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Non-woven fabric filters integrated with decentralized system for domestic wastewater treatment

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ABSTRACT

Pilot plant composed of fabric filters integrated with the decentralized treatment plant ZECUwas tested for its ability to remove the suspended solids and organic matters presented as TSS, COD_t and CODs from wastewater. The filters were made from scrim polyester non-woven fabrics and were tested on gravity driven pressure. The investigation was executed on two phases. In the first phase; the flux rates were changed from 3.5-15 L/m^2/hr and the differential hydraulic head was 1.5 m, average TSS, COD_t and CODs effluent concentrations 40 mg/l, 177 mg/l and 119 mg/l respectively. In the second phase the differential hydraulic head was changed to be 2.5 m, average TSS, COD_t and CODs effluent concentrations were 43.6 mg/l, 133.7 mg/l and 105.3 mg/l respectively. The potential removal mechanism for the suspended solids by fabric filters is straining or sieving by filter pores. The potential removal mechanism for dissolved organic matters is dynamic membrane layer formed on the fabric filters surface and was able to remove soluble organic matters with CODs average removal efficiencies of 21.25% and 18.9%inphase (1) andphase (2) respectively.

Keywords:Wastewater treatment; Decentralized wastewater treatment; Non-woven fabric filters; Cloth media filters.

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I. Introduction

The increasing sanitation services problems in Egyptian rural areas requires a huge efforts to be solved. The Egyptian rural areas are usually associated with the small available area for construction, dispersed population, limited fund for utilities, and limited human expertise for operation.Thus, the construction of a centralized WWTP may not be a feasible solution, and the decentralized WWTPs should be considered.[1]. The decentralized wastewater treatment approach was admitted in some rural areas in developing countries including Egypt [2]. Many decentralized treatment systems were tested and used in different countries such as the septic tank which ischaracterizedwithitssimplicityofconstruction,operationandthelowdesludgingfrequency [3]. Then; the Anaerobic baffled reactors (ABR) were developed following the removal theory of septic tanks, as ABR removal mechanisms are based on the physical treatment (settling) and the biological treatment (anaerobic digestion)[4]. Then the anaerobic filters were used as secondary treatment in household wastewater treatment systems. An anaerobic filter is an attached biofilm system that aims at removing non-settleable and dissolved solids. As septic tanks or anaerobic baffled reactors, anaerobic filters are based on the combination of a physical treatment (settling) and a biological treatment [5].

Then; the"Up-flow Septic Tank Baffled Reactor (USBR)" was tested in several places in Egypt. The system showed promising results in removing COD, BOD and TSS with removal efficiencies 84%, 81% and 89% respectively [6]. The ZECU system was developed as an upgrade to USBR system and showed a very good performance in treating the domestic wastewater of the Egyptian village (Zawyet El Karatsah) [7].Therefore, there is a raising demand to conduct further research to develop the small-scale wastewater treatment system to give better results with less occupied area and less materials cost.

Fabric filters was tested in lab scale to determine the efficiency of treating domestic wastewater. Various woven and non-woven fabric filters were tested on treating synthetic wastewater as a separation material on a bench scale experiment. The experiment indicated that the non-woven scrim polyester gives the best performance and has the lower cost than the other tested materials with removal efficiencies about 77% and 76% for the TSS and COD removal respectively [1].

In this investigation, the main objective was to enhance the performance of the ZECU decentralized WWTP with the replacement of sedimentation tank and sand filter with the fabric filters modules and to test the performance of the fabric filters in the treatment of the modified ZECU effluent. The investigation was performed with the following phases :(1)First phase that includes testing fabric filters on the effluent of biological filters with changing flux rate of fabric filters through six runs.(2) Second phase includes testing fabric filters on the effluent of biological filters with changing the hydraulic head above fabric filters. (3)Third phase includes testing fabric filters on the effluent of anaerobic phases with the best performing flux rate and hydraulic head obtained from the previous phase.

