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Effect of Media Properties on Performance of Sand Filtration for Drain Water Treatment

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ABSTRACT—In an attempt to improve the quality of the agricultural drain in Egypt for its reuse again in the irrigation, low cost solution such as sand filter along with/ without other filtration media have been used in this research, As a result of that, pilot plant of sand filter mixed with other filtration media was tested for its ability to improve the sand performance in removing the suspended solids and organic matters from agricultural drain water of the Belbeis drain (in Sharkia governorate in Egypt). Sand compared with sponge and sand with Liyan Nanfang activated carbon (L.N.A.C) have been tested to find the optimum mixing sand/ medium ratio &optimum infiltration rate. The work has been done on three runs. It was found that sand mixed with sponge gave the best removal efficiency compared to that of the sand only and the sand mixed with L.N.A.C. The results presented that the concentration of CODt, CODsol and TSS was reduced from 125, 47 and 162 mg/l to 44, 34 and 28 mg/l respectively at optimum infiltration rate of 2 m3/m2/d for sand mixed with sponge.

The effluents TSS and CODt in all runs were complied with law 48 for the year 1982 regarding the disposal of wastewater into agricultural drains

Key words: Drain water treatment, Belbeis drain, compact units, reuse, sand filter, and packing material.

1- INTRODUCTION AND LITERATURE REVIEW

Agriculture is a very important sector in Egypt. Irrigation of the agricultural lands in Egypt is mainly from Nile River [1].

Also, Egypt has made significant strides in the water sector that 98% of the population having access to drinking water on premises in urban areas and 95% in rural areas [7,8,10,11]. However, Egypt is dependent on the Nile River for water and its annual quota is fixed and insufficient to meet the growing needs of the population. The country is facing an annual water deficit of about 13.5 BCM/year and is among the ten countries threatened by water scarcity by 2025 [9, 10]. On the other hand, agricultural drains that are receiving water from agricultural fields are polluted and cannot be reused into irrigation as it is considered to be "less clean" water

Presently the vast majority of existing wastewater treatment plants (WWTP)'s in Egypt discharging into agricultural drains, due to the quality of treated wastewater don't allow to discharging into canals. This means that the treated water (and the resultant nutrients included in it) is lost for reuse in the agriculture. [1, 5].

Due to limited resources and capacities, not all WWTP comply with the standards (law 48) for discharging into the drains and became source of pollution to these drains [1, 5]. Also non-point source of pollution coming from untreated sewage from villages are also pollute the drain.

Therefore, the main objective of this study is to apply the drain water reuse in agriculture by improving its quality through water treatment with low cost system such as sand filtration. Also the research focuses on the efficiency of the sand filtration unit mixed with two different packing materials (sponge and activated carbon) in drain water treatment, in which the analysis

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of variable parameters will be conducted, to optimize the design of the unit and to investigate the most efficient configuration for the filtration unit. The optimum design parameters for sand filtration in previous studies were investigated [2, 3, 6] where the following criteria have been selected as optimum design of sand filtration: sand media with effective size (D10) = 0.8~1.2 mm, Infiltration rate of 4 m3/m2/d & filtration depth of 140 cm. [2, 3, 6]

In an experiment to test the filtration media performance with domestic wastewater treatment, the plastic medium mixed with the sand medium had the lowest removal contaminants removal efficiency and the sponge medium mixed with sand medium have the highest contaminants removal efficiencies and the optimum filtration depth was 140cm [6]. In this experiment activated carbon medium was selected to be tested and compared with sponge medium in the treatment of the agricultural drain water due to its stronger attraction forces than the forces that would hold the Contaminants in the water and due to its high surface area for adsorption and its ability to remove a wide range of contaminants [1, 4].Therefore, in this experiment, more mixing sand ratio with sponge were tested and new medium such as activated carbon mixed with sand was also examined.

2. MATERIAL AND METHODS

A) LOACTION:

The experimental setup is connected to bilbeis drain in the village of Adliya. Bilbeis drain is one of two branches that forming Bahr El Bakr main drain that is ending by Manzala Lake .The influent water was pumped from bilbeis drain to the experimental setup. (Figure 2)

B) Experimental setup:

To optimize the design of the unit and investigate the most efficient configuration for the filtration unit, Three filtration column of same diameter and depth have been fabricated, The filtration unit compromises of three PVC columns fixed by a structural frame, in which the filtration media is placed inside and drain water percolates through the medium downwards with various flow rates and media mixing ratio.

