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Technique for Greywater Reuse; Influence of Filter Media Type and its Configuration

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Abstract: Greywater is arich source of renewable non-potable water. It can be reused to provide a large amount of water for daily activities consumption. Before reuse;Greywater it must be treated to match the health standards. The most suitable method for treating Greywater is determined by the extent of its contamination. In case of low loaded Greywater, the physical treatment is satisfactory. In the present study the main objective is to evaluate the filtration method using both up-down and down-up flow in physical treated of greywater,to find out the best technique for Greywater treatment from efficiency point of view, as part of the implementation of the filtration process.Five different strategies based on the filtration media have been tested to evaluate most effective and acceptable one. The filtration media that have been used were;gravel and sand, MBBtablets and sand, fresh apricot kernels with gravel and sand, sand only,and fifth wassponge only. The following evaluation parameters have been monitored; TSS, Turbidity, COD, NO_3-N and Phosphate.Results obtained revealed that the fifth filtration media is the most efficient strategy for greywater treatment. Theremoval efficiency of evaluated parameters for fifth strategy were;98.8%, 86.91%, 67.90%, 71.15% and 86.36% respectivelyfor TSS, Turbidity, COD, Nitrate and Phosphate respectively.Finally results highlighted that filtration treatment of greywater makes it reuse for several purposes such as domestic garden irrigation; firefighting; car washing and toilet flushing box, hence decreased the load in water demand.

Abbreviation: *MBB = Movable Bed Bioreactor;* *TSS = Total Suspended Solids*
COD = Chemical Oxygen Demand *NO3-N = Nitrate – Nitrogen*

Key words: Water conservation · Greywater treatment · Reuse · Strategies · Filter media

INTRODUCTION

Arab countries are being considered as a semi-arid or arid region and its available water resources are limited. The region has around 5 percent of the world's population having access to merely 1 percent of the world's total water resources. Increasing urbanization and industrialization, high population growth rate, failure to adopt basic water conservation principles, insufficient energy for seawater desalination, regional conflicts resulting in mass flow of internal migrants, lack of public awareness, in addition to the use of traditional methods of irrigation and sometimeshigh standards of living, all increase the water demand [1]. The best-known indicator of national water scarcity is per capita renewable water, where threshold values of 500, 1000 and 1700 m^3/person/year are used to distinguish between different levels of water stress as, absolute water scarcity, Chronic water shortage and regular water stress respectively. On this criterion, countries or regions are considered to be facing absolute water scarcityif renewable water resources are <500 m^3 per capita. Figure (1) refers to available water quantity per person per year in different Arab countries. It became very urgent to search for a renewable water sources to maintain the per capita share of drinking water and meet the demand for the amount of water needed for daily activities and projects.Whenever a good quality water is scarce, water of marginal quality is considered for use (Selim, 2008).This paper focuses on finding anon-traditional solution to face the problem of water shortage in Arab world. This solution represented in reuse of treated greywater, just at least to share in water conservation.

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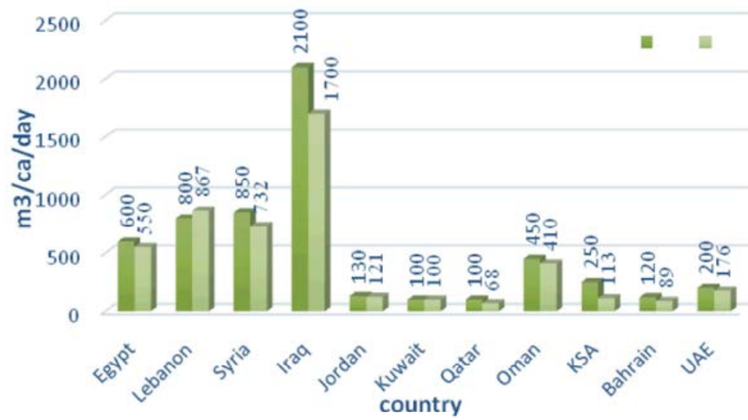

