



# The efficiency of the sand filtration unit mixed with different packing materials in drain water treatment in Egypt

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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 has 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 only, sand mixed with sponge, sand mixed with activated carbon and sand mixed with ceramic cylinders have been tested to find the best media combination and optimum mixing sand/ medium ratio and optimum infiltration rate. The work has been done on four runs. It was found that sand mixed with ceramic cylinders gave the best removal efficiency with respect to total chemical oxygen demand and chemical oxygen demand for solution which were 77, 74%, respectively, whereas sand mixed with sponge had the best removal efficiency with respect to total suspended solids which was 89%. Also, all tested media combination had effluent quality that complied with Egyptian law 48 for the year 1982 regarding the disposal of wastewater into agricultural drains (chemical oxygen demand  $\leq 80$  mg/l, total suspended solids  $\leq 50$  mg/l).

**Keywords** Drain water treatment · Belbeis drain · Compact units · Reuse · Sand filter

## Introduction

At present, Egypt is almost completely dependent on the waters of the Nile with a share of 55.5 billion cubic meters per year as indicated (Bedawy 2014; MWRI 2005, 2014). With Egypt's population growing by 1.3 million every year, the need for water for basic human needs and growing crops is rising proportionately (Alnaggar 2003; Swain 2008; Bedawy 2014).

The total water supply is 66 billion cubic meter (BCM), while the total current water requirement for different sectors is 79.5 BCM/year. Consequently, the current water shortage

in Egypt is 13.5 BCM/year and is expected to continuously increase. Currently, this water shortage is compensated by drainage reuse which consequently deteriorates the water quality (Mohie and Ahmed 2016).

Agriculture is Egypt's main water consumer. It is predominantly irrigated and utilizes the bulk of the available water (about 85%) (Mohamed and Hassan 2007), (MWRI 2014). Agriculture production is dominant contributor to economic growth in Egypt, accounting for approximately 20% of the country gross domestic product (GDP). Moreover, around 55% of the population is dependent on this sector for its livelihood (MWRI 2014).

Presently, the vast majority of existing wastewater treatment plants (WWTP) in Egypt discharge into agricultural drains, because the quality of treated wastewater does not allow discharging into canals. This means that the treated water (and the resultant nutrients included in it) is lost for reuse in the agriculture (Rashed et al. 2007).

Wastewater treatment is performed by various methods. Sand filter is one of the most common methods that has been used in wastewater treatment since the early 1800s and has been identified as an easy low-cost option for the removal of

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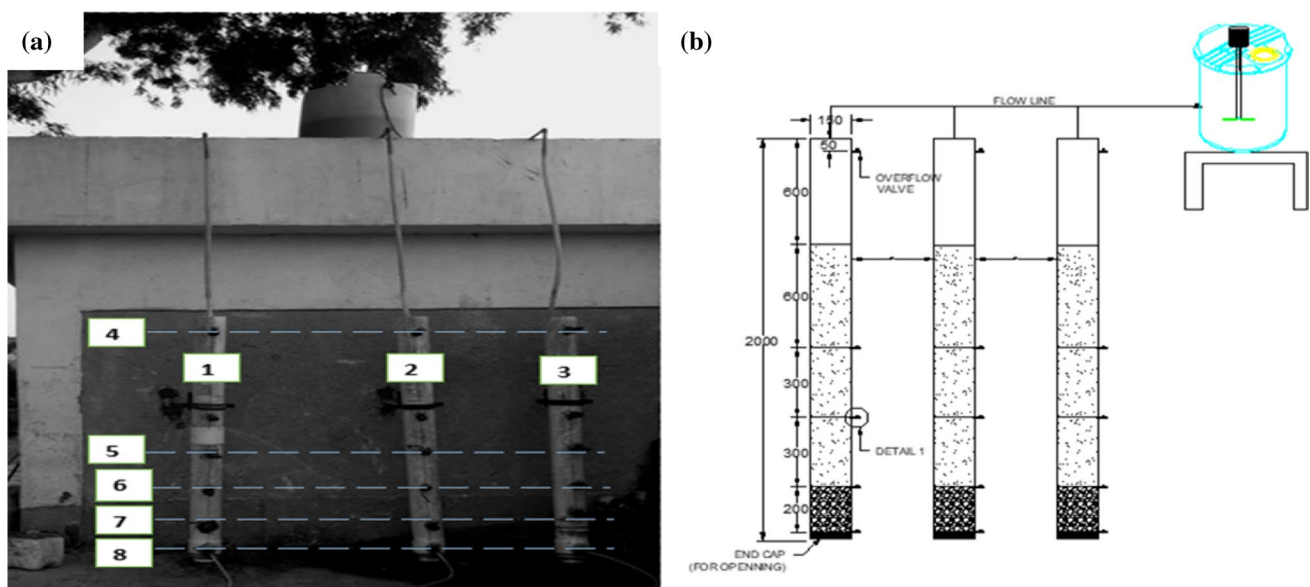
organic and inorganic solids. (Onodera and Syutsubo 2015), (Bryant and Tetteh 2015).

