Fabric filters integrated with ZECU system for sewage treatment in small communities

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Abstract
A laboratory scale system composed of a fabric filter was tested to investigate its ability for wastewater treatment in small communities. Eight types of non-woven fabric materials were tested separately for the treatment of synthetic sewage using gravity driven pressure. The performance of each of the eight fabrics were evaluated based on the removal of TSS and COD from the sewage. The TSS and COD concentrations in the effluents were compared with the limits provided by the Egyptian Law 48 for the Year 1982 regarding the disposal of wastewater into agricultural drains.
The synthetic wastewater (COD 210 mg/L and TSS 160 mg/L) was fed to the reactor under the following conditions; flux rates 36, 67 and 88 L/h/m^2 and water heads of 150, 175 and 200 cm. One type of the successful fabric material from the laboratory scale system was tested at a pilot scale experiment in Zawyet El Karatsah wastewater treatment plant in El-Fayyoum Governorate, Egypt. The pilot-scale experiment was operated using real sewage.

Keywords
Decentralized wastewater treatment systems, Fabric filtration, Non-woven fabric filters, Cloth media

INTRODUCTION

Providing reliable and affordable wastewater treatment in rural areas is a challenge in many parts of the world, particularly in developing countries. The decentralized approach for wastewater treatment which employs a combination of onsite and/or cluster systems is gaining more attention.
In the past decade, substantial efforts and resources have been directed by the Government of Egypt to improving access, reliability and quality of water services both in urban and rural areas. Approximately 85% of rural areas still do not have public sanitation networks. Therefore, new configurations employing the best practices of sanitation technology for rural areas are needed. In an attempt to tackle the sanitation problems in Egypt's rural areas, many researches took place to identify a low cost new technology to solve rural sanitation problems (El-Gendy, et. al, 2012; Sabry, et. al, 2011; and Sabry T. 2010).

This research paper focuses on improving the treated water quality by improving existing technology and optimizing system performance. Using low-cost fabrics in the wastewater filtration have been tested recently with insignificant research works (Chang, et. al, 2006; G.T. Seo, et. al, 2006; Perlmutter, 2010; and Tiranuntakul, et. al, 2011). Fabric filters in general are succeed to improve the quality of wastewater. One of the important factor in improving the quality of the water is in choosing suitable fabric material hence, scientists are focusing in discovering the right fabric (density, woven or non-woven, bore size, weight, etc.) to be used with the wastewater.

The current research aims at studying the performance of different low-cost fabric materials, as an integrated unit within a low-cost treatment system, in the removal of TSS and COD from wastewater.

The research aims at testing the performance of the selected fabric material at the pilot scale in Zawyet El Karatsah wastewater treatment plant in El-Fayyoum Governorate Egypt, using real sewage.

MATERIAL AND METHODS

The current research study was carried out in two consecutive parts, Part I and Part II. In Part I, a laboratory scale setup was tested using a synthetic sewage. In Part II, a pilot scale setup was designed based on the results obtained in Part I. In addition, the pilot scale setup was tested using real sewage.

Part I - Laboratory Scale Experiment

In this part of the research laboratory setup was constructed to investigate the performance of eight different fabrics in the removal of TSS and COD from synthetic sewage. The setup was constructed from a cylindrical PVC column with a diameter of 40 cm and a height of 200 cm as illustrated in Figure 1. At the bottom of the column a fabric filter was installed. The fabric filter is made of a cylindrical frame that has the fabric materials installed at the outer perimeter of the frame.