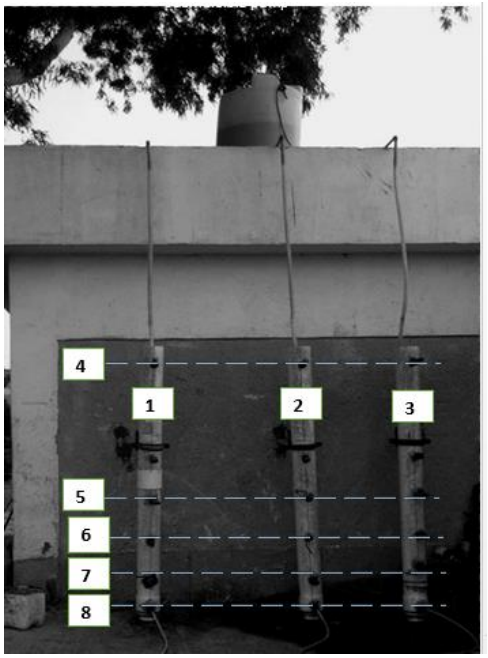

Figure 1: Sand Filtration its influent from the drain water

1. Sand filtration column (1)
2. Sand mix with sponge filtration column (2)
3. Sand mix with Activated carbon filtration column (3)
4. Filtration column overflow valve.
5. Effluent at filtration depth 60cm
6. Effluent at filtration depth 90cm
7. Effluent at filtration depth 120cm.
8. Valves below the gravel bed for system cleaning & media replacement.

The 6" PVC pipes was constructed vertically, in which the pipes were filled with 120cm-sand filtration medium, above 20 cm gravel bed to allow filtration on the whole depth of the sand media. During the experiment the existing head of drain water above the sand was kept 60 cm by applying overflow pipe at this level. Also different types of media mixed with sand have been tested to find the optimum medium (the most reliable medium that gives high efficiency with its availability on low-price). Figure 2, 3 shows the experimental setup and a schematic diagram respectively.

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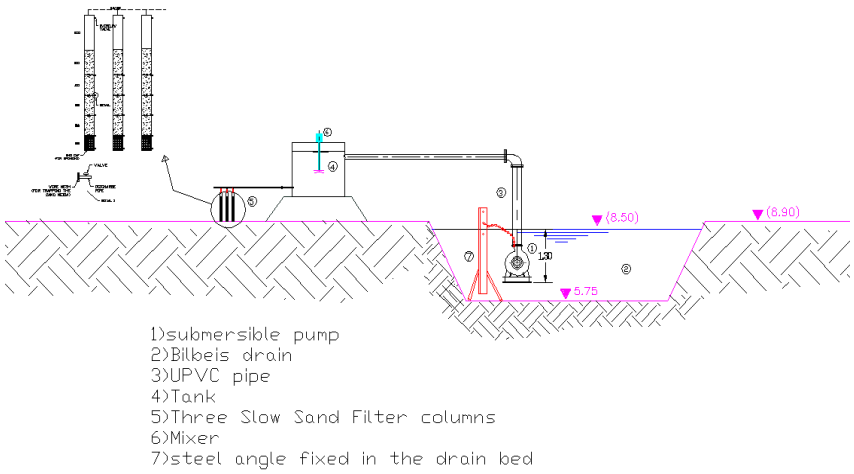

Figure 3: A schematic diagram for the pilot experiment

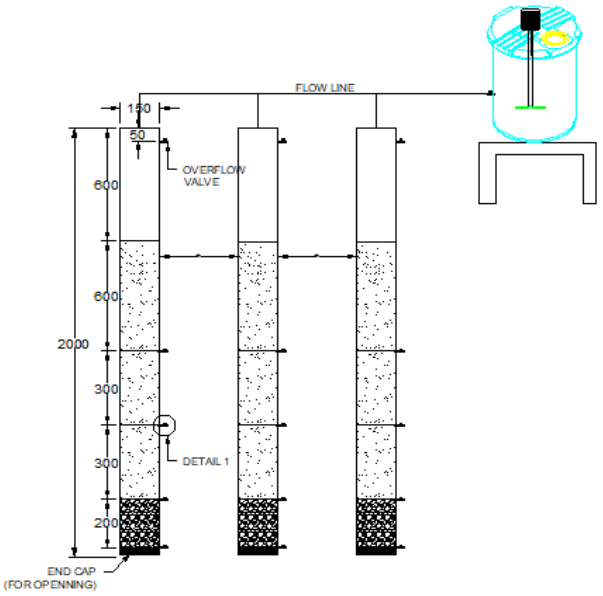

Figure 2: A schematic diagram for the layout of the experiment setu

C) The Filtration Media Properties

The following media properties have been used during the experiment:-

1) **Sand medium** with effective size (D10) = 0.8~1.2 mm, Void Ratio (e) =0.61, Specific Gravity (Gs) =2.58, ((Permeability (K) = (D10)2/100 (m/s) = 0.008281))

