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Reuse of greywater

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ABSTRACT

Greywater is the wastewater resulted in houses through the use of water for laundry and bathroom. This research aims to treat and reuse greywater for agriculture, toilet flushing, and street washing. The treatment system consists of collection tank followed by sedimentation unit and three consecutive filters consisting of different materials such as (gravel, plastic balls, crushed stones, and gravel sand). A dose of chlorine and alum were added to the best sample and tested. (pH, BOD, COD,DO, total suspended solids, and alkalinity) were measured. Samples were tested at three different rates. Results have shown that sand and gravel is the best filter media among the used materials, the best flow rate was 0.0226 l/sec.

KEYWORDS: Greywater Treatment, Recycling, Alum, Chlorine Dose.

INTRODUCTION

The increase of population and the successive growing demand for potable water creates a motivating force for domestic water reuse.Water can be classified as fresh water, salt water, greywater and black water. Greywater is defined as all wastewater generated from domestic and commercial buildings, without that produced from toilets and urinals. Greywater may include wastewater from bathroom sinks, baths, and showers (light grey), also include waste from laundry, dishwashers and kitchen sinks (dark grey). This water is not polluted as toilet water (Black water) and can be easily treated onsite for reuse in non-potable uses such as toilet flushing and garden irrigation. Abd Alaziz and Al-Saqer [1], technologies used for greywater treatment are classified based on treatment principle, and can be divided into physical, chemical, and biological systems, or a combination of these [12,6,4]. Most of these technologies are preceded by three different treatment steps: pre-treatment, main treatment, and post-treatment, whereas, the disinfection step as post-treatment is used to meet the microbiological requirements. Lambe [9], stated that Greywater treatment process at the household level mainly involves screening (grease and silt removal), soap froth removal, equalization, and filtration. Primary treatment (Screening, Equalization tank)-Secondary treatment (Gravel filter, Sand filter). Olanrewaju *et al*. [13], also stated that simple methods used for greywater reuse are usually two-stage systems based on a gravel filtration or sedimentation stage to remove the larger solids followed by disinfection. The gravel filter usually comprises of a metal strainer and disinfection is normally achieved using either chlorine or bromine. The reuse of greywater can decrease the usage of potable water by up to 50%. Studies have estimated that the usable domestic greywater resource could amount to 35% of the total domestic demand .In the USA; several states have developed legislation to allow greywater reuse in different circumstances. California was the first state to study and permit the reuse of greywater. In Arizona, greywater is permitted for use in household garden irrigation [11]. Studies were carried out In Australia by Jeppesen and Solley [8] for greywater reuse, and showed that greywater saving could be made from the reuse of greywater provided adequate safeguards were followed. In the UK, the Environment Agency, CIRIA has published studies on greywater treatment and reuse for toilet flushing in these studies, a number of pilot plants, where greywater was captured and treated for use in toilet flushing have been described. Filtration and disinfection were employed to raise the quality of water to the desired standards [5]. In Tokyo, Japan, the greywater recycling, and reuse are binding with buildings has an area of 30,000 square meters or high rise buildings with a reuse of 100 cubic meters per day as reported by Hanson Pilot studies have also been carried out by the Islamic Network for Water Resource Demand Management in Palestine and Lebanon, although greywater reuse in these countries is not thought to be widespread [7]. Shobha *et al*. [15], researches aimed to treat and reuse greywater for gardening, toilet flushing, and street washing. The treatment system consists of the natural process involving equalization cum sedimentation, filter bed consisting of sand, aggregates and marbles and collection tank. Physico-chemical parameters were analyzed; results have shown that filtration increases DO concentration and other parameters decrease in greywater so as to make it usable. Sara *et al*. [14], proposes a system that collects greywater from residential buildings and recycles it for toilet flushing in both residential and office buildings.

The main objectives of this work were to reduce usage of water and assess greywater reuse for the different purposes like toilet flushing, street washing, and gardening.

MATERIAL AND METHODS

The main objectives of this study were to evaluate the feasibility of treatment and reuse of the greywater in irrigation, toilet flushing, and street washing. The greywater samples were collected from bathrooms of office building station of El-Hwamdia wastewater treatment plant which located at El-Giza. All samples were collected from basins and bath tub assembly in a tank equipped with valves to control the flow of the greywater. To model the compact greywater treatment plant, a pilot plant used consisted of four compartments fiber glass tank, the dimensions of each compartment are 40 cm width, 20 cm length, and 50 cm height. The first compartment for sedimentation, the second compartment acting as roughing filter using alternative roughing media as (gravel, plastic balls, crushed stone). The third compartment is sand filter; the fourth compartment is used as a storage tank. Each compartment connected to the adjacent compartment by a pipe with a valve placed at different heights as follows: the valve between the sedimentation basin and the roughing filter at a height of 10 cm, and the second valve connecting the roughing filter with the sand filter at height 7.5 cm, the third valve connecting the sand filter with the storage at a height of 5 cm. The storage basin equipped with a valve at a height of 2.5 cm from the bottom of the pilot plant. Samples were collected after each tank. A schematic diagram and a photograph of the pilot plant are shown in Figure (1).