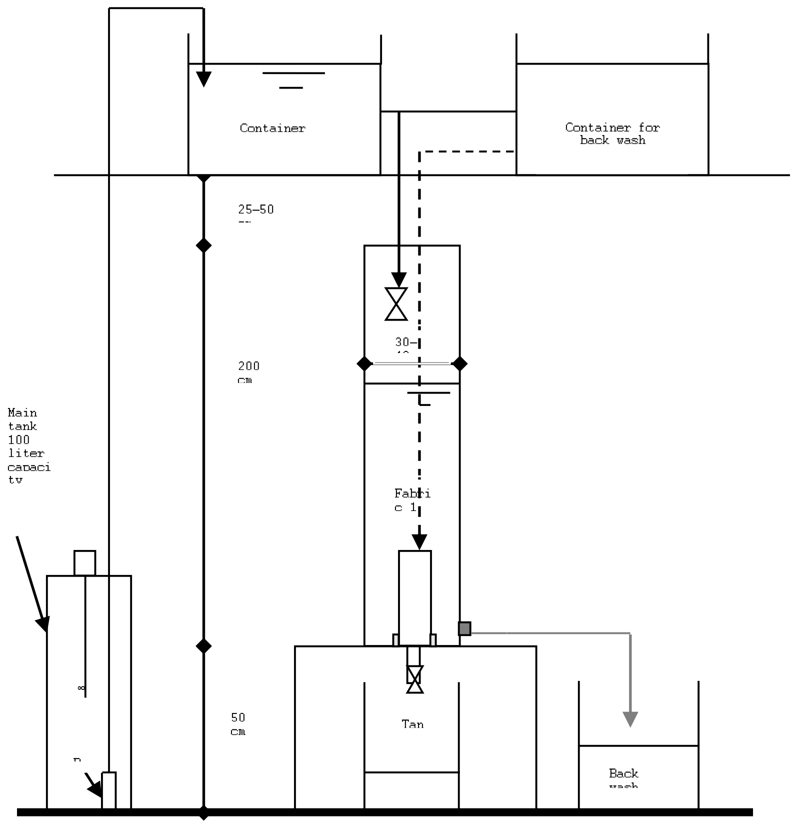


Figure 1 – Schematic Diagram of the Laboratory Scale Setup

Eight types of fabrics (Fabric 1 to 8) with characteristics illustrated in Table 1 were tested in Part I of the current research. The fabrics used in the experiment are either non-woven fabrics or woven fabrics. Non-woven fabrics are known to have good filtration performance in wastewater treatment (Shipard, 2006; V K Kothari, 2007). All fabrics used in the laboratory scale experiment are made from recycled polyester of previously used items such as PET bottles, polyester cloths, etc.

Polyester is a type of polymer that contains ester functional group and is most commonly referred to as Polyethylene Terepthalate (PET). This material is used for making plastic bottle to store drinks in it. Many drink bottles are recycled by being reheated and turned into polyester fibers. The principle ingredient used in the manufacture of polyester is ethylene, which is derived from petroleum. In this process, ethylene is the polymer, the chemical building block of polyester, and the chemical process that produces the finished polyester is polymerization.

The experiments were run using synthetic sewage to simulate different concentration of TSS and COD as if this system is integrated with additional preceding treatments. The different fabrics were tested at different water heads; 1.50, 1.75, and 2.00 m, and various flux rates; 36, 67 and 88 L/h/m^2.

Table 1 – Characteristics of Different Fabrics

Fabric	Type of Fabric	Weight (g/m^2)	Thickness (mm)	Cost (US$/m^2)
Fabric 1	Non woven-woven scrim supported fabric	375	2.57	2.36
Fabric 2	Non woven fabric coated with teflon membrane	542	1.77	6.76
Fabric 3	Non woven polyester low cost	460	1.08	0.68
Fabric 4	Two layers non woven-woven scrim polyester local manufacturing	254	1.69	1.35
Fabric 5	Woven Twill light from high density fibers	298	0.75	2.82
Fabric 6	Two layers of the non woven polyester low cost (Fabric 3)	920	2.16	1.35
Fabric 7	Non woven Fabric (without calendering)	160	0.8	2.25
Fabric 8	Non woven Fabric local recycled plastic	1116	7.02	2.25