2) SPONGE PACKING MEDIUM

The sponge medium was used as packing material to be mixed with the sand medium. As shown in figure 4 the sponge medium with length 5cm and 1.5cm diameter were made from polyurethane foam of 30 kg/cu.m and void ratio of 90% of the volume. The material enclosed in a plastic frame for the purpose of shape retaining and maintaining the normal void ratio of the material.

Figure 4: A Sponge Packing Material

3 Activated Carbon commercial product with reasonable cost such as Liyang Nanfang Activated Carbon (L.N.A.C)

Particle Sizes: 6x12 mesh (3.35 - 1.70) mm

P.H value: 7-8

Density: 480 – 500 kg/m3 Surface Area: 650-800 m2/g

Figure 5: The low Activated carbon from china

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D) Water Sample Analysis

Testing for the samples was conduct in the National Research Centre (NRC) water quality labs, in which the samples were tested for CODtot, CODsol and TSS for the three runs. All analysis were carried out according to Standard Methods for Examination of Water and Wastewater [12].

3- RESULTS AND DISCUSSIONS

RUN (1)

The target of this run is to study the optimum Composite medium from the three Medias (Sand only, Sand mixed with Sponge and Sand mixed with Activated carbon Sand: (L.N.A.C)

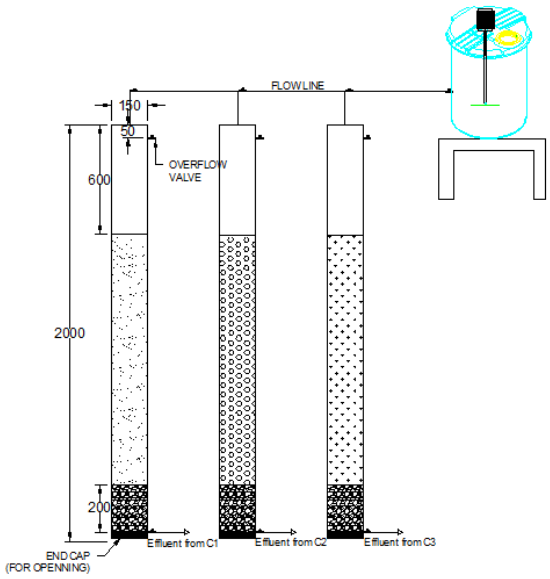

Figure 6: Run (1) for studied the sand, Sponge media and (L.N.A.C)

The run was conducted on (28) consecutive days, results are shown in table (1).It was found that sand mixed with sponge gave the highest removal efficiency with less price than the Activated carbon

	THE MEDIA	Cod total (in)(mg/l)	Cod total (out)(mg/l)	% removal efficiency	LAW 48	Cod sol (in)(mg/l)	Cod sol (out)(mg/l)	% removal efficiency	LAW 48	T.S.S (IN)(mg/l)	T.S.S (OUT)	% removal efficiency	LAW 48
Day 7	SAND ONLY	120	71	41%	≯80	80	42	18%	undefined	183	99	46%	≯50
	SAND :SPONGE (1:0.85)	100	38	62%		20	13	35%		30	7	76%	
	SAND :(L.N.A.C) (1:0.16)	100	41	59%		20	16	20%		30	10	66%	
Day 14	SAND ONLY	120	77	36%		110	53	23%		200	96	52%	
	SAND :SPONGE (1:0.85)	155	55	65%		55	33	40%		195	20	89%	
	SAND :(L.N.A.C) (1:0.16)	155	60	61%		55	39	29%		195	25	87%	
Day 21	SAND ONLY	135	65	52%		98	46	36%		230	115	50%	
	SAND :SPONGE (1:0.85)	171	42	75%		68	33	51%		230	18	92%	
	SAND :(L.N.A.C) (1:0.16)	171	45	74%		68	36	47%		230	20	91%	
Day 28	SAND ONLY	132	53	60%		94	40	44%		175	82	53%	
	SAND :SPONGE (1:0.85)	160	31	80%		50	25	50%		200	6	97%	
	SAND :(L.N.A.C) (1:0.16)	160	32	80%		50	27	50%		200	6	97%	

Table 1: Results for run (1)

Run (2):

As the sponge mixing with sand showed the optimum removal efficiency, the target of this run was to have the best mixing ratio between sand and Sponge media (the sand effective size is: D10 = 0.8 ~ 1.2 mm). Filtration depth was kept constant from run 1 at depth =140 cm. The different mixing ratios that are used in this run are shown in figure (7).