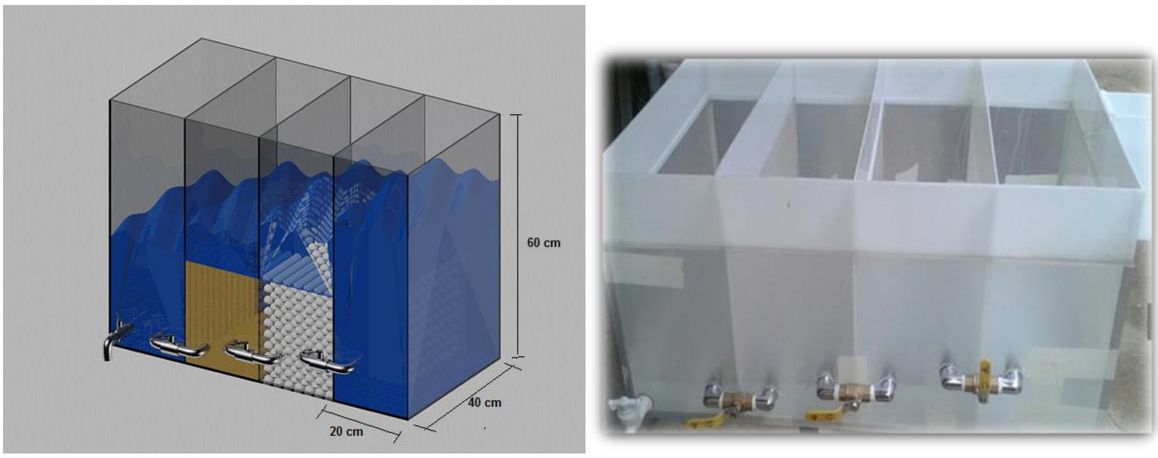

Fig. 1: A schematic diagram and photograph of the pilot plant

The experimental program conducting through nine runs were on three stages, the first three runs were conducted to determine the best roughing filter media (gravel, plastic balls, and crushed stone), these experiments were operated with flow rate 0.082 l/s. After achieving the best roughing filter media, the followed three runs conducted through three different flow rates were 0.06 l/sec, 0.042 l/sec, and 0.0226 l/sec to determine the optimum flow rate which gives the maximum removal efficiency. The best roughing filter media and the optimum flow rate were used in the last three runs of the experiments. In these experiments, chlorine, alum, and chlorine and alum were added separately.To evaluate the compact greywater treatment plant efficiency several parameters; BOD, COD, TSS, DO, pH, and total bacterial count were measured. These analyses were carried out at El-Hwamdia wastewater treatment plant's laboratory according to APHA [3].

RESULTS AND DISCUSSION

The physical and chemical characteristics (biological oxygen demand, chemical oxygen demand, total suspended solids, total bacterial count, dissolved oxygen) of the greywater before treatment were as the following pH (7.39), COD (178 mg/l), BOD (127 mg/l), TSS (156 mg/l), and total bacterial count (1800 MPN-Index/100 ml).

3.1. Stage one: determining the best roughing filter media:

The results of the experiments were shown on the following charts. Figure (2) shows that the optimum removal efficiency of TSS is 48 % at gravel media and 37.2 % at plastic balls media while the removal efficiency of the crushed stone media was 42.3 %. It was showing that the best removal efficiency was in the case of gravel media.