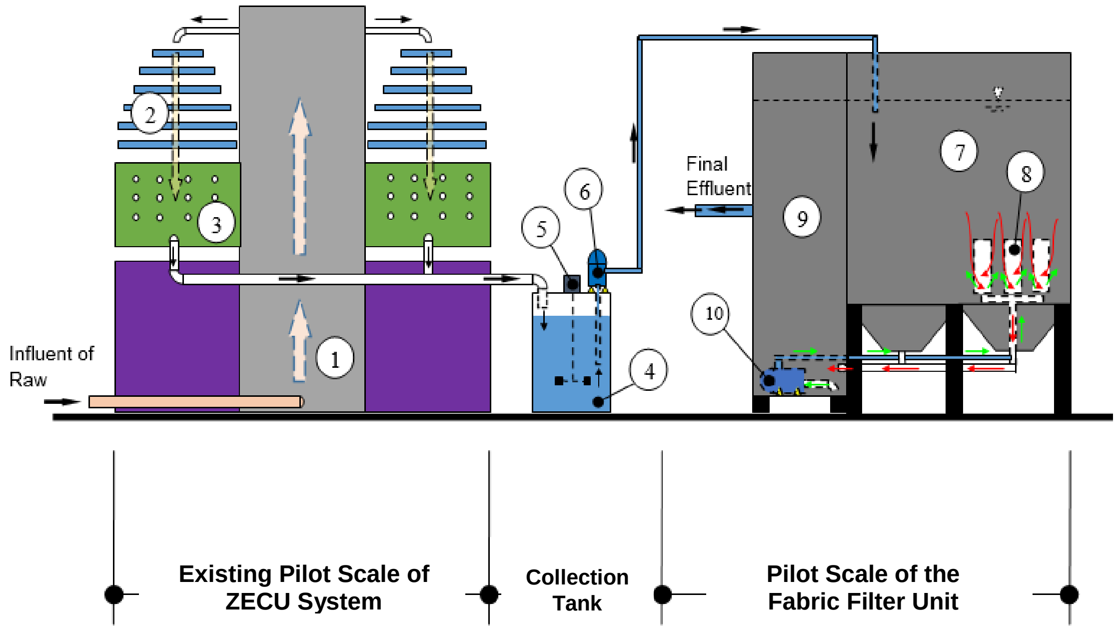
Backwashing of the fabrics using water was carried out after 8 hours of filter operation, at the end of each experiment. The duration of the backwash lasted normally 10 minutes. Backwash was carried out through passing water from a head of 3 m. Chemical wash was carried out using water mixed with Sodium Hypochlorite (NaOCl). The chemical washing lasted for 10 minutes.

Part II - Pilot Scale Experiment

In the pilot scale experiment, a fabric filter system was constructed in Zawyat El-Karatsah wastewater treatment plant in El-Fayyoum Governorate, Egypt. The treatment plant receives sewage from two villages in El-Fayyoum; Manshiat Abdullah and Zawyat El-Karatsah. The treatment plant has an existing pilot-scale setup of ZECU system from a previous research work.

ZECU as a Wastewater Treatment System

Zero Energy Compact Unit (ZECU) is a wastewater treatment unit that composed of different integrated treatment stages. The unit consists of an anaerobic biological treatment stage followed by an aerobic treatment stage; all are gathered in a compact shape to save footprint and for easy installation as shown in Figure 2. In the anaerobic stage, degradable organic matter is utilized by anaerobic bacteria and transformed into simpler materials and biogas. As the water leaves the anaerobic stage, it will contain no oxygen and still contains some other pollutants that need further treatment. Therefore, there is a need for further treatment of the effluent from the anaerobic stage. The aerobic treatment stage which followed the anaerobic stage consists of a passive aeration, an aerobic biological filter and a sedimentation tank. The passive aeration provides the wastewater with dissolved oxygen which improves the performance of the aerobic biological filter. The sludge collected at the bottom of the sedimentation tank can be recycled to the influent of the system at the anaerobic stage.



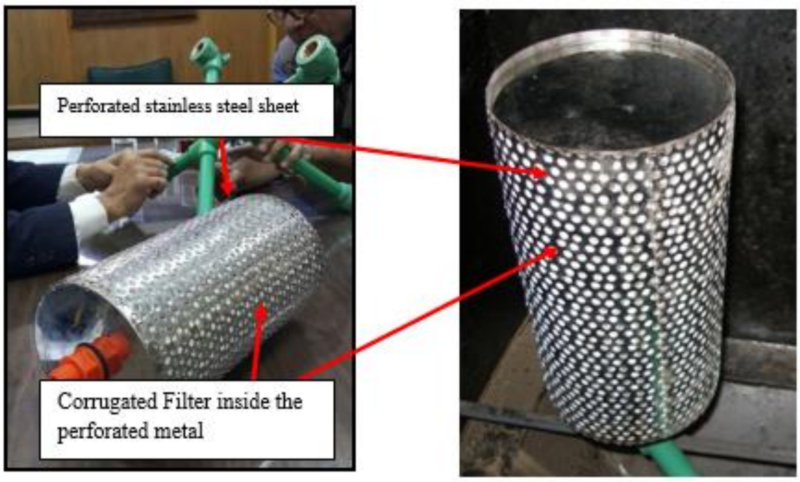
1	Anaerobic Biological Treatment Units of the Existing System
2	Passive Aeration Units of the Existing System
3	Aerobic Biological Treatment Units of the Existing System
4	A Fiber glass tank to collect the effluent of the existing treatment units (New installation)
5	A mixer for keeping the collected effluent in suspension and prevent settling of TSS in the collection tank (New installation)
6	Dosing pump to supply the Fabric Filter System with partially treated wastewater (New installation)
7	Fabric Filters Compartments (4 identical compartments installed next to each other) (New installation)
8	A cartridge of the Fabric Filter. Each compartment of Fabric Filters contains 4 cartridges installed as one module
9	Compartment of filtered water (contact and back wash tank)
10	Backwashing submersible pump installed at the bottom of the compartment of filtered water
	Direction of water filtration through the fabric filter cartridge
	Direction of backwashing flow through the fabric filter cartridge