Main features involving sand filter efficiency include the flow characteristics of the wastewater, the load rate and filter design (Huisman and Wood 1974). The load rate is determined by the time of interaction between the water and the surface, and higher loading rates are designed to reduce filtration duration (Huisman and Wood 1974). Kang et al. (2007) have evaluated turkey waste water treatment at three load rates: 66, 132 and 264 L m<sup>-2</sup> d<sup>-1</sup>; they have found that although every rate has equal biological oxygen demand (BOD) and total organic carbon removal, the two higher loading rates have begun to be reduced in efficiency by 10d within the study, whereas the lowest rate has been at an equal level throughout the study of treatment efficiency of continuously submerged flooded flow (horizontal) sand filters left by wastewater only after the powerful introduction of the method. This filter architecture increases the time of interaction between waste and sand inside the filter and preserves anaerobic conditions. Unsaturated (vertical or flow-through) sand filters, in comparison, cause effect to percolate through unsaturated media in air, resulting in a very short period (all other factors being equal) in contact and retention (Sun et al. 2006). The loading cycle of the unsaturated filter design creates alternating conditions of saturation (wetness/oxygen depletion) and aeration (dryness) on the surface of the sand, which could create conditions appropriate for both nitrification and denitrification (Li et al. 2008; Nurk et al. 2009). Typically, when a soil is saturated, all the voids are filled with water and the moisture content is numerically equal to the porosity. The moisture content mainly influences

the downward movement of a solution. Generally lower moisture content, as in sandy soils, provides more movement inside the soil media (Ahmed et al. 2018; Sabry et al. 2010a, b). To treat polluted river water in Iran for drinking (Dastanaie et al. 2007), a horizontal gravel filter with a filtration rate of 1.8 m h<sup>-1</sup> was used and achieved concentration reductions of 90% for total suspended solids (TSS), 94% for fecal coliforms and 16% for iron. These results are comparable to those of Kang et al. (2007) who treated turkey processing wastewater using vertical filtration with layers of coarse sand, fine sand and gravel. Those authors reduced total organic carbon by 94% and BOD5 by 98% at a dosage of 132 L m<sup>-2</sup> d<sup>-1</sup> (Kang et al. 2007). Bosak et al. (2016) constructed a randomized complete block design with four replicates (blocks), each with six filters (24 in total). Each replicate contained all combinations of the two treatments: filter type (saturated or unsaturated) and loading rate (150, 300 or 600 ml d<sup>-1</sup>) (Bosak et al. 2016).

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 has the highest contaminants removal efficiencies and the optimum filtration depth was 140 cm (Ahmed et al. 2018).

Therefore, the main objective of this study is to apply the drain water reuse in agriculture by improving its quality through wastewater 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



**Fig. 1** a The experimental setup of the sand filter, b a schematic diagram for the layout of the experiment setup

treatment, in which the analysis 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 experimental setup is connected to Bilbeis drain in the village of Adliya. Bilbeis drain is one of two branches forming Bahr El Bakr main drain that is ending by Manzala Lake. The experiment was performed from September 1, 2018, to February 1, 2019.