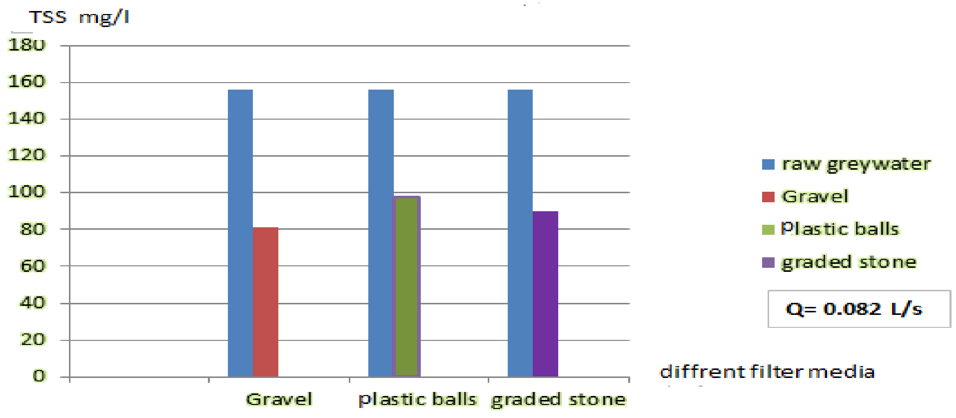

Fig. 2: The relationship between TSS &different filter media

For the BOD and COD the results were showing on Figures (3&4); gravel achieved the best removal efficiency 26 & 31 %, respectively as influent BOD&COD of the raw greywater were (127&178) mg/l and the effluent of the treated greywater was (94&123) mg/l .The values were in accordance with Leal *et al*. [10]. Only 40% COD removal was achieved using an HRT with a UASB for 12-24 hours. The poor removal efficiencies were also explained [12,6,4]. Solely using physical greywater treatment processes as the main treatment method is insufficient for greywater treatment, since it does not guarantee adequate reduction of organics, nutrients, and surfactants, except in situations where the organic strength is extremely low.

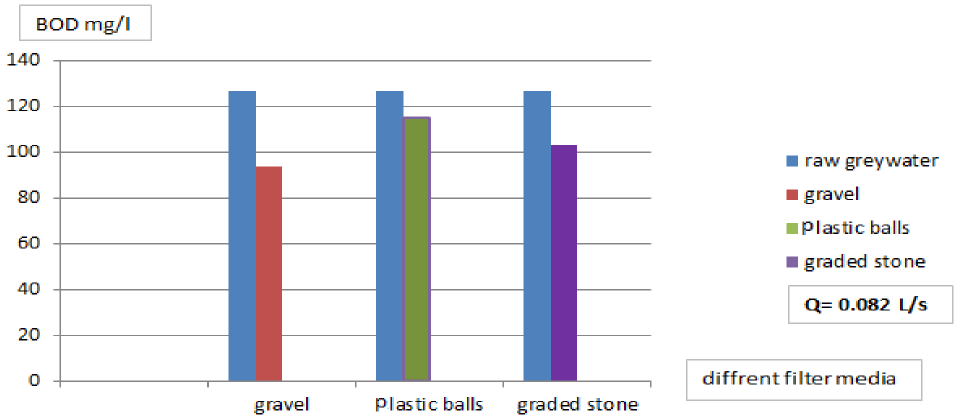

Fig. 3: The relationship between BOD & filter media

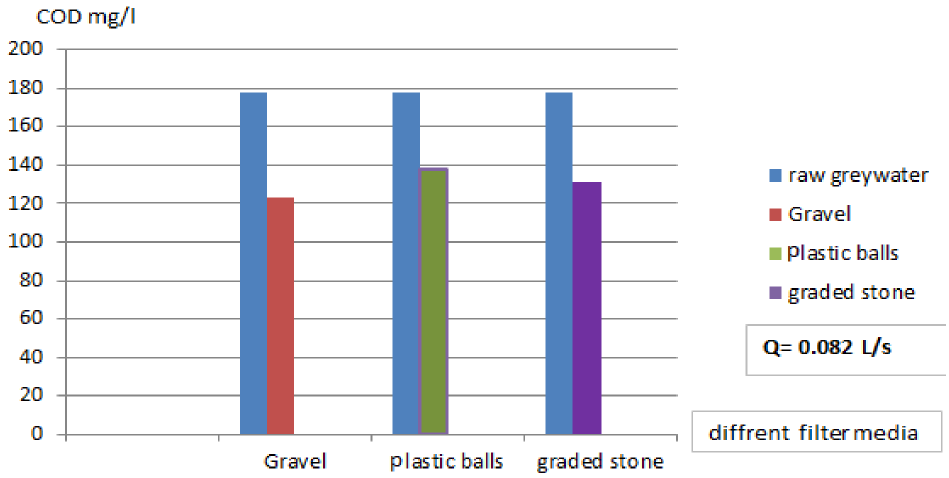

Fig. 4: The relationship between COD & filter media

Figure (5) shows the removal of different media for total bacteria where the entry raw greywater was (1800) and output of greywater in the case of gravel was (610), it was found that the best removal was (66) %. The relation between varied media and (DO & PH), it was shown that no observed change was seen between different media. The physical and chemical characteristics of greywater before and after treatment of this stage were measured and summarized as shown in Table (1).