Figure 2 - Schematic Diagram of the Existing and Fabric Filter (New) Systems installed in Zawyat El-Karatsah WWTP

The existing pilot-scale of ZECU is operated using real sewage at a maximum capacity of 9 m^3/d. As shown in Figure 2, the fabric filter unit was constructed to integrate with ZECU by replacing the sedimentation tank and roughing filter in ZECU with the fabric filter. The raw sewage is pumped to the existing system using a submersible pump placed after the screens and grit removal of Zawyat El-Karatsah waste water treatment plant. The effluent of the aerobic biological filter in ZECU is discharged under gravity through a hose to a collection tank. Then, pumps installed in the collection tank deliver the wastewater into the fabric filter unit.

Fabric Filter Unit

The fabric filter unit in Part II was designed using the results obtained from Part I. Also, the pilot scale unit was operated at the optimum flux rate obtained from Part I. The fabric filter unit was divided into four compartments which are connected to each other and a compartment to collect filtered water. At the bottom of each fabric filter compartment, a cluster/module of fabric filter cartridges is installed as shown in Figures 2 and 3. In order to increase the filtration performance, four fabric filter cartridges were connected to form a module of filters as illustrated in Figure 3. Each cartridge of the filtration module composed of a corrugated fabric surface inside a perforated metal frame as shown in Figure 3. The corrugated fabric design is to provide high surface area (1 m^2) of the fabric and as a result high flux rate using a small size of the cartridge.



(a) A cartridge of the fabric filter

(b) A module/cluster of the fabric filter cartridges

(c) A module of cartridges installed at the bottom of a compartment in the fabric filter unit

Figure 3 – cartridge and module/cluster of a fabric filter

Fabric 1 (Table 1) was used in each cartridge of the fabric filter modules. The fabric filter unit was operated at a flux rate of 11.6 L/h/m^2. The unit was operated at a discharge of 3.1 L/min. The fabric filters were operated with a differential head of 1 m between the water surface in the fabric compartments (#7 in Figure 2) and filtered water compartment (#9 in Figure 2).

The fabric filter unit has a backwash system which includes a submersible pump placed in the filtered water compartment as shown in Figure 2 and piping system with controls. The pump is used for pumping filtered water in the reverse direction of filtration for backwashing the fabric in the cartridges of each compartment. Each compartment was washed separately than other compartments. The washing frequency of each compartment was every 8 hours with a rate of washing equal to five times the flux rate. The washing time was for 2 minutes.

Sample collection and analysis

Water samples were collected twice weekly from the influent and effluent of the fabric filter unit. The collected samples were analysed for total suspended solids (TSS) and chemical oxygen demand (COD). All sample collection and analysis were carried out according to the Standard Methods for Water and Wastewater Analysis (APHA et al., 1992).

RESULTS AND DISCUSSIONS

Results of Part I - Laboratory Scale Experiment

In Part I of this study, out of the tested eight fabrics only four were very promising. The very promising fabrics include Fabrics 1 to 4 (Table 1). However, Fabrics 5 to 8 did not perform well in the removal of TSS and COD from synthetic sewage. Therefore, they were excluded from any further discussion.