## Material and methods

The influent water was pumped from Bilbeis drain to the experimental setup.

In this study, the optimum design parameters for sand filtration in previous studies were obtained by investigating previous studies (Sabry et al. 2010a, b), (Onodera and Syutsubo 2015), (Ahmed et al. 2018), where the following criteria have been selected as optimum design of sand filtration: sand media with effective size ( $D_{10}$ ) = 0.8 ~ 1.2 mm, infiltration rate of  $4 \text{ m}^3/\text{m}^2/\text{d}$  and filtration depth of 140 cm.



Fig. 2 Photograph of the filtration model

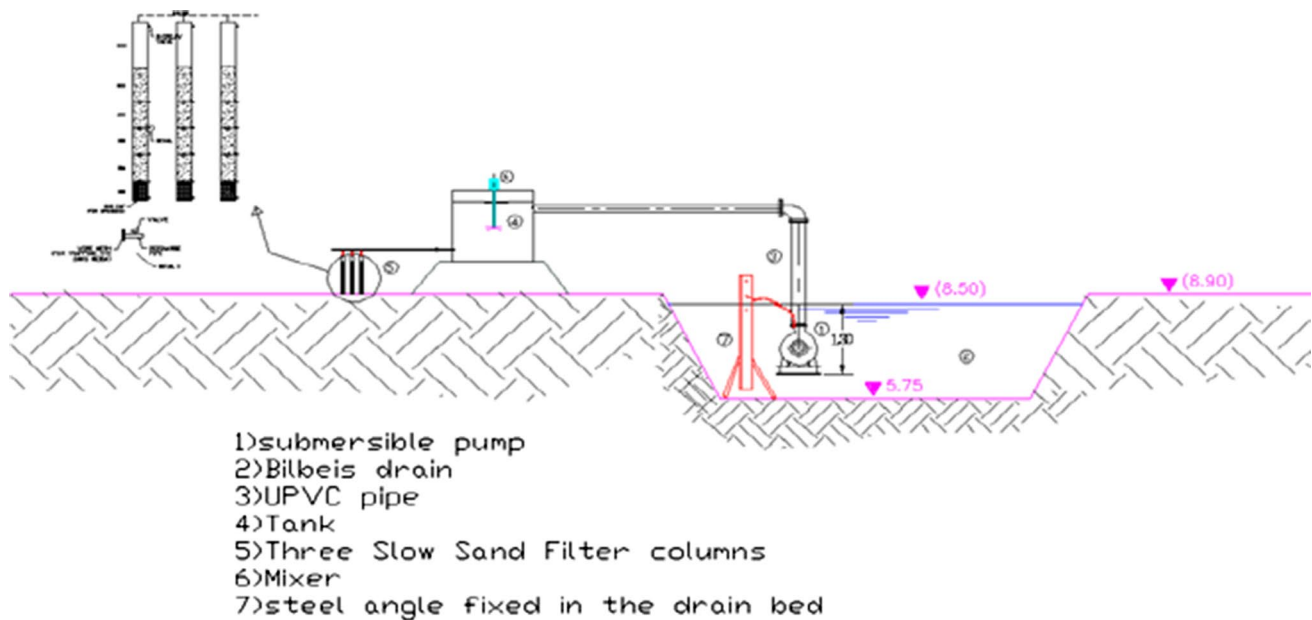


Fig. 3 A schematic diagram of the pilot experiment



**Fig. 4** A sponge packing material



**Fig. 5** The low activated carbon from China



**Fig. 6** Ceramic cylinders

Therefore, in the current experiment, in order to optimize the treatment efficiency, different mixing (and way of mixing) sand ratios with sponge were tested and more filtration