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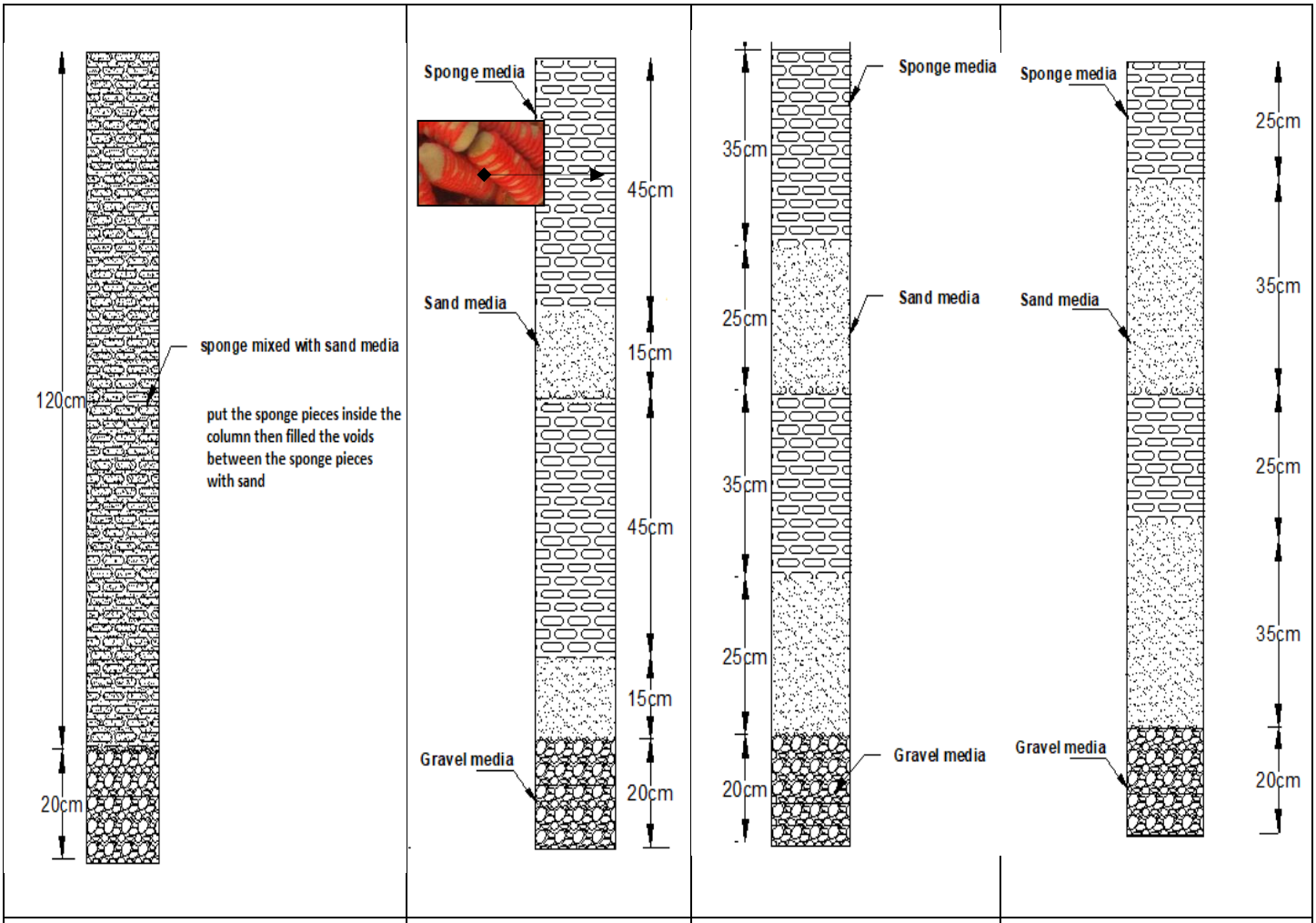

Column (1): the percentage of the sponge in the mixing ratio was 46% so the mixing ratio of Sand:Sponge was 1:0.85 with respect to volume	Column (2): the percentage of the sponge in the mixing ratio was 34% so the mixing ratio of Sand:Sponge was 1:0.5 with respect to volume	Column (3): the percentage of the sponge in the mixing ratio was 26% so the mixing ratio of Sand:Sponge was 1:0.35 with respect to volume	Column (1): the percentage of the sponge in the mixing ratio was 19% so the mixing ratio of Sand:Sponge was 1:0.23 with respect to volume

Figure 7: varying maxing ratio between the sand and Sponge media

The run was conducted on (28) consecutive days and sampling was collected and analyzed every (7) days (one simple every week) .The results are shown in the tables (2).