Figure 4 shows a typical graph for the change in TSS concentration with time in the effluent of the promising fabrics (Fabrics 1 to 4) used in the laboratory scale experiment. The figure also shows the allowable limit of the TSS for the disposal of the treated effluent into agricultural drains according to the Egyptian Law 48 for the year 1982. Figure 4 shows the results obtained at certain operating conditions of the laboratory scale setup (Initial flux rate of 36 L/h/m^2 and a constant water head on the fabric of 175 cm). As shown in the figure, Fabrics 1 to 4 were able to remove TSS from the influent of the fabric filter unit and were able to provide effluent concentrations comparable to the limits of Law 48 (TSS concentration of 50 mg/L). As shown in Figure 4 and as obtained from the different other operating conditions, Fabric 3 has the poorest performance, while Fabric 2 has the best performance among the four promising fabrics.

Figure 5 shows a typical graph for the change in COD concentration with time in the effluent of the promising fabrics (Fabrics 1 to 4) used in the laboratory scale experiment. The figure also shows allowable limit of COD for the disposal of the treated effluent into agricultural drains based on Law 48 for the year 1982. As shown in the figure, the general performance of the fabrics in the removal of COD were poor compared to their performance in the removal of TSS. This could be due to presence of COD in suspended and soluble forms. The removal of TSS as shown in Figure 4 can contribute to the removal of part of the suspended fraction of the COD and as a result contribute towards the COD removal as shown in Figure 5. Fabric 2 were able to provide the highest efficiency in the removal of COD from the influent wastewater and were able to provide effluent concentrations comparable to the limits of Law 48 (COD concentration of 80 mg/L). This could be due to the Teflon membrane coating on the non-woven fabric.

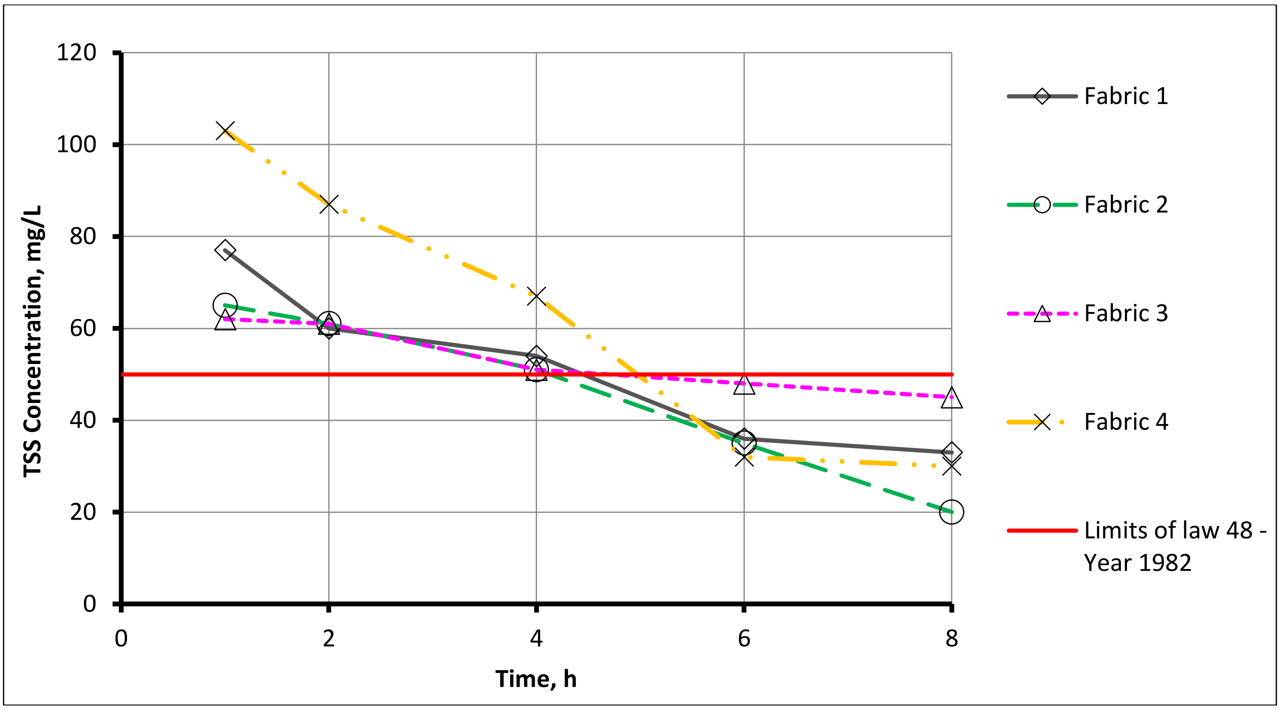


Figure 4 - TSS removal along the time of the experiment (Initial TSS concentration 160 mg/L, Initial flux rate of 36 L/h/m^2 and a constant water head on the fabric of 1.75 m)

