing, the average effluent TSS value was about 39.75 mg/lit and that of COD total was 90.06 mg/lit. This reflects removal efficiencies of 80.03 % and 78.65 % for TSS and COD total respectively. From the figures it can be noticed that the effluent values are high at the beginning of the run and drop as the filtration progresses.

From figure 8 we can deduce that the filter operated at a net flux of 72.30 % of the initial flux rate of 555 lit/m^2/hrs. Thus

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the system net flux is 401.25 lit/m^2/hrs and this reflects on the filter production as it drops due to clogging.

IV. Conclusion

The separation of grey water and treating it on-site and then reusing it for non-potable purposes (toilet flushing, landscape irrigation. etc.) provides a good potential source of raw water that will alleviate the current stress and demand on the natural raw water sources; it represents about (65-75) % of the total household wastewater.

Conventional sand filtration is one of the good options that can be adopted for the treatment of grey water both on large scale and on-site. It is a clean, green and renowned technology that is cost-effective both in construction and operation.

Sand filtration doesn't require skilled manpower for its operation compared with other treatment technologies and it can be operated intermittently. This intermittent operation option is a viable technical and economical asset that makes it easy to operate and maintain locally on-site without the need of high skilled manpower.

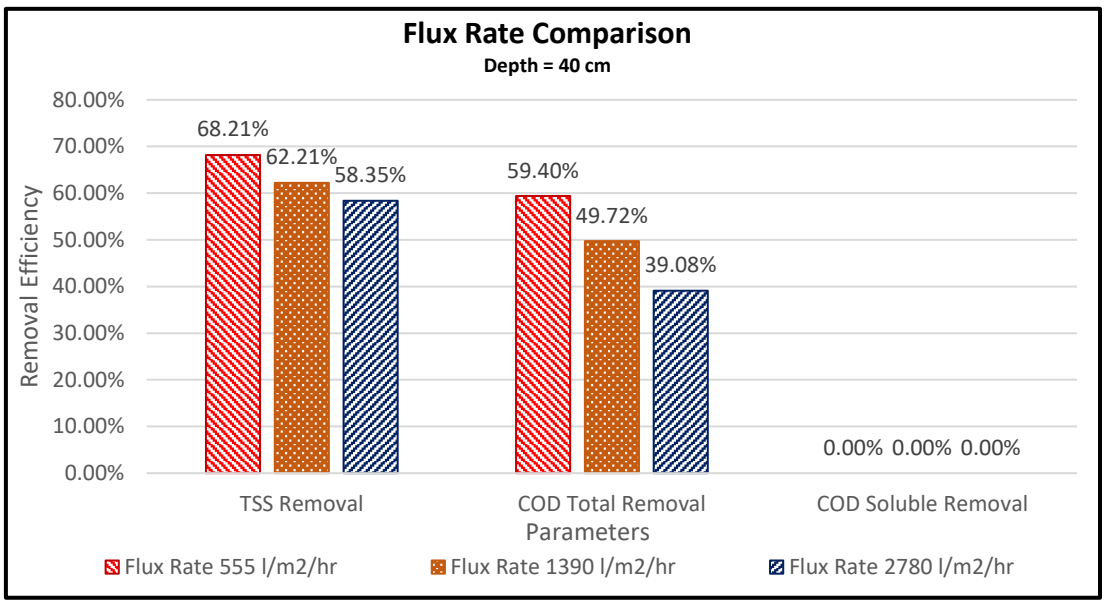

Fig. 3. Flux rate comparison for 40 cms sand depth

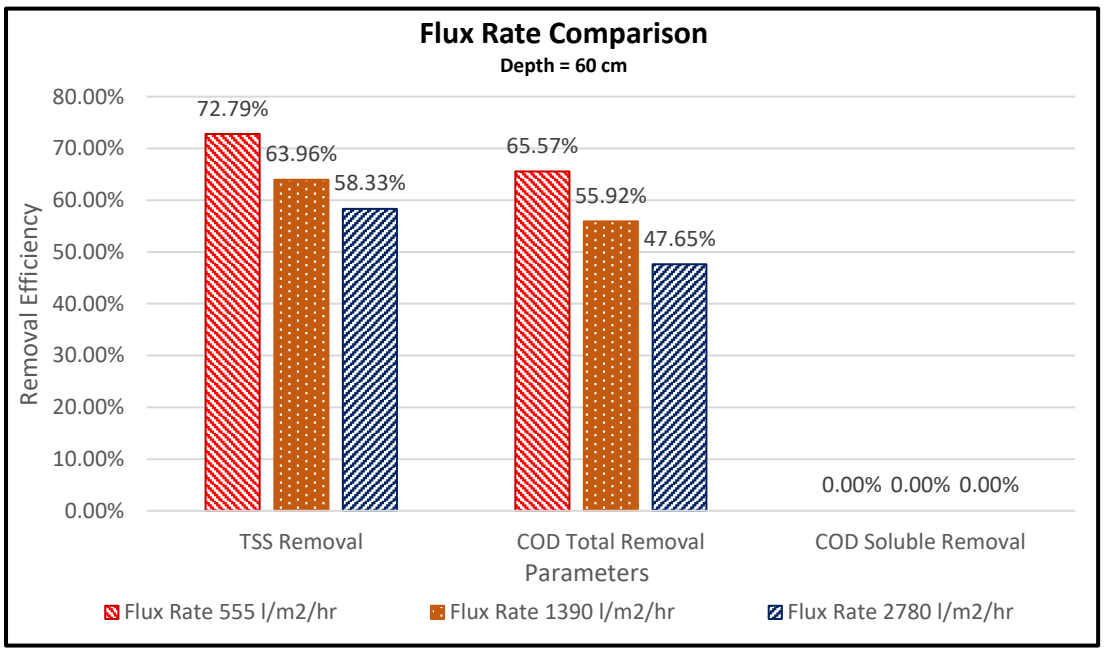

Fig. 4. Flux rate comparison for 60 cms sand depth

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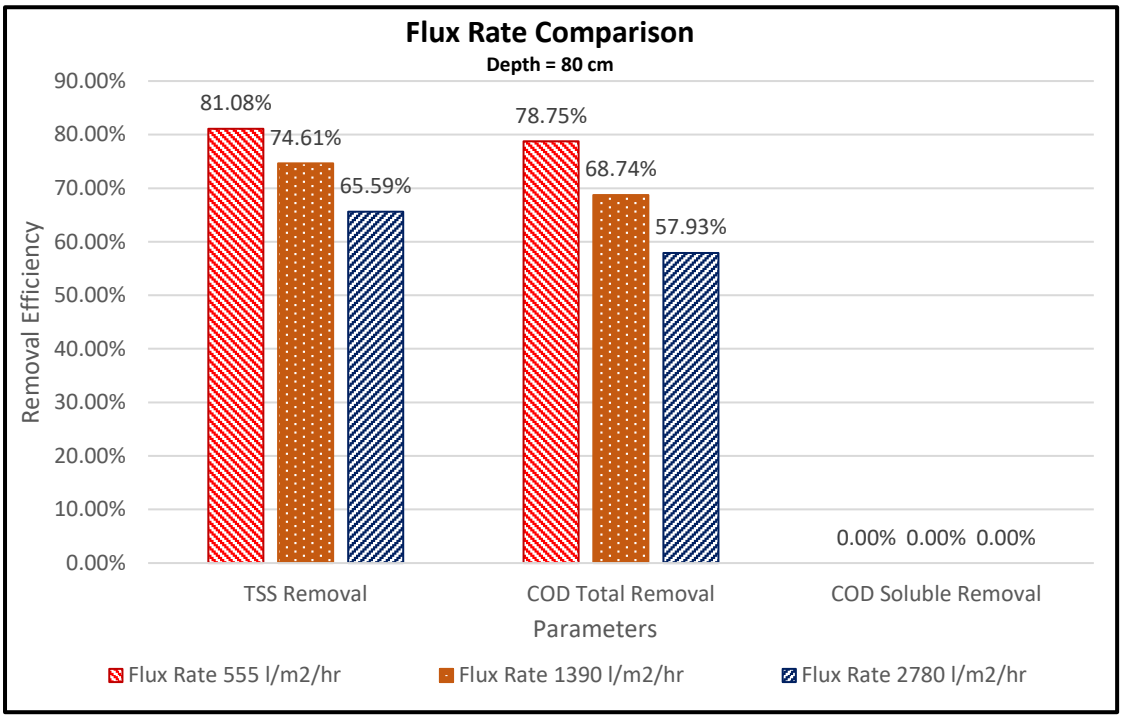