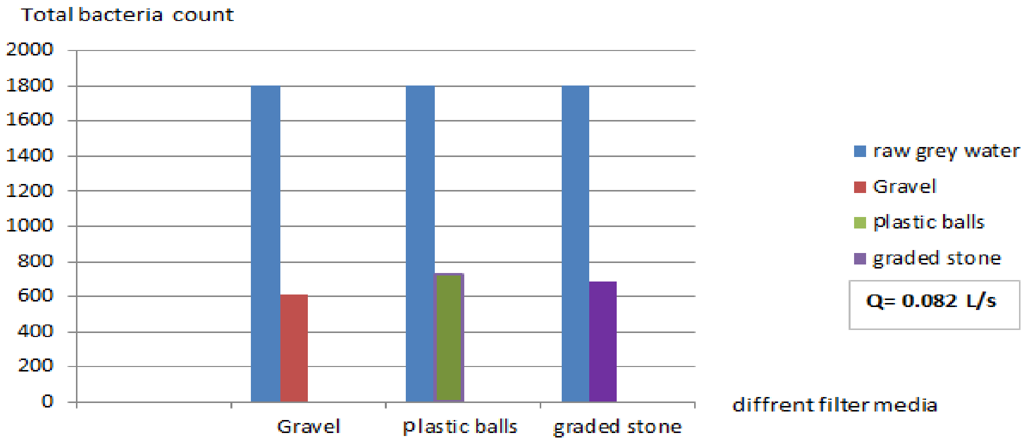

Fig. 5: The relationship between Total bacterial count & filter media

Table 1: The physical and chemical characteristics of greywater before and after treatment (stage 1)

Tests	Raw greywater	Roughing filter's media		
		Gravel	Plastic balls	Crushed stones
TSS (mg/l)	156	81	98	90
BOD (mgO_2/l)	127	94	115	103
COD (mg/l)	178	123	138	131
PH	7.39	7.46	7.62	7.71
DO mg/l	5.8	5.9	5.9	5.9
T.B.C (cell/100cm^3)	1800	610	730	690

From the previous results it was shown that the best roughing filter's media used was gravel. So it was used in the roughing filter in the following runs.

3.2. Stage two: determining the optimum flow rate:

In the following three runs, greywater was discharged with three different flow rates (Q1= 0.06 L/s, Q2= 0.042 L/sec, and Q3= 0.0226 L/sec) and hold the same previous experiments to show the most appropriate one. The results were as shown in the following Figures (6-9).