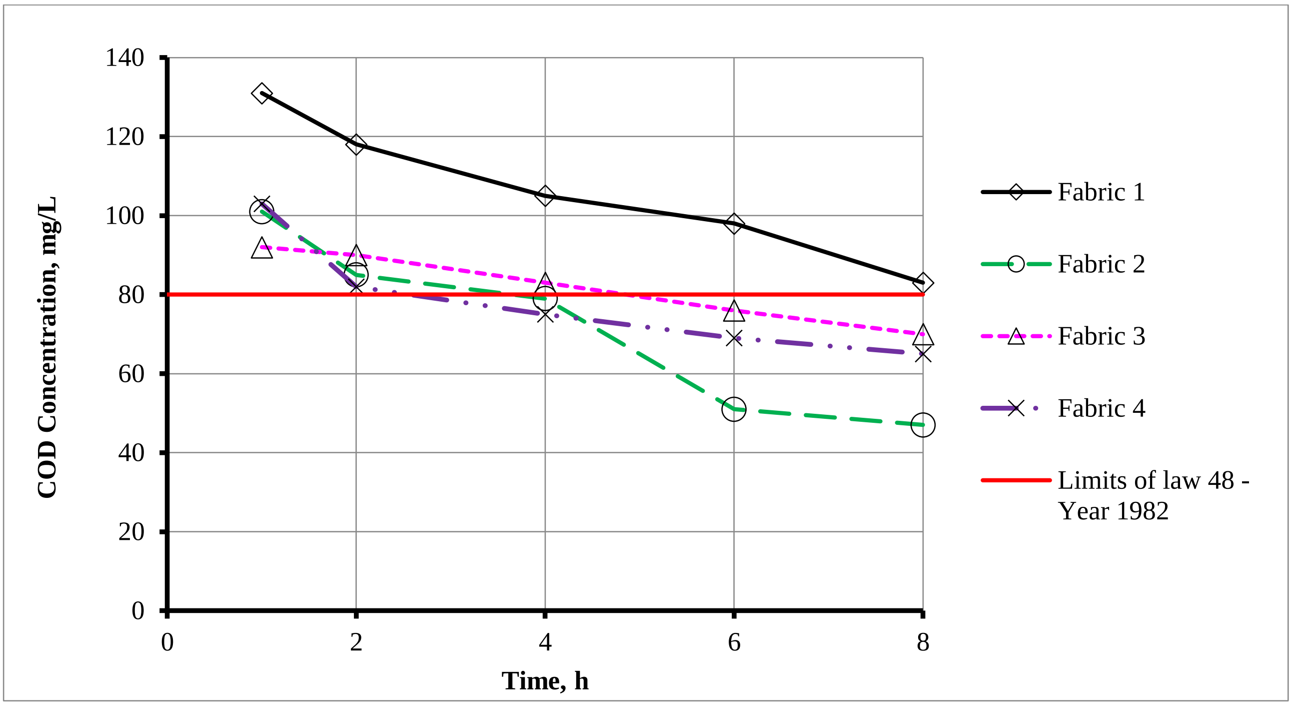


Figure 5 - COD removal along the time of the experiment (Initial COD concentration 220 mg/L, Initial flux rate of 36 L/h/m^2 and a constant water head on the fabric of 1.75 m)

The results of the laboratory scale experiment indicated that the fabric of the highest performance is Fabric 2, Non-woven fabric coated with Teflon membrane, with a weight of 542 g/m^2 and a thickness of 1.77 mm. In addition, the recommended operating conditions that provide the highest performance of all promising fabrics are at a flux rate of 36 L/h/m^2 and a water head of 1.5 to 1.75 m. The results also shown that as flux rates increased the efficiency of the fabrics in the removal of TSS and COD decreased.