Fig. 5. Flux rate comparison for 80 cms sand depth

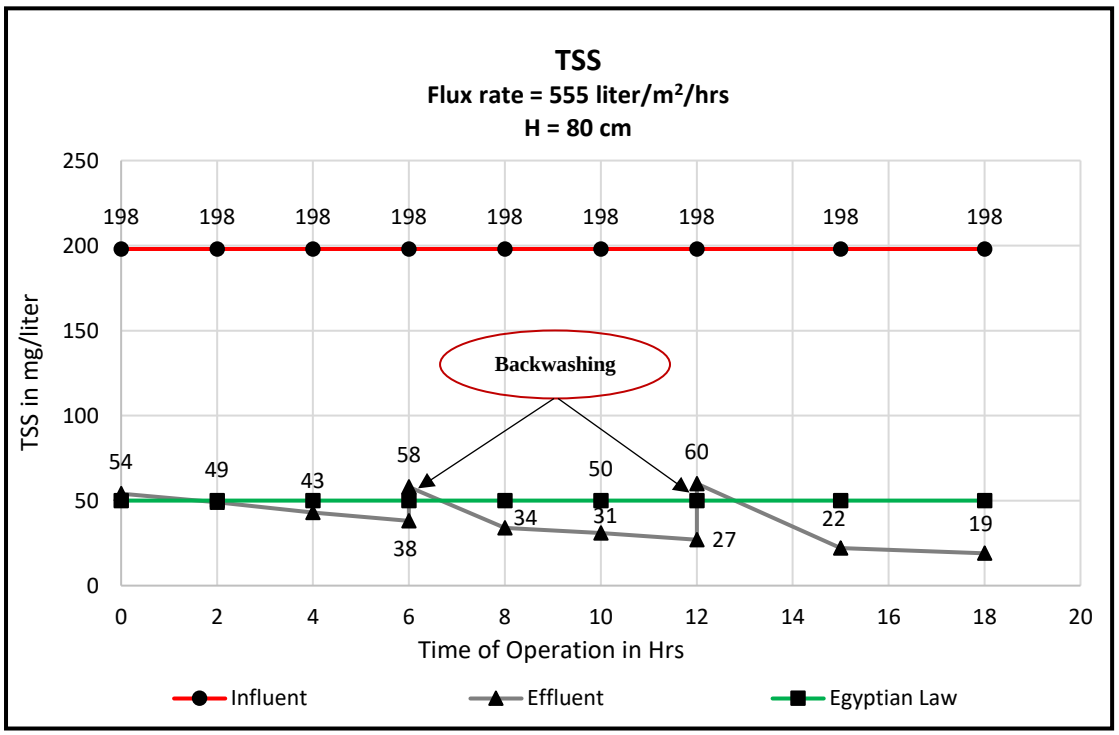

Fig. 6. TSS effluent values for the extended run

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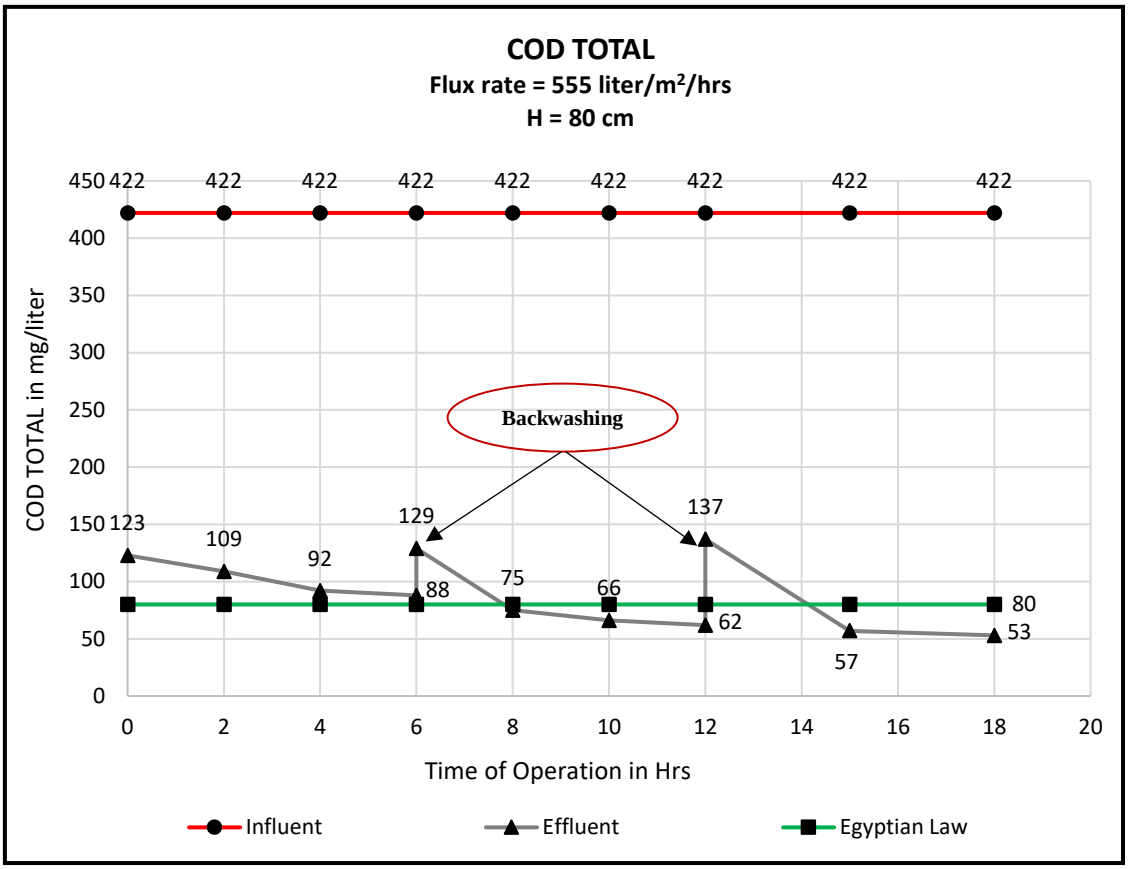