II. Experimental work

a. Experimental setup

The research experimental work was carried out at Zawyet Al Karatsah WWTP which is located in El-Fayoum governorate in Egypt. The influent wastewater to the pilot plant was continuously pumped from after the grit removal chamber of the main plant through submersible pump with daily discharge of $9m^3$.The pilot plant comprises of ZECU and the fabric filters tank. ZECU tank comprises of the following: (1) Anaerobic up-flow and down-flow units. (2) Cascade plates for aeration.(3) Biological filter.(4) Sedimentation tank.(5) Sand filter. Through this investigation, the ZECU was modified to reduce the treatment phases and replace them with the new installed fabric filters tank. In the first and second phases of this research; the sedimentation tank and sand filter were eliminated from the ZECU unit. In third phase; the cascade plates, biological filter, sedimentation tank and sand filter were eliminated and the wastewater was pumped to the fabric Filters directly after anaerobic treatment.

The final effluent wastewater from ZECU was drained to the collection tank made from fiber glass material and its function was only to hold the ZECU effluent wastewater and pump it to the fabric filters tank with the required flow rate through the installed dosing pump, the pumping flow rate of dosing pump can be adjusted by changing the number of rotations per minute (rpm) of thedosing pump motor according to the researchplan.

Also allow speed mixer was installed on the top of the collection tank to keep suspended solids in suspension and prevent them from settling in the collection tank in order to keep wastewaterwith the same characteristics to the effluent wastewater from ZECU. Figure (1) shows the pilot plant units arrangement.

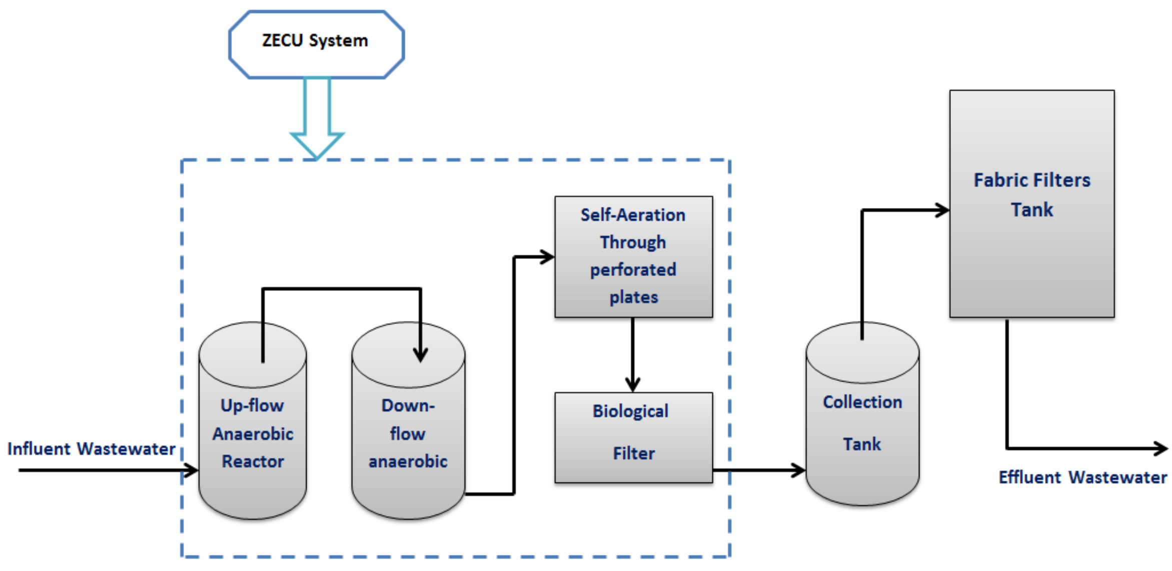

Figure 1 Schematic Diagram of treatment phases

i. Fabric filters tank

The fabric filters tank was designed to have a good arrangement of fabric filters, good flow distribution and maintaining the flexibility of changing the operating water heads and flux rates. Also the fabric filters tank was designed to allow the backwash of fabric filters with the required backwash frequency. The tank consists of four compartments each one containing a set of four fabric filter modules, and one another compartment for holding the final effluent treated wastewater and containing the submersible pump for backwash purpose. The tank was made from epoxy coated steel.