Results of Part II - Pilot Scale Experiment

From the results of Part I, Fabrics 1 to 4 were promising in the treatment of sewage if integrated with ZECU system. Fabric 2 proved to be the best fabric. However, as indicated in Table 1, Fabric 2 is the most expensive fabric. Also, Fabric 3 were the poorest among the most promising fabrics. This leaves Fabrics 1 and 4 as the most suitable fabrics to be used in the pilot scale experiment (Part II of the study). Fabric 1 is more available in the market and has easier workability. Since, fabrics that are easy to fold is needed to create corrugated fabrics in the cartridges of fabric filters that has high surface area. Therefore, Fabric 1 was selected for use in cartridges of the pilot scale setup.

Figure 6 shows a typical graph of the change in TSS concentration with time for the pilot scale experiment. Figure 6 shows also the TSS removal efficiency for the fabric filter unit. From Figure 6, it can be seen that the fabric filter unit was able to remove TSS with an average efficiency of 43%. The fabric filter unit were able to remove 32% of the total mass of TSS removed from the raw sewage through the integration of ZECU and the fabric filter unit.

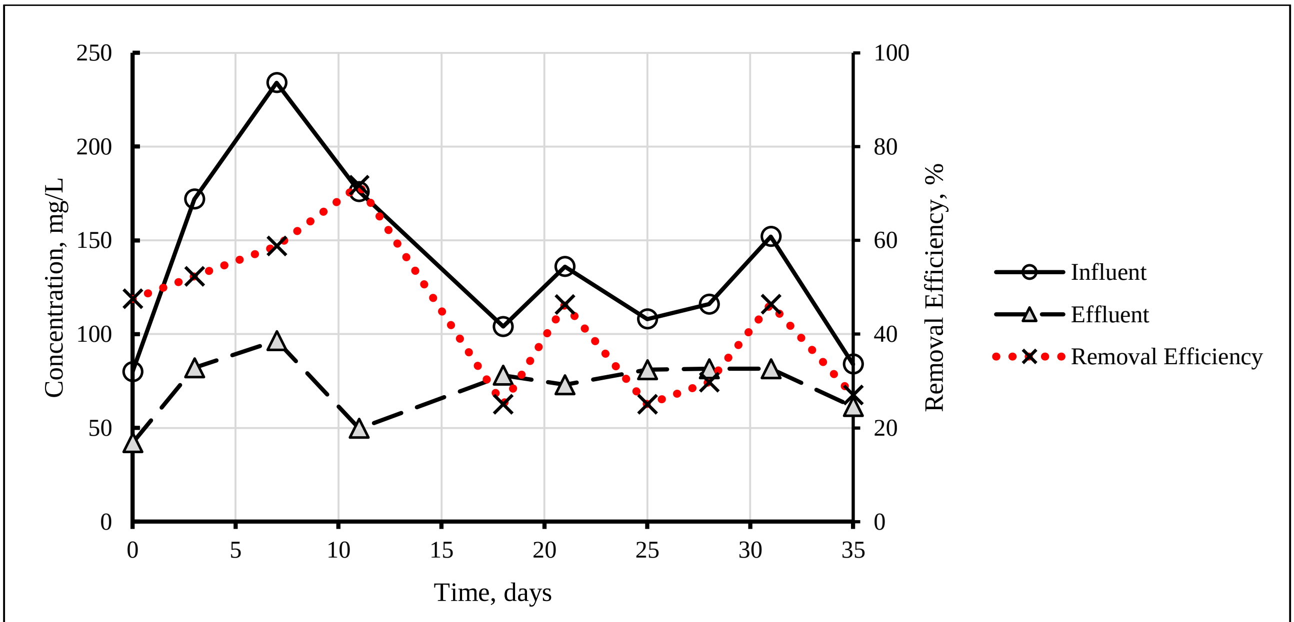


Figure 6 TSS removal with time of the pilot scale experiment

Figure 7 shows a typical graph of the change in COD concentration with time for the pilot scale experiment. Figure 7 shows also the COD removal efficiency for the fabric filter unit. From Figure 7, it can be seen that the fabric filter unit was able to remove COD with an average efficiency of 13.4%. The fabric filter unit were able to contribute an average removal of 12.6% from the total mass of COD removed from the raw sewage using integration of ZECU and the fabric filter unit.