Fig. 1: Available water quantity per person per year in different Arab countries(source:Arab Forum for Environment and Development - AFED)

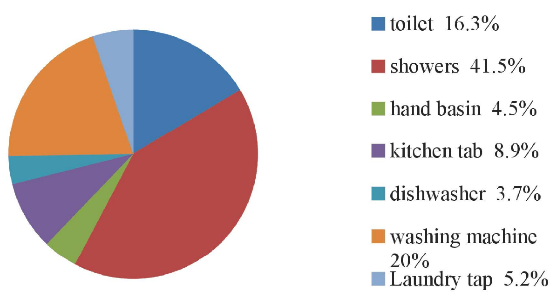

Fig. 2: Domestic water drainage
*Other references refers to around 27 % of indoor household water reuse consumed in toilet flushing.

Greywaterreuse is an appropriate methodasa source ofrenewable water, to can meet daily water needs it is a sustainable. It is not seasonal like rainwater and produced in large quantities daily through individual consumption of water and greywater is easier to treat and reuse than black wastewater.

Greywater is the domestic wastewater except forwater comes from toilet (black water) [2], black water needs complex treatment processes and high deficit in uses even in agriculture sectors.Some studies except wastewater from kitchen,where it contains large amount of organic matter due to the leftover food, requires biological treatment[3].Greywater accounts for 84% of household drainage, classification of domestic water drainage shown in Figure (2).

Greywateris divided into two types, low- loaded greywater, which includeswastewater comes from hand basin, showers and bath tubes [4], greywater comes from Mosques that used for Wodoa and its amount represents more than 70% of the total greywater [5] and high- loaded greywater which iscomes from kitchens and dishwashing. The properties of low and high loadedgreywater can be summarized in the following table.

Table 1: Properties of low and high loaded Greywater, Ref. [6, 7].

	Low-Loaded GW		Mix (low and highloaded) GW	
Properties	Range	Mean	Range	Mean
BOD (mg /L)	85 – 200	111	250 – 550	360
COD (mg /L)	150 – 400	225	400 - 700	535
TSS (mg /L)	30 -70	40	45 - 330	93
Turbidity (NTU)	NA	19	22 - 200	67
Total coliforms (MPN/ml)	101 – 105	103	102 - 106	104

Greywater Characterizations and Reuse: Greywater characterizations depend on some factors as living level, personal hygiene, detergents and cosmetics are used and dirty clothes limit [8, 9, 10]. Greywater reuse is useful in several purposes, these benefits can be summarized as:

- ✓ Toilet flushing [11, 12] Thus, 30% of potable water can be conserved [13]
- ✓ Washing cars and firefighting [14].
- ✓ Cultivate some crops to avoid famines [15].
- ✓ Domestic garden and public clubs irrigations [16].
- ✓ Cementmanufacture [12].
- ✓ Improve wetlands [17].
- ✓ Biomass output [18].
- ✓ Improve water resources utilization [19].
- ✓ Reduce freshwater that consumed for daily domestic proposes, at the rate of 30% [20-22].

Greywater Treatment: Greywater treatment depends on the type and degree of load. Biological treatment as Wetlands, Rotating Biological Contactor (RBC), Sequencing Batch Reactor (SBR) and Membrane

Bioreactor (MB) is required for high loaded greywater Considered, because it contains high organic matter. Chemical treatment as oxidation, adding Chlorine, Ozonation and Active Carbon andPhysical treatment as sedimentation, filtration and ultraviolet light, can be applied for low loadedgreywater, whichprecedes any biological or chemical treatment process that mentionedabove. There are different factors affecting the suitable method that should be used for greywater treatment, contains but not limited to:

Greywater Source: Greywater that comes from kitchens and dishwashing basins is rich in organic matter, which considered the most polluted greywater. Greywater from washing machine contains a large amount of phosphate as a result of the use of powder detergents and suspended solids due to the escape of fibers.As for the greywater from bathroom, it contains suspended solids such as hair, nails and skin, contains also Xenobiotic Organic Compounds (XOC) due to the use of shampoo, perfume, shower gel and personal care products.