Each compartment of the fabric filters tank contains a fabric filters module having four fabric filters cartridges in each one. The fabric filters were made from non-woven scrim polyester with weight of 375 g/m^2 and rate of air permeability equal to 3.03 $L/m^2/sec$ and 2.57 mm thickness. The selected fabric filter material was chosen because of its low cost in comparison to the imported one sand the showed promising removal efficiencies for the TSS, BOD_5 and COD in the lab scale experiments on synthetic wastewater. Each fabric filter module hasa cylindrical shape with 15 cm diameter and 40 cm height with total filtration surface area of 1.00 m2. The large surface area of filter relative to the dimensions is due to give higher surface area with same dimensions to increase flux rate. The outer surface of the fabric filter tube was covered with perforated metal sheet. Figure (2) shows the fabric filters modules.

Figure 2 fabric filters module

b. Experimental protocol

The experimental work was executed on three phases of continuous operation. The first and second phases were executed with the same flow line, as the wastewater passed through the same treatment phases only in the third phase the treatment flow line was changed by the elimination of the biological filter and cascade plates from the experiment.

i. **First phase:** The purpose of the first phase was testing the performance of the fabric filters through changing the influent flow rate to the fabric filters in order to reach the optimum flux rate range for the fabric filters.

Through this phase there were six runs, each of them differs only in the fabric filters influent flow with constant differential hydraulic head 1.5 m.The following table (1) shows each run influent flow.

Table 1 First phase operational parameters

Run	Fabric filters influent flow (L/min)
1	1.00
2	1.50
3	2.50
4	4.00
5	9.50
6	13.50

ii. **Second phase:** In the second phase, the hydraulic head on fabric filters was changed to 2.5m to test its effect on fabric filters removal efficiency and on the percentage of passage. The influent flow rate was the optimum one with respect to complying with the Egyptian law 42 for the year 1982 from the first phase.

c. Sampling and measurements

Samples were collected from different locations of the pilot plant by an equipped car and taken to the American university in Egypt (AUC) environmental engineering laboratory where the samples measurements took place; Samples were taken twice a week in order to have a good monitoring of the system during the experiment period.

Samples were taken to test the fabric filters performance; as Sample (1) was taken from the influent of the fabric filters tank and sample (2) from the effluent of the fabric filters tank.

TSS, CODt and CODs were measured to test the fabric filters removal efficiency for suspended solids and organic matter.

III. Results and discussion

a. Efficiency of suspended solids removal

Suspended solids in wastewater mainly comprises of organic and inorganic solids, the total suspended solids is presented by TSS concentration. The suspended solids removal efficiency of fabric filters was evaluated through comparing the TSS of effluent wastewater to those in the influent wastewater. The potential removal mechanism of suspended is mainlystraining.

i. First phase

The following figure (3) shows the TSS concentration in the fabric filters influent and effluent wastewater for each run in this phase, also removal efficiency is shown in the same graph. Each point in the shown graph represents the average value of TSS concentration and removal efficiency of each run. The only changed parameter in each run is the fabric filters flux rate.