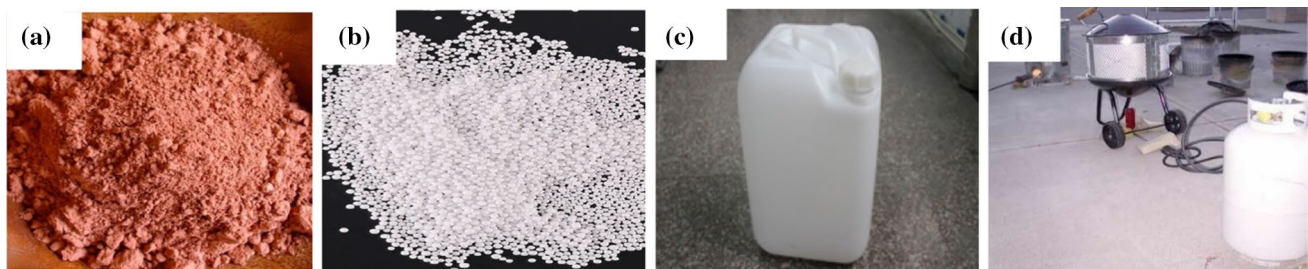
rates are examined. In this study, an experiment activated carbon medium was selected to be tested and compared with sponge medium in the treatment of the agricultural drain water due to its stronger attraction forces than the forces that would hold the contaminants in the water and due to its high surface area for adsorption and its ability to remove a wide range of contaminants (Bryant and Tetteh 2015). Also, sand mixed with ceramic cylinders as a local available media has been tested and compared with other media combinations.

### Experimental setup

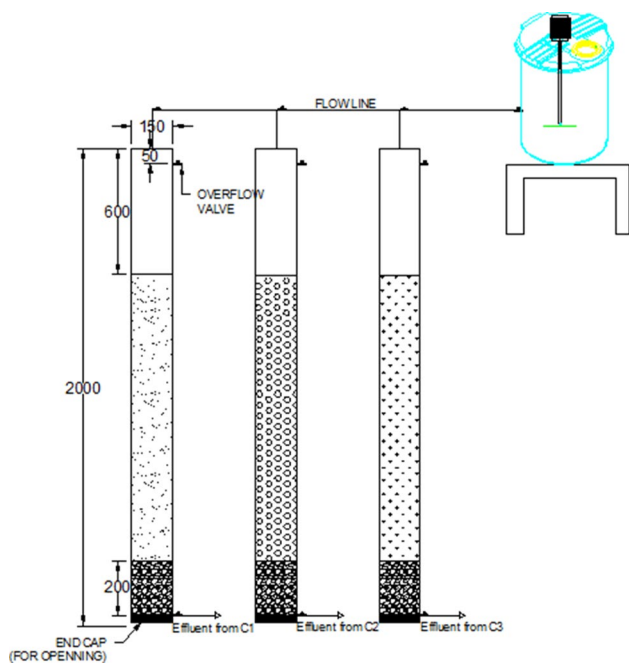
To optimize the design of the unit and investigate the most efficient configuration for the filtration unit, three filtration columns of same diameter and depth have been fabricated. The filtration unit comprises three PVC columns fixed by a structural frame, in which the filtration medium is placed inside and drain water percolates through the medium downward with various flow rates and media mixing ratio as shown in Fig. 1.

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

The 6" PVC pipes were constructed vertically, in which the pipes were filled with 120-cm-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 in order to promote continuity. The head of drain water above the sand not constant depth as the 60 cm was the remains of the column. Due to small voids ratio through the sand layers, the sand media built water depth of more than 60 cm above the sand



**Fig. 7** The raw ingredients used in manufacturing the ceramic cylinders: **a** red clay powder, **b** foam balls (1–3 mm), **c** water, **d** very simple oven