As the results in table 2, the best mixing that gave the best efficiency was at percentage of the sponge in the mixing media of 34% (The mixing ratio Sand:Sponge was 1:0.5). In general, all chosen mixed ratio have effluent quality that are complied with law 48,year 82 with respect to CODtot &CODsol &T.S.S . However the removal efficiencies were increased as the sponge in the mixing ratio were increased as well.

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	THE mixing ratio between Sand :Sponge	Cod total (in)(mg/l)	Cod total (out)(mg/l)	% removal efficiency	LAW 48	Cod sol (in)(mg/l)	Cod sol (out)(mg/l)	% removal efficiency	LAW 48	T.S.S (IN)(mg/l)	T.S.S (OUT)	% removal efficiency	LAW 48
Day 7	(1:0.5)	110	48	56%	≯ 80	35	24	32%	undefined	125	40	68%	≯50
	(1:0.35)	110	53	52%		35	26	26%		125	48	62%	
	(1:0.23)	110	56	49%		35	27	22%		125	58	54%	
Day 14	(1:0.5)	125	50	60%		44	27	38%		112	30	73%	
	(1:0.35)	125	56	55%		44	31	30%		112	37	67%	
	(1:0.23)	125	60	52%		44	32	27%		112	44	61%	
Day 21	(1:0.5)	100	32	68%		30	17	43%		131	23	82%	
	(1:0.35)	100	17	83%		30	19	37%		131	35	73%	
	(1:0.23)	100	23	77%		30	21	30%		131	40	69%	
Day 28	(1:0.5)	130	34	74%		49	27	45%		95	11	88%	
	(1:0.35)	130	42	68%		49	29	41%		95	21	78%	
	(1:0.23)	130	52	60%		49	32	35%		95	27	71%	

Table 2: Results for run (2)

Run (3):

The target of this run is to study the optimum infiltration rate from three various infiltration rate which were 2, 4, 6 m3/m2/d. (0.096, 0.144 & 0.192 L/m2/hr).

To study the head loss in each column to study the time needed for backwashing the filter to avoid media clogging ,two piezometers were added to each column as shown in the figure (9) to measure the head loss in each column to study the period that the media should be cleaned (the time when the media need to wash) .

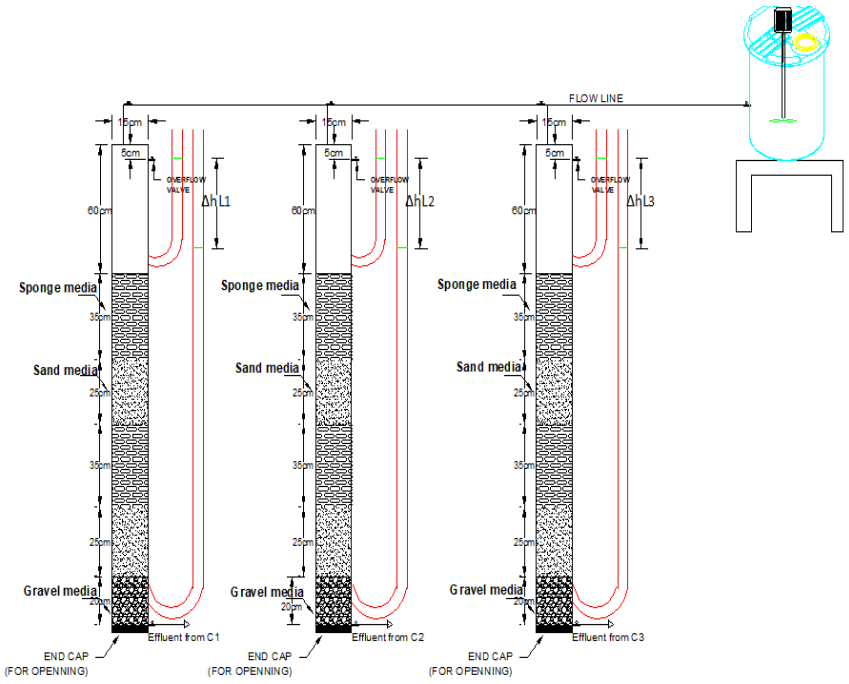

Figure 9: Run (3) for studied the various infiltration rate for sand mixing with Sponge media