Consumers: Statues of the population havea strong impact on the extent of greywater pollution, where living level and the work of the population in addition to the situation of the population if they are families or university students.All such factors affect the daily activities that need to use water and degree of greywater pollution.

The Propose of Greywater Reuse: The more people exposed to treated water, the more greywater treatment is needed to avoid the health risks.

Many studies were conducted to evaluate methods of greywater treated, among these ultra-filtration (UF), which could reduce chemical oxygen demand (COD) [23] and [24] and biological oxygen demand (BOD) [23], but the treated was not at the satisfied limits [24]. Nano filtration (NF) membrane, which could treated greywater comes from gymnasium showers (contains suspended solids (SS) and COD), to the level for unrestricted reuse [25]. Using chemical disinfection after filtration treatment able to removes coliforms but turbidity and BOD were still in the high level. The advantage of the filtration system is reducingthe pollution in greywater but it cannot achieve the required standards.Low strength greywater was treated implementing Nylon Sock type followed by sedimentation then disinfection stage, reduces COD, Turbidity, SS and total nitrogen (TN) [26]. The effluent from treatment system can reused in toilet flushing but it has to betaken into consideration a time of saving not more than 48 hours and chlorine concentration in toilet tank no less than 1 mg/l. Using Slanted Soil Filtration to treat greywater from kitchen basins, this soil is composed of alumina and hydrated silica,a method is considered a mix of filtration and biodegradation.The effluent proved that the treatment process could reduce COD, BOD, SS, TN and total phosphorus (TP) [27]. Greywater disinfection by Ultraviolet light(UV) is very effective for faecal coliforms removal, but its efficiency is weak of inactivation of heterotrophic plate count [28]. Greywater treatment was studied by using microfiltration membrane (A2O- MF membrane)and oxidation process (OP), (A2O-MF membrane) achieved a decrease in color 98%, turbidity 99%, COD 99%, SS 99% and E.Coil, Salmonella and Staphylococcus 30% and the OP system decreased color, E.Coil, Salmonella and Staphylococcus 100% [29]. It was found that the MF membrane is economic than the UF membrane or NF membrane. Indian residential school, the system which is set up for greywater treatment and reuse in toilet flushing, food crops irrigation and cleaning of school floors, treatment system consist of synthetic sponge, sedimentation graded settlement tank as a primary treatment for sucking soap suds, sand/gravel filter as a secondary treatment to influent filtration and aeration and chlorination system as a tertiary treatment, then effluent pumped to toilet flushing [30]. It was found by some researchers that the membrane bioreactor system (MBR) is an effective solution to treat greywater, which collected from residential buildings [31]. J. Jong *et al*., [32] recommended to do disinfection process before the reuse greywater treated by membrane bioreactor system (MBR)[32].D. Mandal, *et al*., found that up flow and down flow treatment system that contains sifting, deposition, filtration and disinfection, leads to reduce COD and E.coil[33].Greywater treatment by using a system consisting plastic collection tank, pump suction located at the bottom of the tank, filter through a stainless steel screen and a UV disinfection unit is studied by C. Santos, *et al*., [34]. Photo catalytic oxidation with titanium oxidation and UV were used to treat greywater and enables to get rid 90% of organic matter [35]. Use a set of filtration, alum flocculation, sedimentation and disinfection, thatachieved to a low-cost system can make physical, physiochemical and biological treatments [36]. Prior to the filtration have to make a pretreatment to remove oils, fats and grease. The impact of use activated carbon and ozone on micropollutants removal was studied by L. Hernández-Leal, *et al*., (2012). It was based on adsorption and ozonation technique [37]. The effect ofthe treatment systemthat includes five stages (storage tank, sedimentation tank, sand gravel filter, coconut shell coal plus charcoal filter and disinfection) have been tested and showed a difference in greywater quality before and after treatment [38]. Using Green Roof- top Water Recycling System (GROW) can achieve removal efficient higher than 82%, the parameters that are removed are TSS, TN, TP and NO_3-N [39].