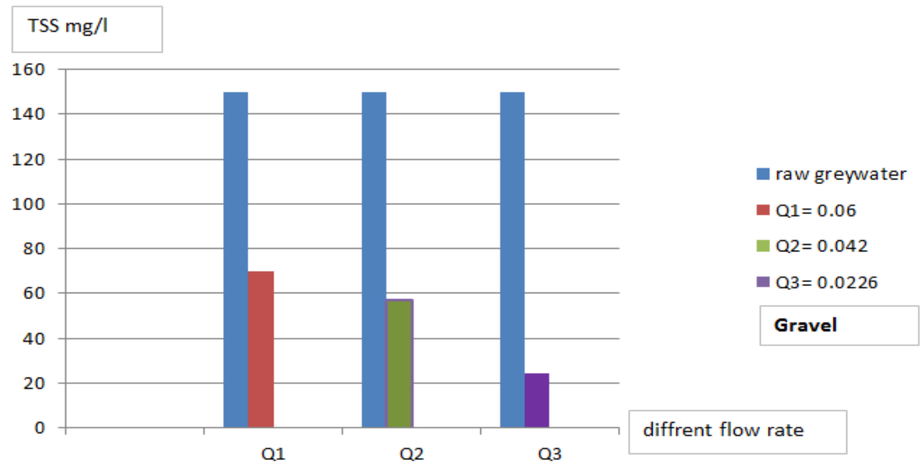

Fig. 6: The relationship between TSS & flow rate

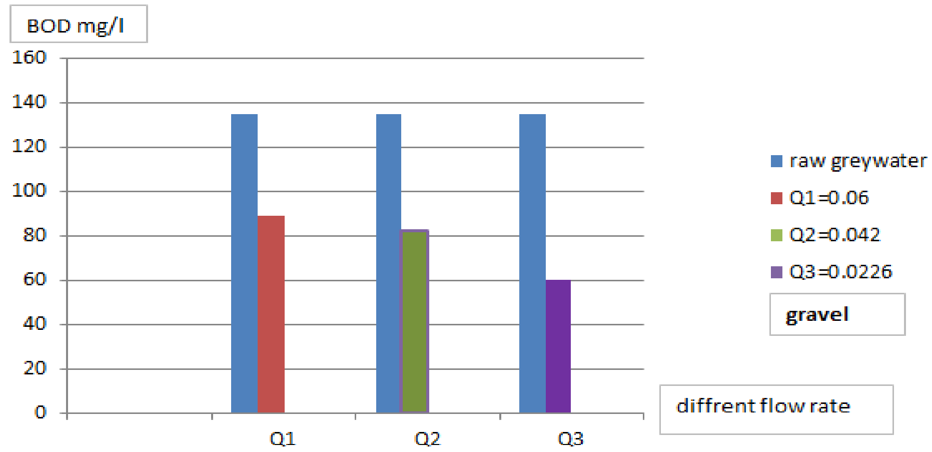

Fig. 7: The relationship between BOD & different flow rate

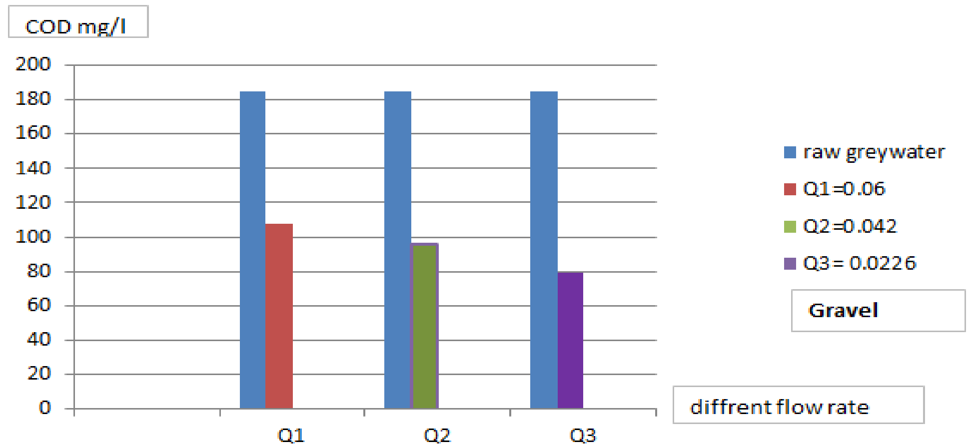

Fig. 8: The relationship between COD & different flow rate

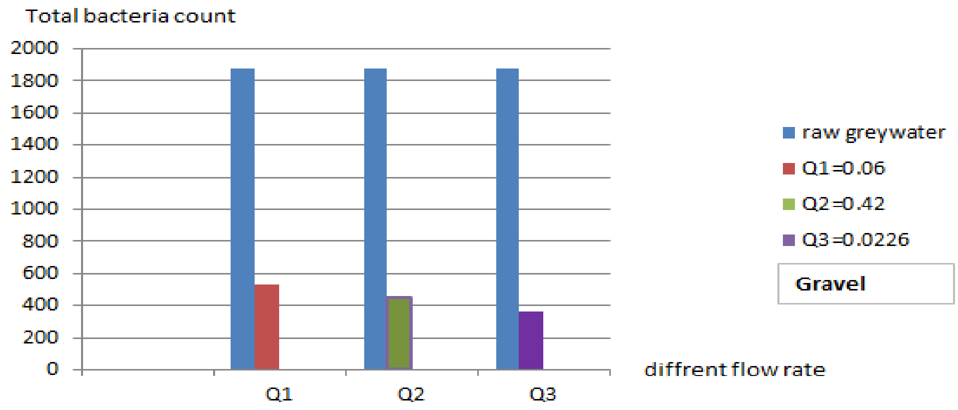

Fig. 9: The relationship between Total bacteria count & different flow rate

From the above Figures (6-9), it was shown that the best flow rate was Q3= (0.0226) L/s, which achieved84%, 56%, 57%, and 81% removal efficiency for (TSS & BOD & COD &Total bacteria account) respectively. And these result agree with Chaillou *et al.* who investigated the potential of a sand bed filter to treat bathroom greywater. A mean removal of 30% COD and a maximum *E. coli* removal of two log CFU/100 mL was observed. Similarly, Zuma *et al.* [16], observed that a mulch tower system consisting of mulch, coarse sand, fine gravel, and coarse gravel removed 26% of COD and 52% of TSS while the level of FC and total coliforms remained unchanged. Also, minor change in (DO& PH) with different flow rate was measured that was not significance. The physical and chemical characteristics of greywater before and after treatment of this stage were measured and summarized as shown in Table (2).