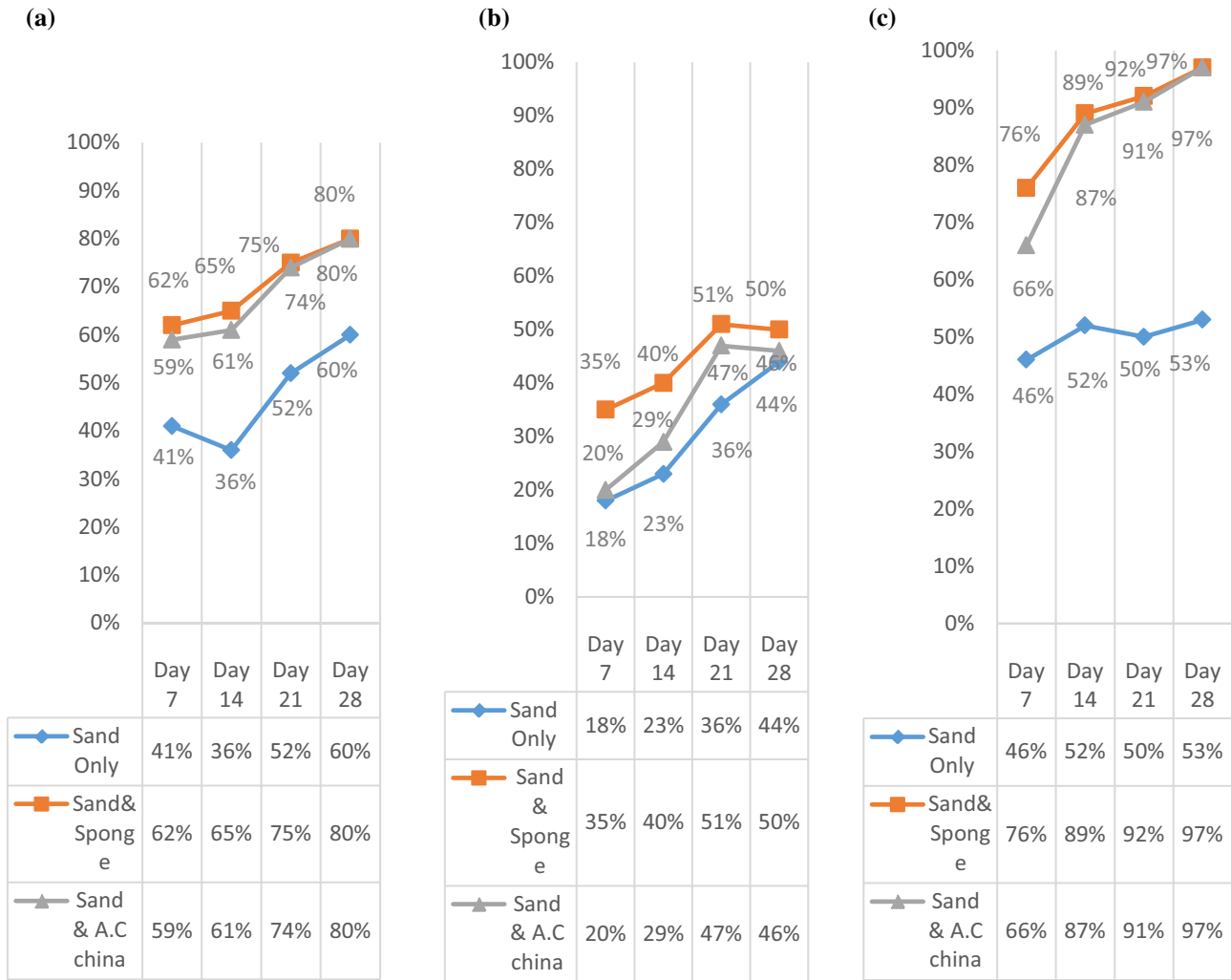


**Fig. 8** The experimental setup for run (1) for optimum composite medium

surface (Angraini 2018). To stabilize the water head above the sand, overflow pipe has been erected at 60 cm above sand layer. 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). The sand filter full construction is shown in Fig. (2). Each column of the three columns of the experimental setup was filled with one type of filtration medium. The column with sand medium was filled by pouring sand in the column in layers. Each layer was compacted before adding the next layer till the desired medium depth was reached. The column with sand and sponge mix was filled by first adding sponge till filling the desired depth of the filtration medium. Then, sand was poured to fill gaps surrounding the sponge media. The column of sand and activated carbon medium was filled by mixing sand and activated carbon at the previously mentioned ratio, and then the mix was poured into the column. The main purpose of the third run is to test the use of ceramic cylinders for improving the performance of the filtration and removal of pollutants from drain water. In this run, three mixing ratios of ceramics and sand were tested. This is in addition to the control which includes sand only. The tested mixing ratios were: sand/ceramics cylinders (1:0.06), (1:0.14), (1:0.27) on volume basis (Fig. 3).