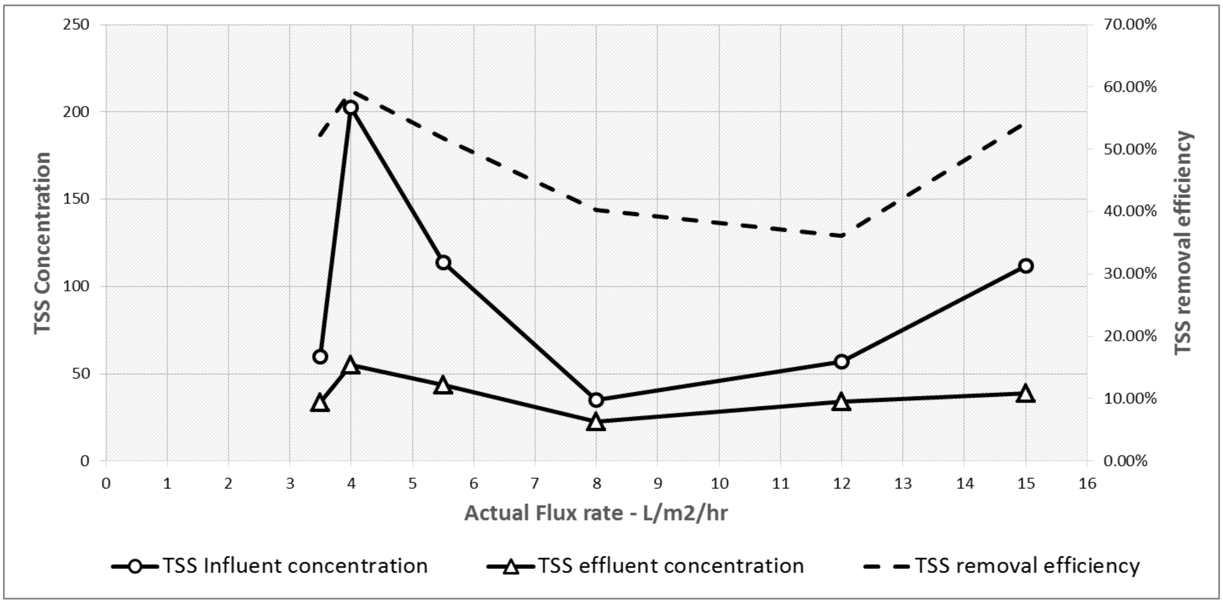

Figure 3 TSS concentrations and removal efficiencies in first phase

As shown in the previous figure, the average values in each run for fabric filters TSS concen- tration in the influent wastewater fluctuates from 35 to 202 mg/l with an average value of 97mg/l, and effluent wastewater varied from 33.5 to 55 mg/l with an average value of 40 mg/l, while the removal efficiencies ranged from 40% to 60% with average value of 49% during this phase. The TSS concentration in the effluent wastewater was not affected by the TSS concentration in the influent wastewater to fabric filters nor the flux rate of fabric filters, the reason of this phenomena is that the fabric filters remove the particles of pore size larger than the fabric filters pore size no matter the concentration of TSS in the influent wastewater. This means that the removal efficiency increases with the increase of influent wastewater TSS concentration. Also this means that all the tested flux rates are acceptable to operate on those fabric filters.

ii. Second phase

The following figure (4) shows the TSS concentration in the fabric filters influent and effluent wastewater in this phase, also removal efficiency is shown in the same graph. The only changed parameter in this phase is the fabric filters hydraulic head.