Fig. 7. COD total effluent values for the extended run

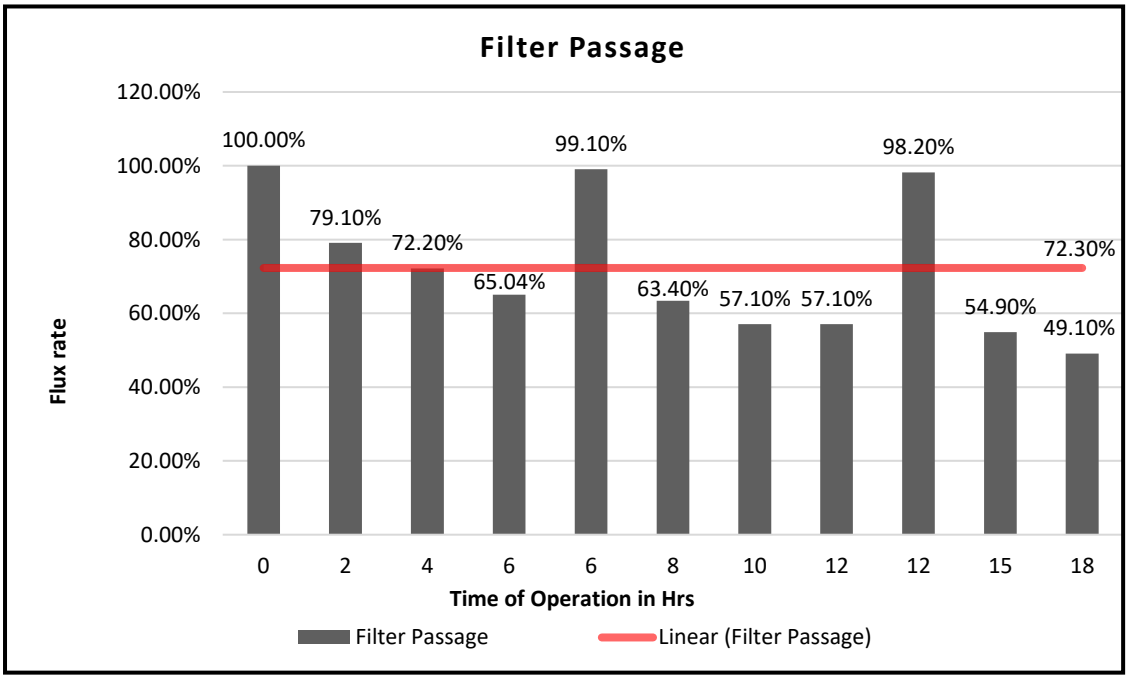

Fig. 8. Filter passage for the extended run

Consequently, from the results shown above, it can be deduced that the best effluent values for the treated grey water are obtained at low flux rates and deep sand filters. Of the three flux rates monitored in this research work, the lowest value of 555 lit/m^2/hrs gave the most efficient removal efficiencies at a sand media depth of 80 cms. Removal percentages of 81.08 %

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and 78.75 % were achieved for TSS and COD total respectively reflecting average effluent values of 39.25 mg/lit and 92.25 mg/lit. TSS effluent values abided with the Egyptian Standards stated in Law 48 for the year 1982 regarding the disposal of wastewater into agricultural drains (COD ≤ 80 mg/lit, TSS ≤ 50 mg/lit) while the COD values were slightly higher in average but as the filtration progressed the values dropped below the standards. As with regards reuse in agricultural irrigation, the TSS effluent values fall within Grade B according to the requirements of code 501/2015.

The main disadvantage of conventional sand filtration in the treatment of grey water is the rapid clogging of the sand media; although the water passage rate within the filter drops due to clogging but the removal efficiency increases. Also sand filtration gave very poor results for the removal of soluble COD.

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