**Table 1** Results obtained from run (1)

	The media	COD <sub>tot</sub> (in) (mg/l)	COD <sub>tot</sub> (out) (mg/l)	% R.E	Law 48	COD <sub>sol</sub> (in) (mg/l)	COD <sub>sol</sub> (out) (mg/l)	% R.E	Law 48	TSS (in) (mg/l)	TSS (out) (mg/l)	% R.E	Law 48
Day 7	Sand only	120	71	41	> 80	80	42	18	Undefined	183	99	40	> 50
	Sand/sponge 1:0.85	100	38	62		20	13	35		30	7	76	
	Sand/sponge 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/sponge 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/sponge 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/sponge 1:0.16	160	32	80		50	27	50		200	6	97	



**Fig. 9** Results obtained from run (1), **a** %R.E. of COD<sub>tot</sub> for different media, **b** %R.E. of COD<sub>sol</sub> for different media, **c** %R.E. of TSS for different media

## Prototype

### The filtration media properties

In the theory of filtration, there are different removal mechanisms that occur in the sand filter. The mechanical straining, the adsorption process and the biological treatment are from the mechanisms that occur in the sand filter (Anggraini 2018). The sponge packing medium was used to study the improvement in mechanical straining process in the mixed media for the removal efficiency. Liyang Nanfang Activated Carbon (L.N.A.C) was used to study the improvement of the adsorption processes in the mixed media for the removal efficiency. The ceramic cylinders (CR) medium was used to study the improvement in the biological treatment in the mixed media for the removal efficiency.