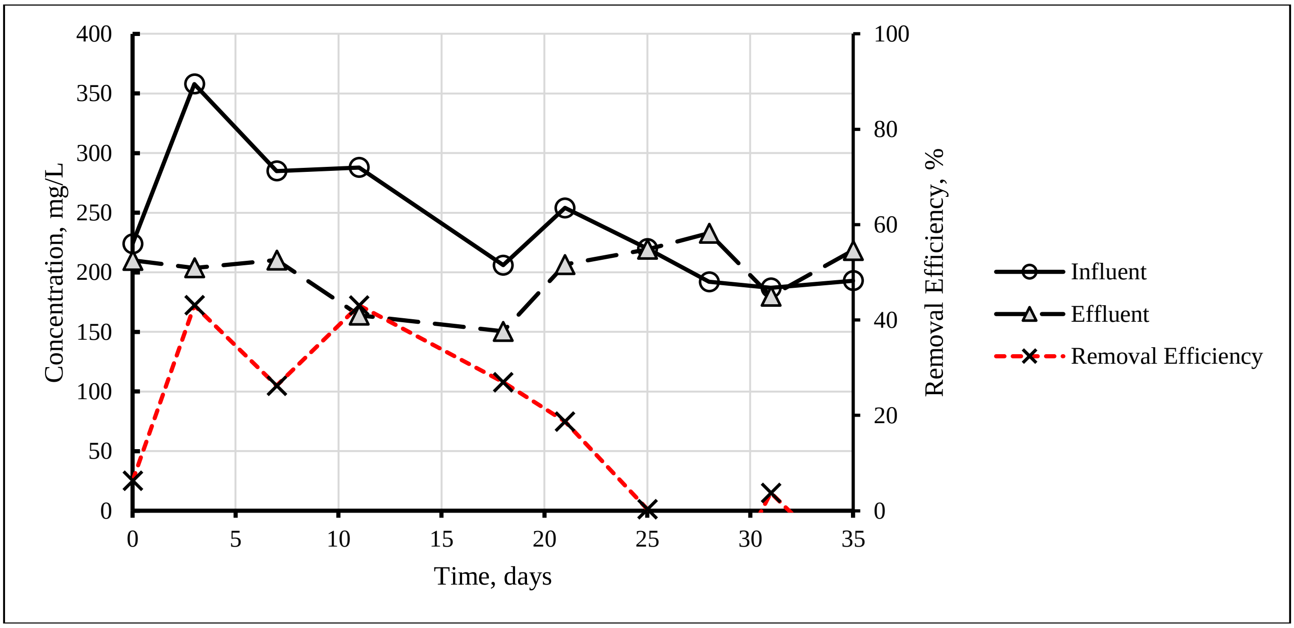


Figure 7 – COD-total removal with time in the pilot scale experiment

The fabric filter unit were unable to efficiently remove COD-soluble (no removal) or BOD (14.9%). However, it can slightly remove COD-total. This indicate that the fractions of BOD or COD-total that were removed by the fabric were due to the removal of suspended BOD and COD through the removed TSS.

CONCLUSIONS

1- Fabric materials were found to be useful in water filtration therefore they can be used in wastewater treatment.

2- Fabric filtration using nonwoven fabrics was found to be an effective tool for waste water treatment in small communities.

3- The non-woven fabric coated with Teflon membrane (Fabric 2) having a specific weight of 542 g/m^2 and thickness of 1.77 mm was found to be the best fabric in terms of performance in the removal of various parameters under the following operating conditions; Flux rate 36 L/h/m^2 and a water head of 1.5-1.75 m. However, this fabric has the highest price. Therefore, the non woven-woven scrim supported fabric (Fabric 1: having a specific weight of 375 g/m2 and thickness of 2.57 mm) and a locally manufactured nonwoven–woven scrim polyester fabric material (Fabric 4: having a weight 254 g/m^2 and a thickness of 1.76 mm) are recommended for use as filtration materials in fabric filter cartridges. This is due to their performance in removal of TSS, workability and availability.

4- It is concluded that the complete system (ZECU integrated with the fabric filter unit) and which was installed in Zawyet El Karatsah wastewater treatment plant in EL Fayyoum Governorate (Egypt) succeeded to efficiently remove TSS. The average removal efficiency of TSS using the fabric filter unit were found to be 43%.

5- The fabric filter unit were unable to efficiently remove COD and BOD because the major fractions of these parameters were dissolved in wastewater.

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