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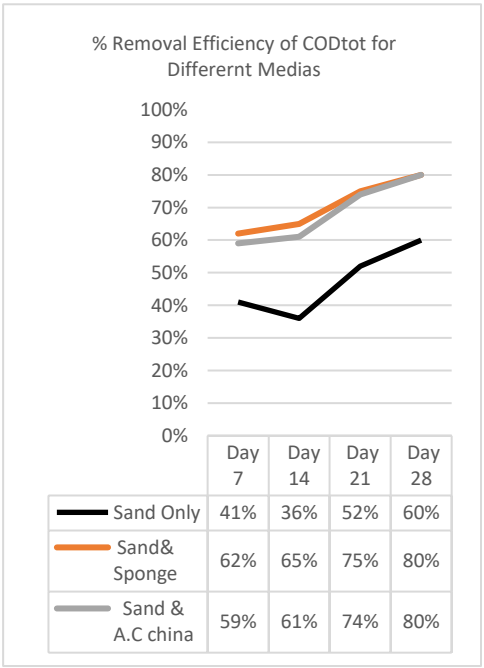
The run was conducted on (28) consecutive days and sampling was collected and analyzed every (7) days (one simple every week) .Results were shown in the tables (3).It was found that IR=2 m3/m2/d. has the best removal efficiency by (2%) and with the least head loss by (59%) from 6 m3/m2/d. The removal efficiencies of CODt and CODsol and TSS for the three runs are shown in the following charts:

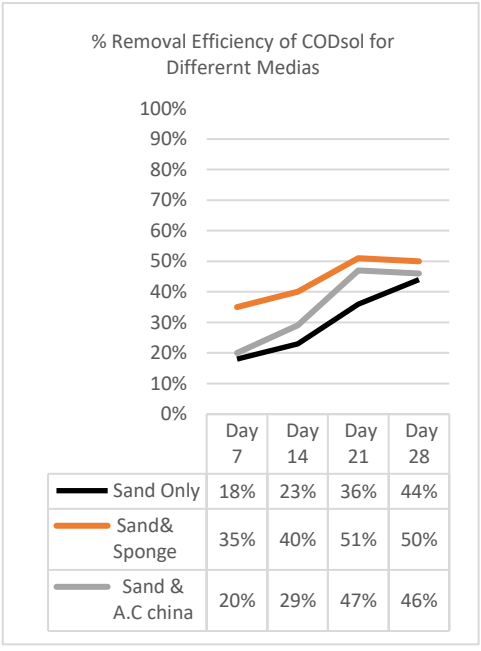
	The infiltration rate ($m^3/m^2/d$)	Cod total (in)(mg/l)	Cod total (out)(mg/l)	% removal efficiency	LAW 48	Cod sol (in)(mg/l)	Cod sol (out)(mg/l)	% removal efficiency	LAW 48	T.S.S (IN)(mg/l)	T.S.S (OUT)	% removal efficiency	LAW 48	Head loss. (ΔhL)
Day 7	2	125	52	58%	⩾80	49	32	35%	undefined	148	44	70%	⩾50	9cm
	4	125	57	54%		49	34	31%		148	52	65%		15cm
	6	125	61	51%		49	36	26%		148	56	62%		18cm
Day 14	2	110	48	56%		40	25	38%		132	33	75%		14cm
	4	110	46	58%		40	25	38%		132	38	71%		24cm
	6	110	51	54%		40	28	30%		132	43	67%		28cm
Day 21	2	135	42	69%		59	33	44%		187	35	81%		23cm
	4	135	46	66%		59	35	41%		187	43	77%		30cm
	6	135	53	61%		59	37	37%		187	52	72%		39cm
Day 28	2	129	33	74%		41	22	46%		180	23	87%		32cm
	4	129	37	71%		41	23	44%		180	32	82%		40cm
	6	129	41	68%		41	24	41%		180	40	78%		48cm

Table 3: Results for run (3)