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

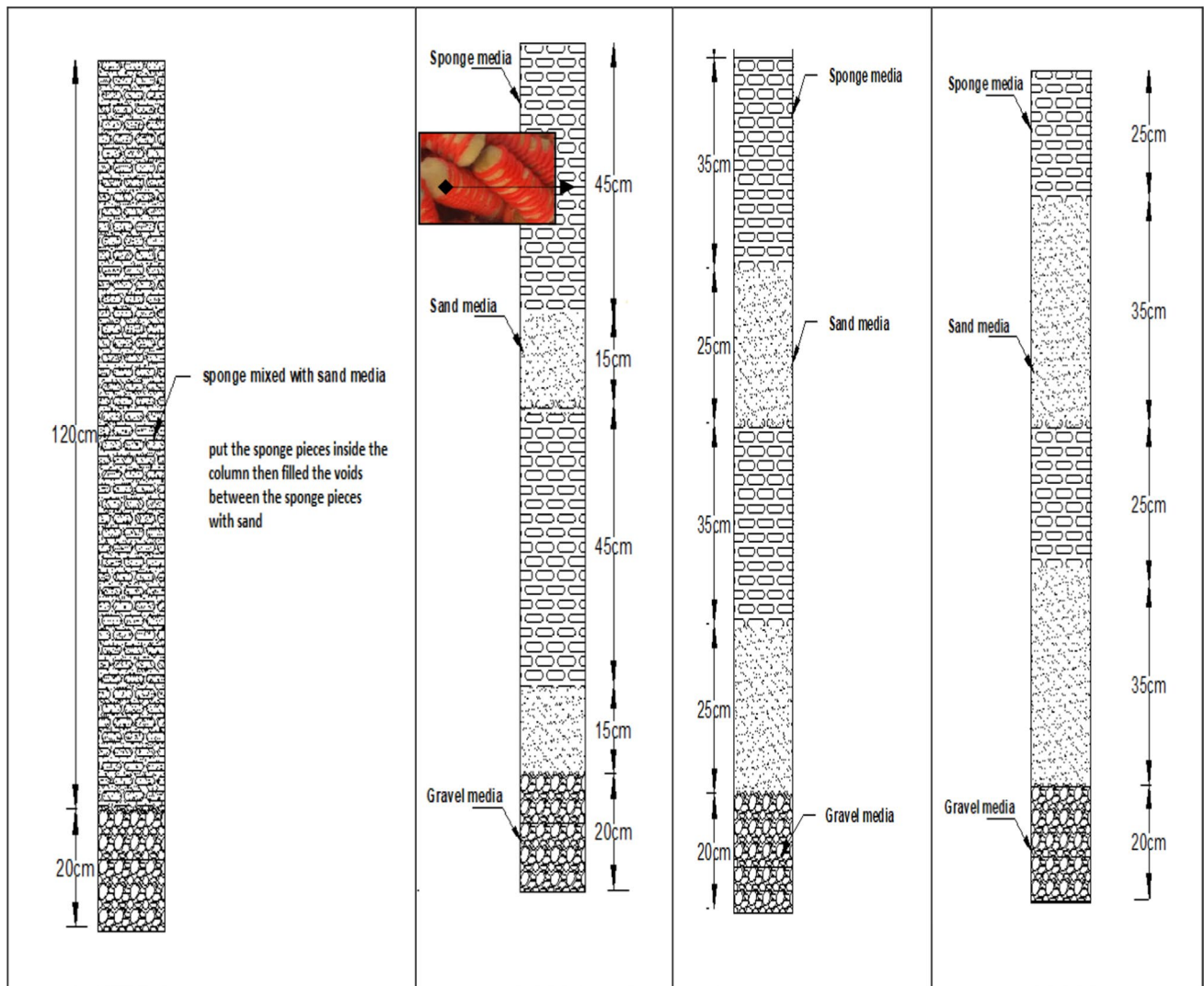
**Sand medium** with effective size ( $D_{10}$ )

$$= 0.8 \sim 1.2 \text{ mm, void ratio } (e) = 0.61, \text{ specific gravity } (Gs)$$

$$= 2.58 \text{ ((permeability } (K) = (D_{10})^2/100 \text{ (m/s) = } 0.008281))$$

### Sponge packing medium

The sponge medium was used as packing material to be mixed with the sand medium. As shown in Fig. 4, the sponge medium with length 5 cm and diameter 1.5 cm was made from polyurethane foam of 30 kg/m<sup>3</sup> and void ratio of 90% of the volume. The material was enclosed in a plastic frame



**Fig. 10** The experimental setup for run (2) for the best efficiency mixing ratio 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

for the purpose of shape retaining and maintaining the normal void ratio of the material.

**Activated carbon commercial product with reasonable cost such as liyang nanfang activated carbon (L.N.A.C)**

As shown in Fig. 5, the activated carbon medium is used to be mixed with the sand media with specific weight of one grain 16.8 gm. Particle sizes: 6 × 12 mesh (3.35—1.70) mm. The uniformity coefficient of this product < 1.7 surface area was 650–800 m<sup>2</sup>/g, Effective size of 1.0 mm and the P.H value from 7 to 8 with density of 480 kg/m<sup>3</sup>.

**Characteristics of ceramic cylinders (CR)**

The ceramic cylinders’ material was used to be mixed with the sand media. As shown in Fig. 6, the material hollow shape allows the sand to be properly mixed with ceramic cylinders to avoid air voids within the filtration column. With length 1.6 cm and diameter 1.6 cm, the BET test showed that surface area was 0.7869 m<sup>2</sup>/g, pore size was 8.96121 nm, and pore volume was 0.004933 cm<sup>3</sup>/g.