Table 2: The physical and chemical characteristics of greywater before and after treatment (stage 2)

Tests	Raw greywater	Q1=0.06 L/s	Q2=0.042 L/s	Q3=0.0226 L/s
TSS (mg/l)	150	70	57	24
BOD (mg/l)	135	89	82	60
COD (mg/l)	185	108	96	79
PH	7.5	7.79	7.84	7.92
DO (mg/l)	5.7	6.1	6.3	6.5
T.B.C (cell/100cm^3)	1875	530	450	360

3.3. Stage three: using coagulation and disinfection:

Based on the literatures, it was found that chemical processes such as coagulation, followed by a filtration and/or disinfection stage, can reduce the suspended solids, organic substances, and surfactants in low-strength greywater to an acceptable level that can meet non-potable urban reuse needs [2]. So in the following runs alum and chlorine were used each separately and together. Figure (10) illustrates the extent of removal in the last three runs with chemical material (chlorine, alum, and (chlorine + alum)) for TSS. It was found that the best removal efficiency in the case of using (Chlorine+ Alum) as the value effluent of TSS equal 18 mg/l that was under the allowable limit of Egyptian Code that equal 20 mg/l.

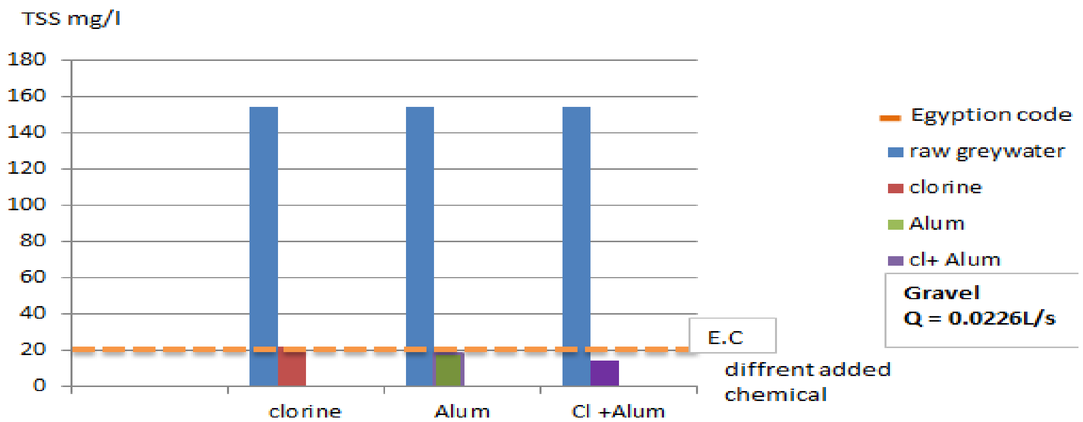

Fig. 10: The relationship between TSS & different added chemical

Figures (11&12) show the extent of removal of chemical material ((chlorine) & (alum) and (chlorine + alum)) for BOD and COD. It was found that the best removal was in the case of (Chlorine+ Alum); as the effluent of BOD equal 19 mg/l was under the allowable rate of Egyptian Code that equal 20 mg/l and the values effluent of COD was 39 mg/l was under the allowable rate of Egyptian Code that equal 40 mg/l.