MATERIALS AND METHODS

Objectives: The main tarjet of this study is to construct a model can be used for greywater treatment, then reuse this treated greywater in different fields to saving partially the resources of water. The efficiency of this treatment unit should sufficient and economic as it is possible.

Experimental Unit: The physical treatment process is the treatment methodthat chosen to treat greywater non including kitchens. This means thatgreywater doesn't contain organic matters, only by simple value, which can avoid its harm by some precautions when used.

Filtration is the Physical treatment process chosen by up flow -down flow method, the treatment unit contains four chambers.The first chamber for sedimentation for the disposal of large amount of suspended solids. The greywater flows to the weir at second chamberthrough a double elbow, the elbow lifted from the unit bottom by a distance 5 cm to prevent the transfer of the suspended solids settled in the first chamber. The weir works as reservation of the remaining suspended solids. The second chamber works as extra clarifier, to ensure that is no impurities will pass to filter media and clog their voids. Then the greywater flows to the third chamber, which contains a coarse filtration media, through an overhead pipeto ensure the transfer of the greywater without suspended solids. Then passes to forth chamber follow down-up flow. The forth chamber contains another kind of filter media based on the strategy that will follow. Figures (4) and (5) show the geometric details of the experimental unit.

Table (2) refers to description of different types of filtration media that have been used in eachstrategy.

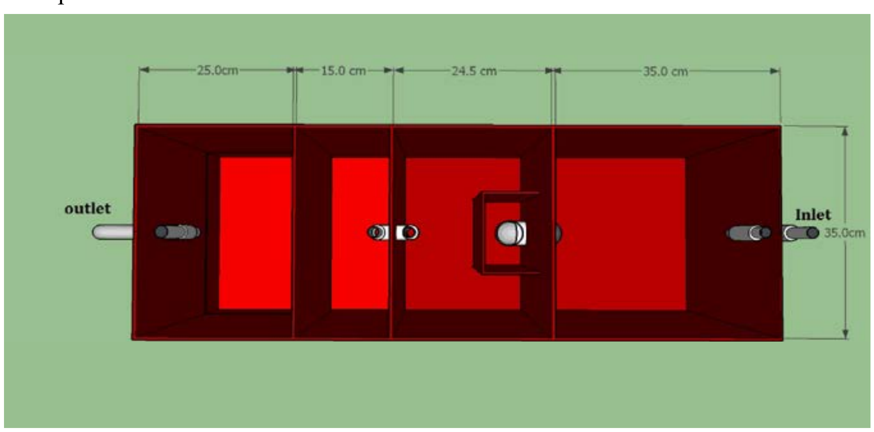

Fig. 4: Top view of the experimental unit

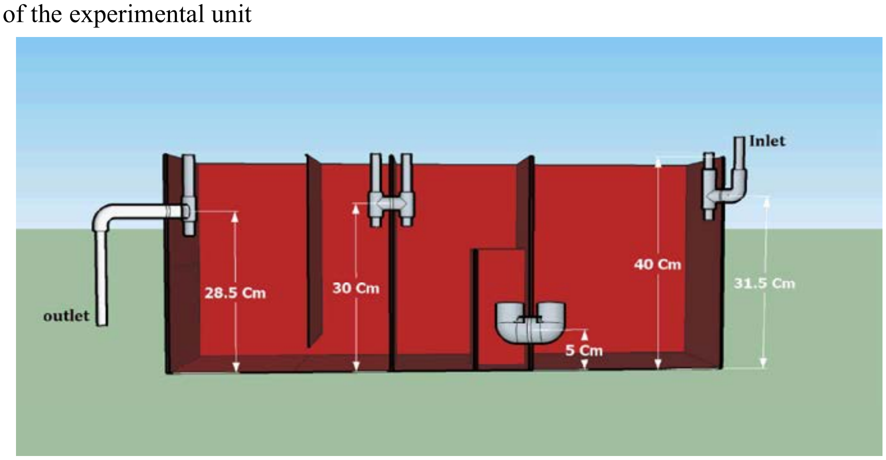

Fig. 5: Elevation of the experimental unit

Table 2: Types of filtrationmedia for eachstrategy:

	3rd chamber		4th chamber	
Strategies Number	*filtration media*	*Thickness (cm)*	*filtration media*	*Thickness (cm)*
1	Gravel	20	Sand	15
2	MBB* tablets	20	Sand	15
3**	Gravel	20	Sand	15
4***	Sand	15	Sand	15
5	Sponge	20	Sponge	20

** Movable Bed Bio- filter with 2 cm gravel used as cover.*

***The third strategy contains fresh apricot kernels in second chamber.*

**** Sand layer in 3rd chamber covered by 5 cm sponge.*

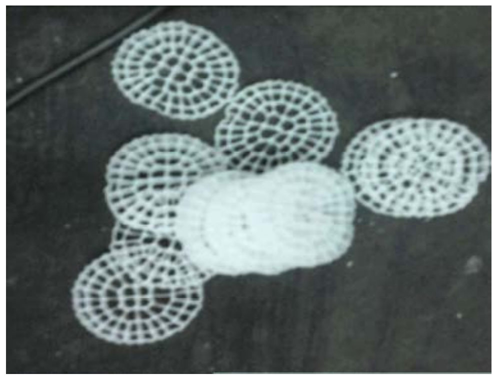

Photo 1: Movable Bed Bio- filter (MBB)

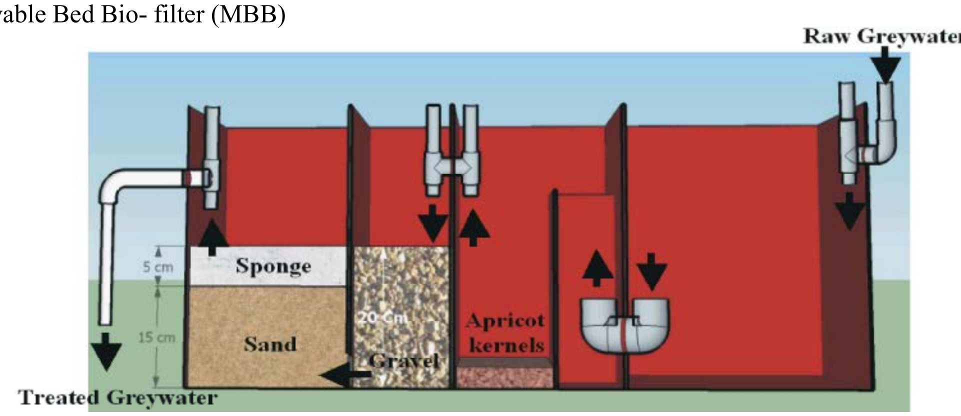

Fig. 6: Types and configuration of filter media in third strategy

Gravel that have been used as a filter media were with size of 2.8, 4.75, 9.5 mm and for sand were 1.4 and 2.8 mm. Sponge as a cover layer with thickness of 5 cm has been used above the sand filter in 4 th chamber, in all strategies that have been tested.

The following figure shows the configuration of filter media for third strategy as an example and the direction of flow for the Greywater.

Synthetic Greywater: Synthetic greywaterused in the study was created in Sanitary and Environmental Lab. Of Engineering Faculty, Aswan University, Aswan, Egypt. Analysesof synthetic greywater indicated that: TSS 500 mg/l, turbidity 34.5 NTU, Nitrate(NO_3-N) 3.6 mg/l, phosphate 0.35mg/l, COD 330 mg/l, BOD_5 50 mg/l and PH 7.5 mg/l.The concentration of nutrients (Nitrogen & Phosphorus) were so low, just to match with the properties of natural Greywater.The synthetic greywater is pumped to the experimental unit three times per day for 30 minutes each (8:30 – 9:00, 13:30 – 14:00 and 19:30 – 20:00). Feeding time of greywater selected to simulate the variation of daily water consumption.The synthetic Greywater Samples were collected from theinlet and outlet of the unit. For physical analysis, total suspended solids (TSS) were measured by gravimetric method and turbidity by WTW device. And concerned with chemical analysis, the measured parameters were; Nitrate, Phosphate and COD by HANNA Device and PH by WTW device.