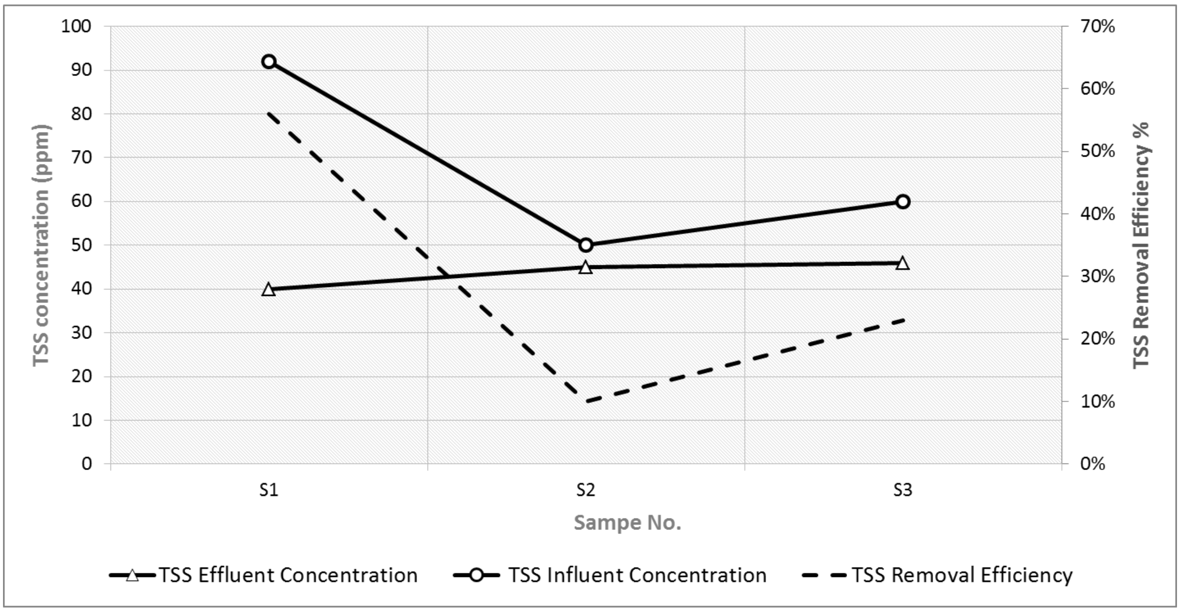

Figure 4 TSS concentrations and removal efficiencies in second phase

As shown in the previous figure, the average values for fabric filters TSS concentration inthe influent wastewater fluctuates from 52 to 90 mg/l with an average value of 67 mg/l, and effluent wastewater varied from 40 to 46 mg/l with an average value of 43.6 mg/l, while the removal efficiencies ranged from 10% to 56% with average value of 30% during this phase. The TSS concentration in the effluent wastewater was not affected by the changing the hydraulic head as the effluent wastewater TSS concentration remained below the governing Egyptian law limit.

3.2 Efficiency of organic matter removal

Organic matter mainly comprises of suspended and dissolved organics, the total organic matter is presented by BOD_5 and COD_t while dissolved organic matter is presented by COD_s. The organic matter removal efficiency of fabric filters was evaluated by comparing the BOD_5,COD_t

and CODs of effluent wastewater to those in the influent wastewater. The removal mechanism of suspended organic matter is the same as suspended solids while the removal of soluble organic matter proves the existence of bio-film on the fabric filters surface oxidizing the organic matter presents in influent wastewater.

3.2.1 First phase

The influent wastewater to fabric filters in this phase has a total organic matter concentration presented as COD_t concentration ranged from 141 to 467 mg/l with an average value of 265 mg/l, and soluble organic matter presented as COD_s ranged from 99 to 232 mg/l with an average value of 143mg/l.

The organic matter concentrations in effluent wastewater presented as COD_t concentration in effluent wastewater fluctuates from 107 to 333 mg/l with an average value of 177 mg/l, finally; COD_s concentration ranged from 62 to 231 mg/l with an average value of 119 mg/l in effluent wastewater.

The fabric filters calculated removal efficiency was ranged from 20% to 50% with an average value of 33.5% in COD_t and from 1% to 39% with an average value of 21.25% in COD_s. The following figures (5) and (6) shows the concentration of COD_t and COD_s respectively in influent and effluent wastewater to fabric filters showing removal efficiency of each parameter on the same graph, each point in the graph is represented in the average values of the run over its entire period.