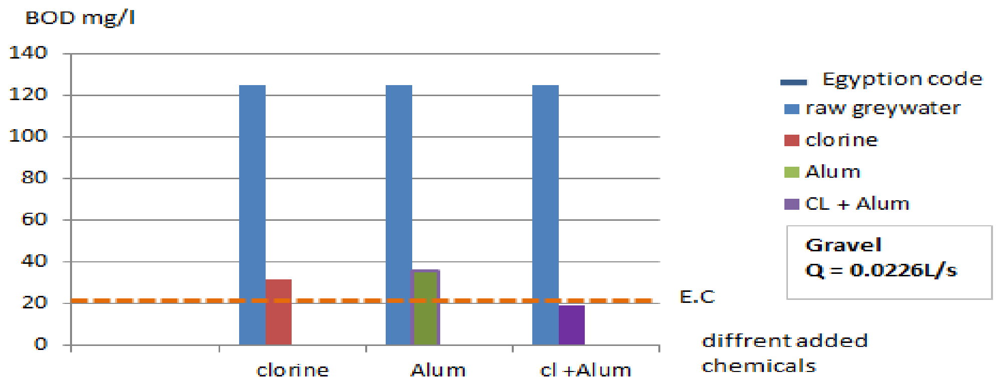

Fig. 11: The relationship between BOD & different added chemical

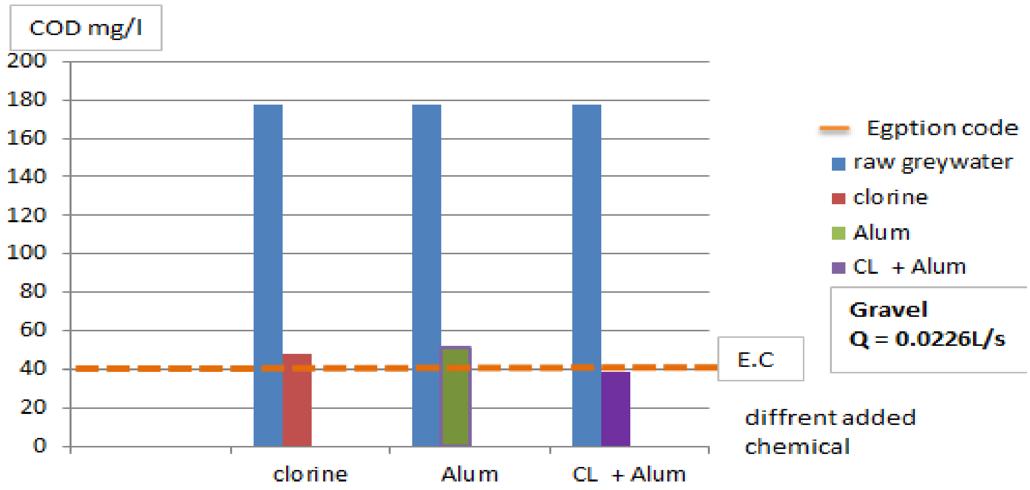

Fig. 12 The relationship between COD & different added chemical

Also, Figure (13) shows the extent of removal for total bacteria, and it was found that the best removal in the case of (Chlorine+ Alum). As the values effluent of Total bacteria count, equal 62 that under the allowable of Egyptian Code value ≤ 100. Figures (14&15) show the extent of removal for DO and pH.it was found that the best results were in the case of (Chlorine+ Alum). as the values effluent of DO equal 9.2 was about allowable of Egyptian Code value 9 mg/l.and the values effluent of PH was 7.95 in range of allowable Egyptian Code values from 6 to 8.4.

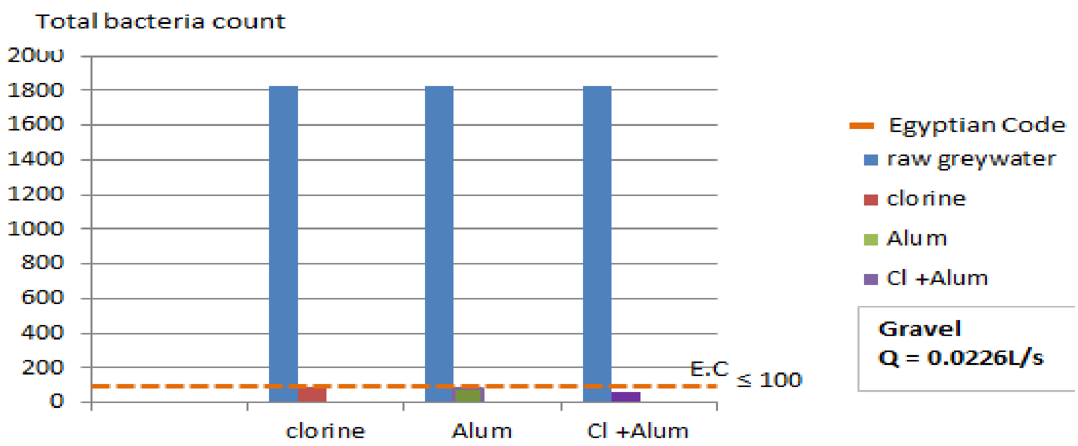

Fig. 13: The relationship between Total bacteria count & different added chemical