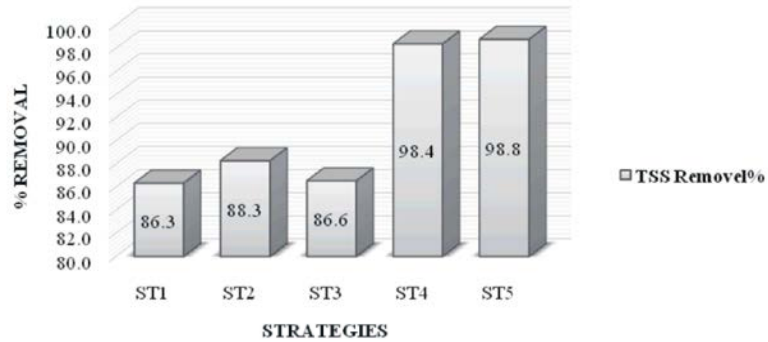

Fig. 7: Efficiency of strategies forTSS removal

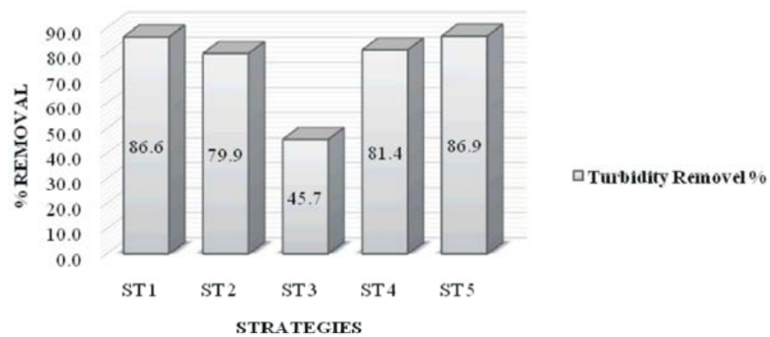

Fig. 8: Efficiency of strategies forturbidity removal

RESULTS AND DISCUSSIONS

Removal Efficiency: Removal of different evaluation parameters such physical parameters repesented by total suspended solids (TSS) and turbidity, or other parametrs like Chemical Oxygen Demand (COD), which represents the organics content of the smples, or phosphate and Nitrate-Nitrogen (NO_3-N), all were studied. Percentage of removal has been calculated based on following equation:

$$Persentage\ of\ removal = \left(\frac{Ic - Fc}{Ic}\right) \times 100 \quad (1)$$

where:
I c = Initial concentrations of evaluated parameters.
Fc = Final concentrations of evaluated parameters.

The experiments conducted under different boundary conditions, represented by name of strategy. The main variables in different strategies were the configuration of filter media that have been used and their thicknesses.

Physical Contaminant: It was observed anincreasein TSS removal ofthe five strategies with convergent values. The fourth and the fifth strategies were better, due to filtration media thathas largest surface area and it enables to reserve the largest amount of suspended solids. To obtain the best results of TSS removal, the hydraulic retention time (HRT)should be sufficient to ensure that most solids settled in first chamber and use a filtration media that has small voids with low flow rate.The water velocity can move the trapped suspended solids and sand grains when using fine sand as filtration media in case of a high flow rate, whichjustifications have been met in fourth and fifth strategy so it achieved the best results of TSS removal. Removal efficiency of TSS for all strategies shown in Figure (7).

The ability of the strategies in Turbidity removal is high, except the third strategy. The turbidity didn't go down as required, in spite of used the same filtration media in the first strategy. The reason may be goes to, the stagnation of fresh apricot kernels in second chamber of the unit, which after three days it leads to bad odor and color of greywater changes to yellow. Figure (8) indicates the ability of the five strategies in Turbidity removal.