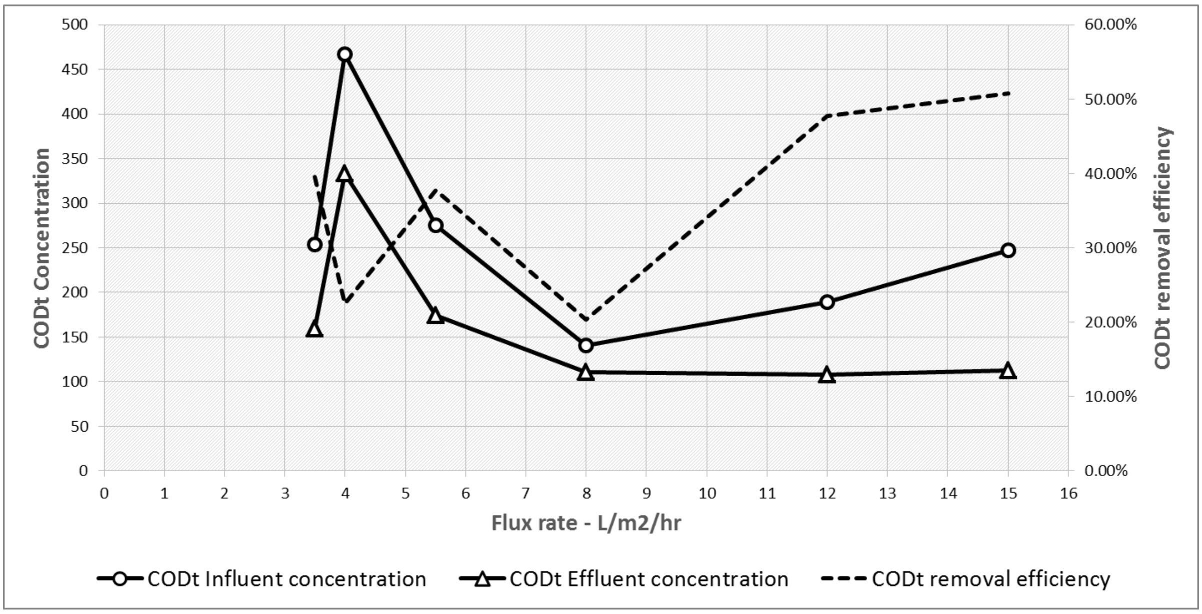

Figure 5 COD_t concentrations and removal efficiencies in first phase

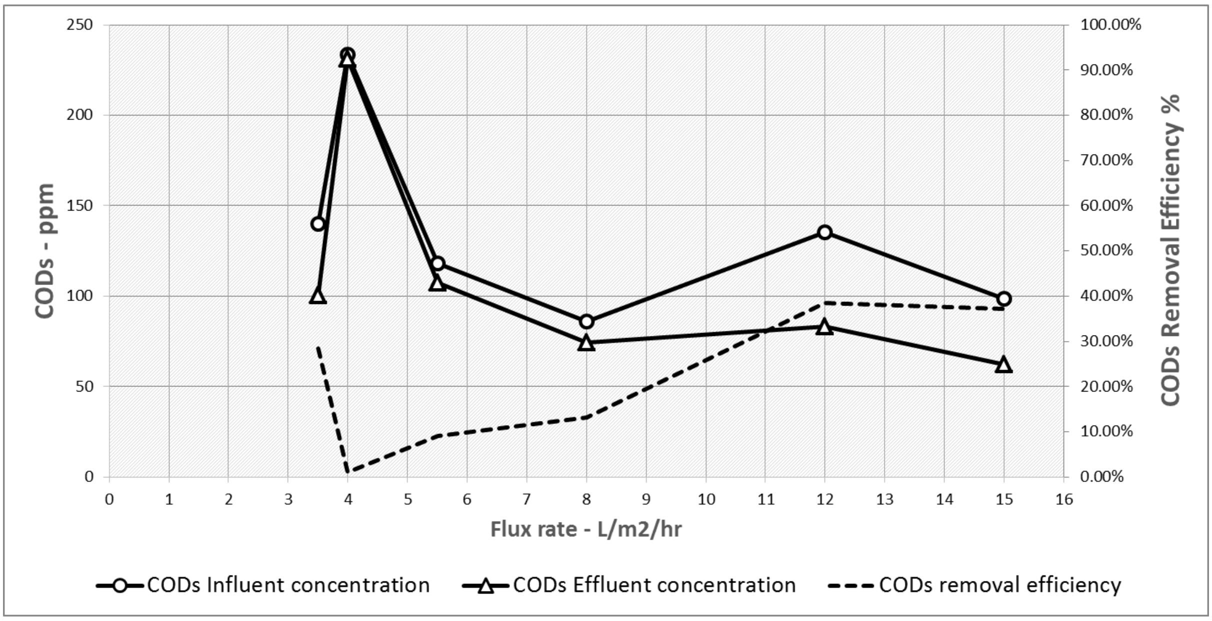

Figure 6 CODs concentrations and removal efficiencies in first phase

3.2.2 Second phase

The influent wastewater to fabric filters in this phase has a total organic matter concentration presented as COD_t with a fluctuation from 136 to 217 mg/l with an average value of 169 mg/l. The soluble organic matter in influent wastewater presented as COD_s ranged from 108 to 133mg/l with an average value of 118.7mg/l.

The organic matter concentrations in effluent wastewater presented as COD_t ranged from 124 to 145 mg/l with an average value of 133.7 mg/l, and COD_s concentration ranged from 103 to 108 mg/l with an average value of 105.3 mg/l in effluent wastewater.

The fabric filters calculated removal efficiency was ranged from 6% to 43% with an average value of 18.5% in COD_t, and from 6% to 28% with an average value of 18.9% in COD_s. The following figures (7) and (8) shows the concentration of COD_t and COD_s respectively in influent and effluent wastewater to fabric filters showing removal efficiency of each parameter on the same graph.