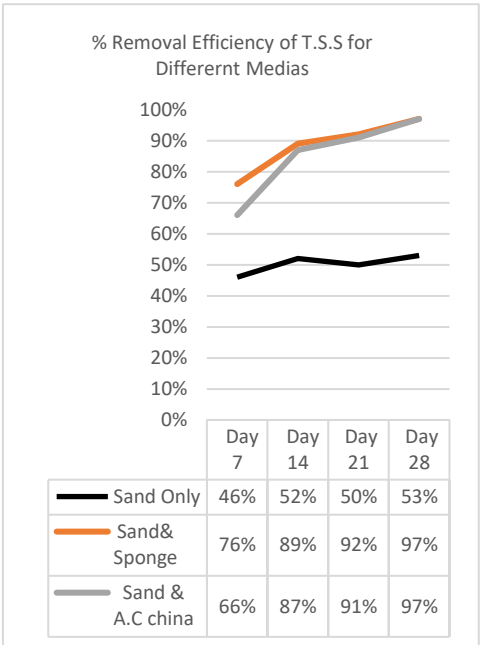


	Day 7	Day 14	Day 21	Day 28
Sand Only	41%	36%	52%	60%
Sand& Sponge	62%	65%	75%	80%
Sand & A.C china	59%	61%	74%	80%

4-The ANALYSIS



	Day 7	Day 14	Day 21	Day 28
Sand Only	18%	23%	36%	44%
Sand& Sponge	35%	40%	51%	50%
Sand & A.C china	20%	29%	47%	46%



	Day 7	Day 14	Day 21	Day 28
Sand Only	46%	52%	50%	53%
Sand& Sponge	76%	89%	92%	97%
Sand & A.C china	66%	87%	91%	97%

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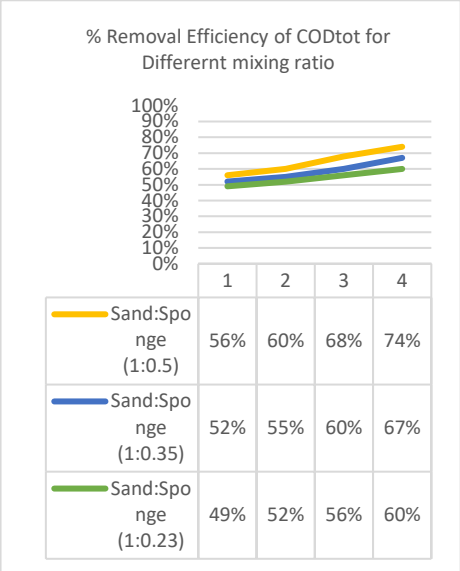
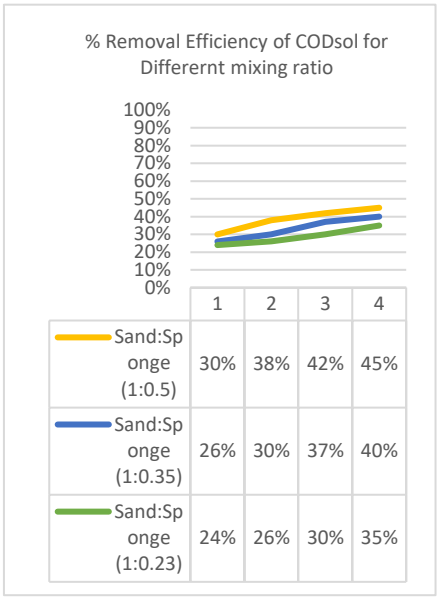
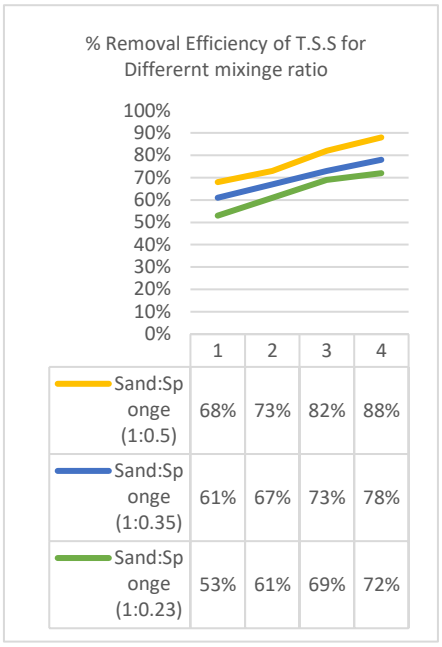