Chemical Contaminants: It is clear that the strategies efficiency at COD removal is close. Figure (9) shows the convergence, but the third strategy efficiency is not efficientmay be due to use fresh apricot kernels that has

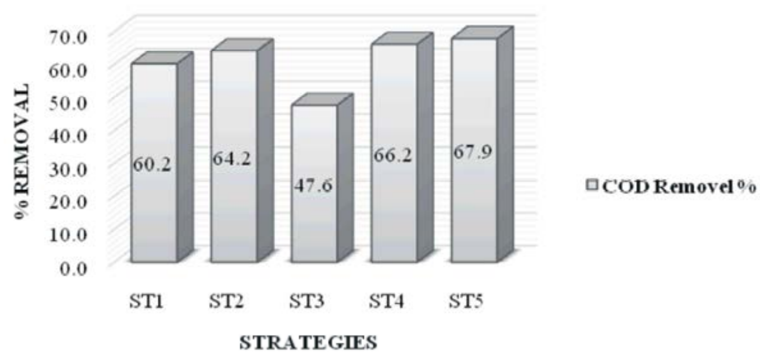

Fig. 9: Ability of strategies for COD removal

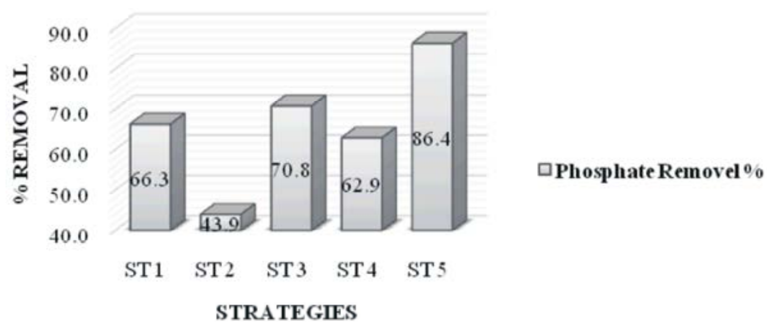

Fig. 10: Ability of strategies forphosphate removal

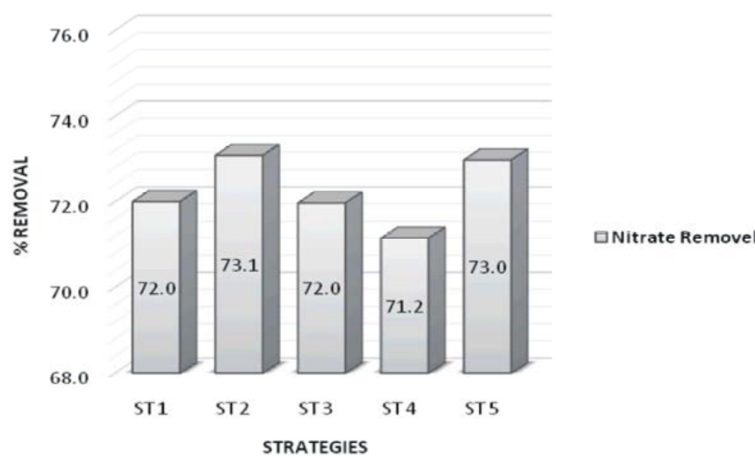

Fig. 11: Ability of strategies fornitrate removal

a large amount of organic matter dissolve in a Greywater,in turn raises COD value. The study is in disagreement with reference [40]; it proved that apricot kernels had the capability of purifying water as active carbon and its ability to absorption due to its high surface area. This problem may be is attributed to the use of fresh apricot kernels in the treatment without separating the nucleus from the shell.

Phosphate is indicated by the presence of soap, remove it refers to soap disposal.Strategies efficiency is variant at phosphate removal. The best removal of phosphate was achieved in the fifth strategy due to ability of sponge to absorb foam produced from soap. The second strategy is the worst, where the breadth of MBB tablets pore fails in catching foam.Figure (9) refers to the phosphate removal efficiency by applying different strategies.