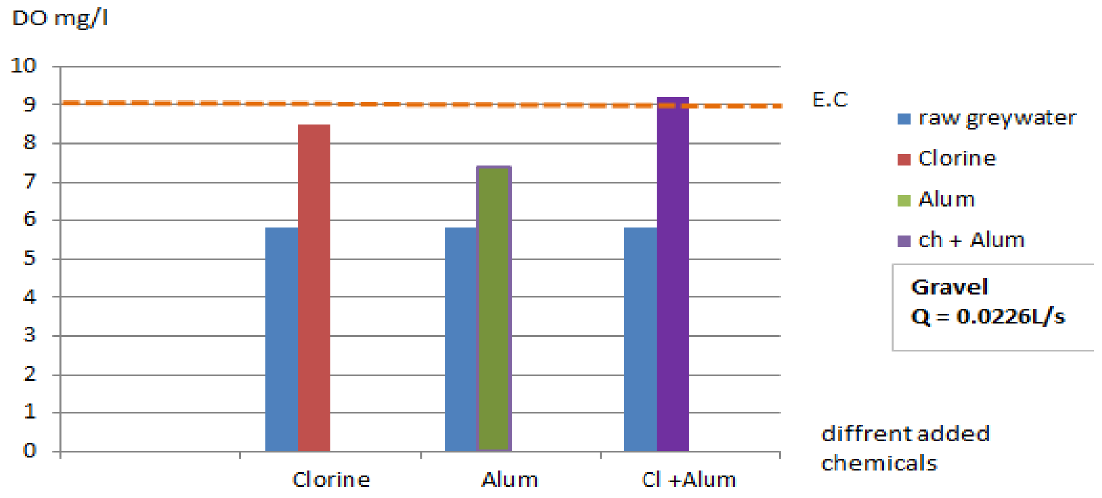

Fig. 14: The relationship between DO & different added chemical

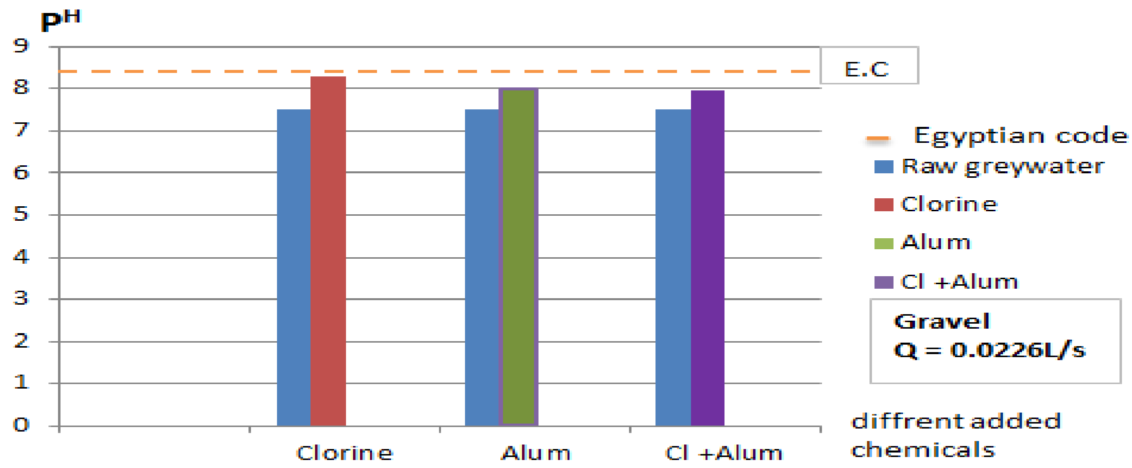

Fig. 15: The relationship between pH& different added chemical

The physical and chemical characteristics (biological oxygen demand, chemical oxygen demand, total suspended solids, total bacterial count, and dissolved oxygen) of greywater before and after treatment of the final stage were measured and summarized as shown in Table (3).

Table 3: The physical and chemical characteristics of greywater before and after treatment (stage 3)

Tests	Raw greywater	Chlorine	Alum	Chlorine and Alum
TSS (mg/l)	154	22	18	14
BOD (mg/l)	125	32	36	19
COD (mg/l)	197	48	51	39
PH	7.5	8.29	7.98	7.95
DO (mg/l)	5.8	8.5	7.4	9.2
T.B.C (cell/100cm^3)	1830	89	76	62

Conclusions:

Based on the experimental program executed in this research, and limited on both the tested materials and the testing procedures employed, the following conclusions had been reached:

- The good engineering design of the pilot gives a final effluent greywater was suitable for crop, landscape irrigation, toilet flushing, and street washing.
- The final values of all physic- chemical parameters were 39, 19, 14, 9, 7.95 and 64 for COD, BOD_5, TSS, DO, pH, total bacterial count in the final effluent of greywater respectively within the limits recommended by Egyptian code.
- The percentage of DO increases.

- When using three different roughing filter media (gravel – plastic balls – crushed stone) results of the previous experiments showed that the best media was gravel.
- The best flow rate in three different values (Q1= 0.06 L/sec, Q2= 0.042 L/sec, Q3= 0.0226 L/sec) was Q3 = 0.0226 L/sec.
- By adding different chemicals ((chlorine) & (alum) and (chlorine + alum)), the best results were achieved by using (chlorine and alum) together.

This treatment system can also be used in small scale basis like houses, hotels, office etc. With the using of chlorine.

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