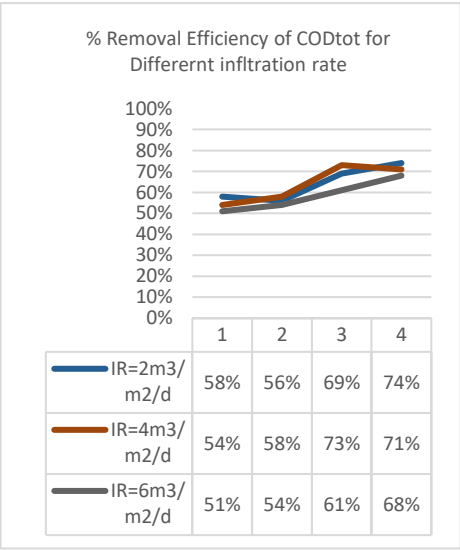
	1	2	3	4
Sand:Sponge (1:0.5)	56%	60%	68%	74%
Sand:Sponge (1:0.35)	52%	55%	60%	67%
Sand:Sponge (1:0.23)	49%	52%	56%	60%



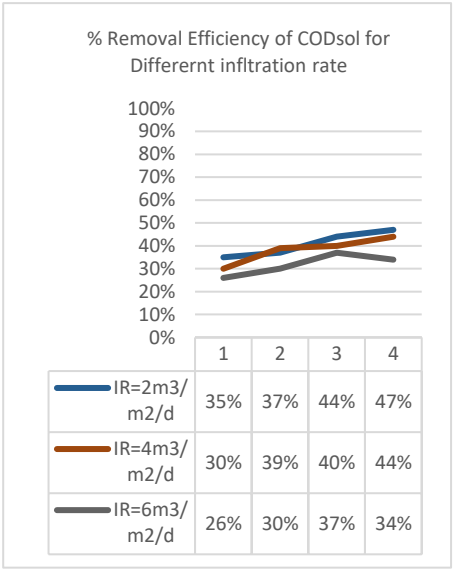
	1	2	3	4
Sand:Sponge (1:0.5)	30%	38%	42%	45%
Sand:Sponge (1:0.35)	26%	30%	37%	40%
Sand:Sponge (1:0.23)	24%	26%	30%	35%



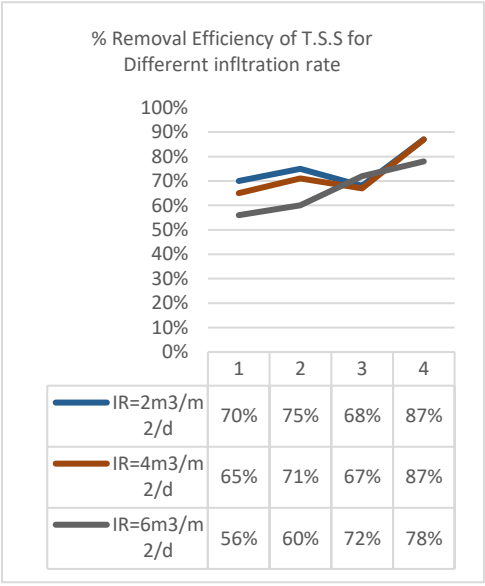
	1	2	3	4
Sand:Sponge (1:0.5)	68%	73%	82%	88%
Sand:Sponge (1:0.35)	61%	67%	73%	78%
Sand:Sponge (1:0.23)	53%	61%	69%	72%



	1	2	3	4
IR=2m3/m2/d	58%	56%	69%	74%
IR=4m3/m2/d	54%	58%	73%	71%
IR=6m3/m2/d	51%	54%	61%	68%



	1	2	3	4
IR=2m3/m2/d	35%	37%	44%	47%
IR=4m3/m2/d	30%	39%	40%	44%
IR=6m3/m2/d	26%	30%	37%	34%



	1	2	3	4
IR=2m3/m2/d	70%	75%	68%	87%
IR=4m3/m2/d	65%	71%	67%	87%
IR=6m3/m2/d	56%	60%	72%	78%

The name of all the Figures according to their titles

5- Conclusion

The sponge mixing with sand media that have the best result in removing the pollutants and least head loss and overflow are found to be with the following characteristics: Sand: Sponge (1:0.35) with infiltration rate 2 m3/m2/d.. These characteristics succeeded to produce effluent quality that can be reused in the irrigation. Also, sponge medium is less cost than the activated carbon.

The high organic and solids removal efficiencies when using sponge medium can be **attributed** to the following reasons:

1-The high amount of biomass that are retained in the small huge number of holes in the sponge are expected to be the reason for expediting the wastewater treatment.

2-The high potential of sponge medium for water retention makes the water treated under longer retention conditions than in another medium.

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