Nitrate removal is acceptable and is close at all strategies, as shown in Figure (11). The presence of Nitrate in greywater is less than its presence in black water, where its presence is limited to the use of liquid detergent and personal care production [41].

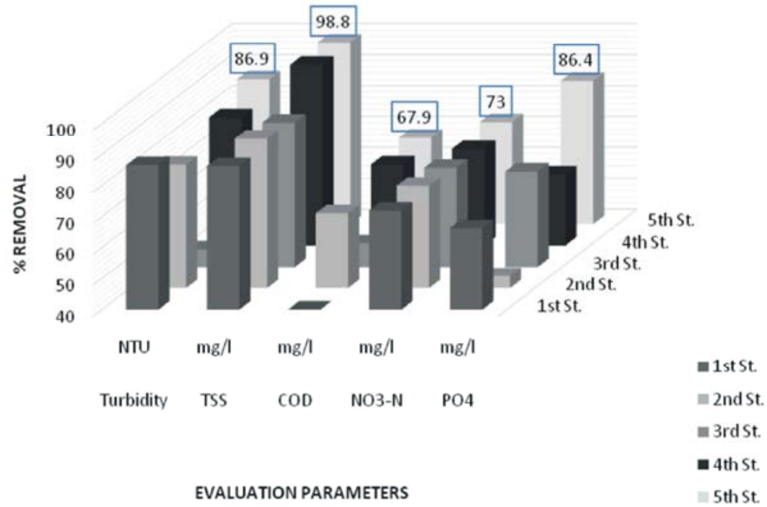

Fig. 12: Removal efficiencies in different strategies

The nitrification process occurs in the presence of oxygen. This process is responsible for the generation of nitrate and was easy to dispose by filtration. The denitrification process can take place at anoxic condition in treatment unit and in turn help in remove of nitrate.

PH value doesn't influenced on treatment process where its value ismoderate and limited between (7-7.5) before and after treatment processes, it doesn't need any modification.

Figure (12) summarizes the removal efficiencies of different parameters by applying the five variant strategies. Fifth strategy was the best one from the removal efficiency point of view. The main factor that plays the effective role was the kind of filter media layers and their height or thickness.

Comparing between concentration of pollutants in treated Greywater applying fifth strategy and Egyptian standards code in field of Greywater reuse, the effluent match with category B and can be reused in different fields. According to Egyptian standards code, treated wastewater at zone B can be reused in:

✓ Toilet flushing.
✓ Irrigating the green areas of educational facilities.
✓ Irrigating private or public parks.

CONCLUSION AND RECOMMENDATION

Based on the experimentalwork and analysis of its results,the following have been concluded:

- Filtration media plays an important role in the treatment process, despite the treatment process was identical in all strategies but results were asymmetric.
- Theproposed unit can treatlow load greywater for reuse inthe daily activities.
- The fifth strategy achieved higher removal efficiency, where its removal efficiency for TSS, Turbidity, COD, NO_3-N and PO_4 were 98.8%, 86.91%, 67.90%, 71.15% and 86.36% respectively.
- The best treatment levels occurred in the fourth and the fifth strategies, which attributed to the filtration media containing finer granules.The removal efficiency will be higher with the high surface area.
- The use of fresh apricot kernelshave counter effect on treatment process and it reduced removal efficiency, which can be explained by using fresh kernels without excluding their seeds and without any pretreatment.
- All strategies that have been tested were close in NO_3-N removal, this indicates that filtration media doesn't havea main effect on Nitrate removal. The convergence of efficiencies is attributed to the removal occurring due to denitrification process.
- It is recommended to use the Fifth Strategy unit for low load greywater treatment, the effluent can be reused in zone B according to Egyptian code.

To achieve the desired benefit of the study,a separateplumping system is required to separategreywater from black water in discharge. At the end of greywatereffluent pipes, itis recommended to build an inspection room containing the suggested treatment unit. The treated greywater is re-pumped into the houses in separate lines from the drinking water supply pipes, it enables the residents to reuse it for several purposes such as domestic garden irrigation and firefighting or car washing, as well as pump it into the toilet flushing box.

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