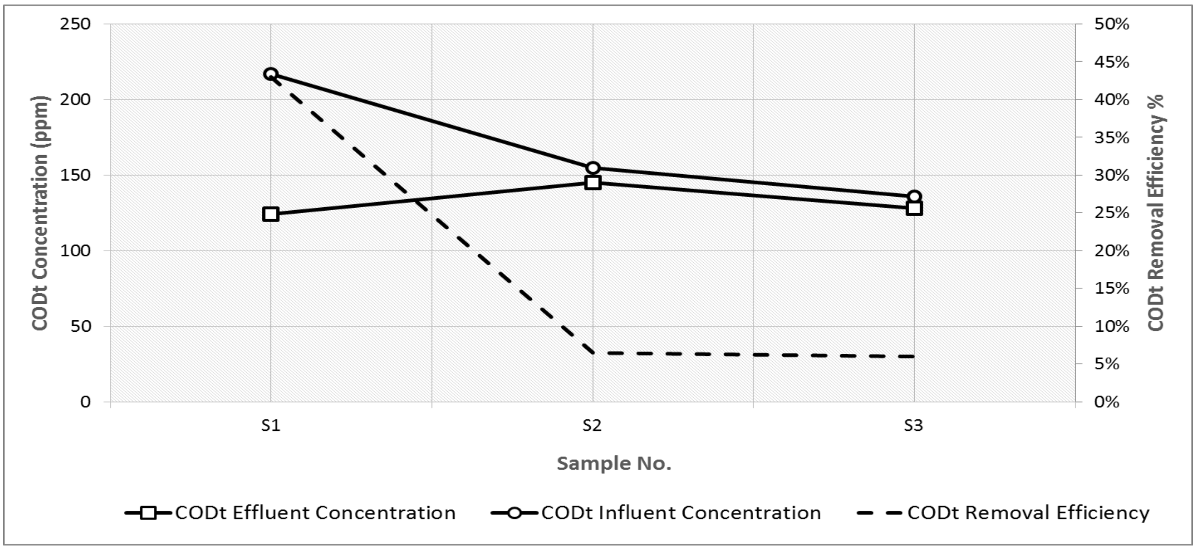

Figure 7 COD_t concentrations and removal efficiencies in second phase

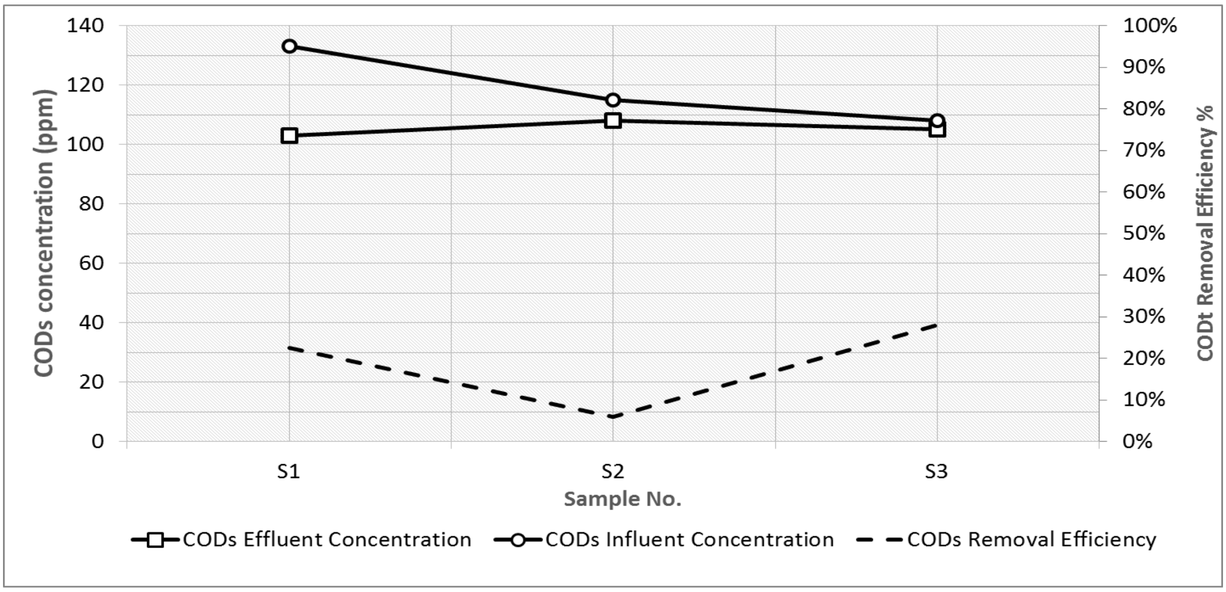

Figure 8 CODs concentrations and removal efficiencies in second phase

IV. Conclusion

1. Non-woven fabric filters were successful to remove TSS with the following effluent concentrations:
   - Average effluent concentration 40 mg/l with 1.5 meter hydraulic head and flux rates varying between (3.5 - 15 $L/m^2/hr$) from the biological filter effluent wastewater.
   - Average effluent concentration 43.6 mg/l with 2.5 meter hydraulic head and flux rate 12 L/m2/hr from the biological filter effluent wastewater.
2. Effluent wastewater TSS concentration values complied with the governing Egyptian Law 48 for the Year 1982 (50mg/l).
3. Non-woven fabric filters were successful to remove COD_t with the following effluent concentrations:
   - Average effluent concentration 177 mg/l with 1 meter hydraulic head and flux rates varying between (3.5 - 15 $L/m^2/hr$) from the biological filter effluent wastewater.
   - Average effluent concentration 133.7 mg/l with 2.5 meter hydraulic head and flux rate 12 L/m2/hr from the biological filter effluent wastewater.
4. COD_t removal efficiency increases proportionally with the increase of COD_t influent concentration as the main removal mechanism is sieving the suspended organic matters.
5. Non-woven fabric filters were successful to remove $COD_s$with the following effluent concentrations:
   - Average effluent concentration 119 mg/l with 1 meter hydraulic head and flux rates varying between (3.5 - 15 $L/m^2/hr$) from the biological filter effluent wastewater.
   - Average effluent concentration 105.3 ppm with 2.5 meter hydraulic head and flux rate 12 L/m2/hr from the biological filter effluent wastewater.

6. The potential removal mechanism of dissolved organic matters is the dynamic membrane layer formed on the surface of fabric filters, as the average removal efficiency of $COD_s$was 21.25%and 18.9% in phase (1) and phase (2)respectively.
7. Effluent wastewater COD_t concentration values did not comply with the governing Egyptian Law 48 for the Year 1982 (80mg/l).

V. Acknowledgement

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