**Table 2** Results obtained from run (2)

	The Mixing Ratio sand/sponge	COD <sub>tot</sub> (in) (mg/l)	COD <sub>tot</sub> (out) (mg/l)	% R.E	Law 48	COD <sub>sol</sub> (in) (mg/l)	COD <sub>sol</sub> (out) (mg/l)	% R.E	Law 48	TSS (in) (mg/l)	TSS (out) (mg/l)	% R.E	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	



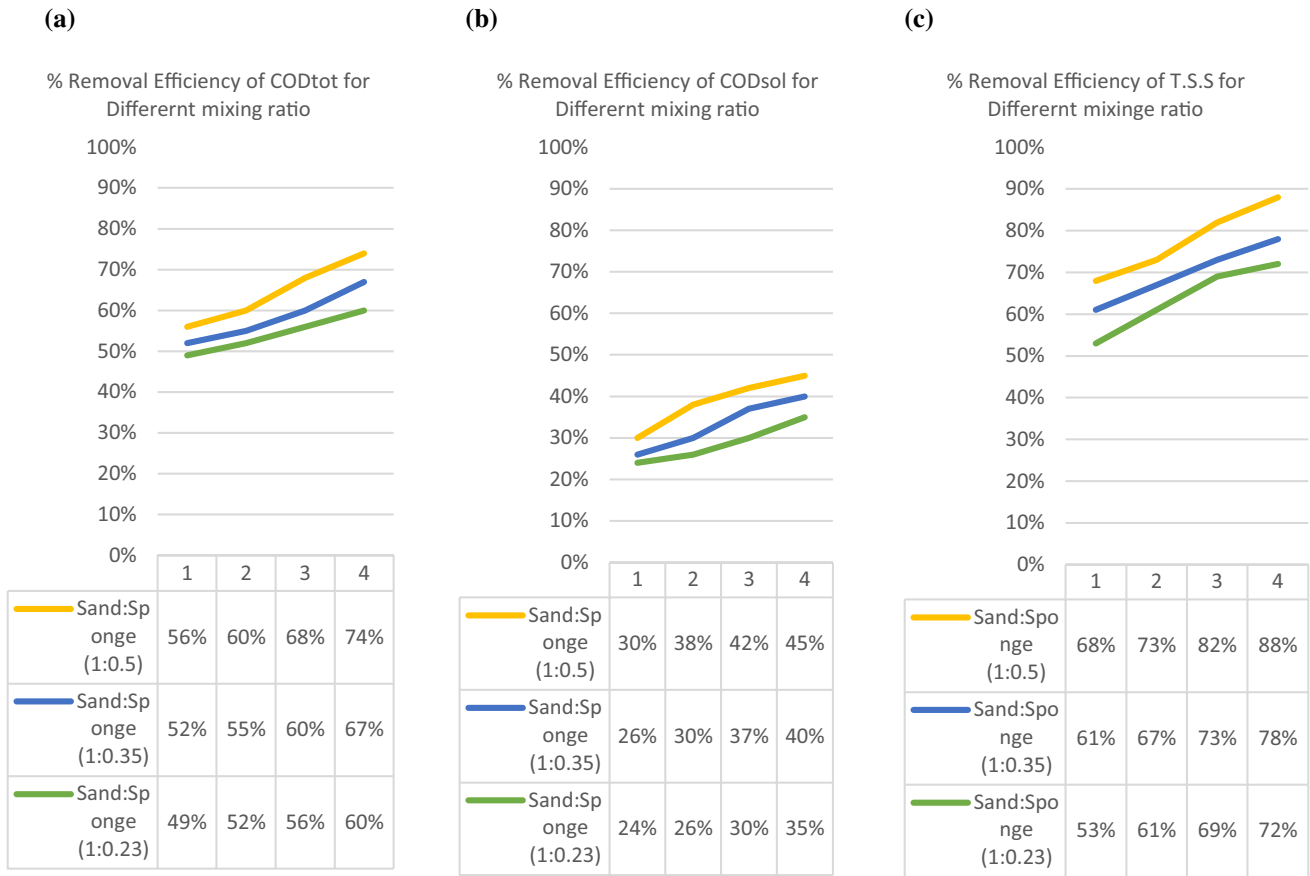


Fig. 11 Results obtained from run (2), a %R.E. of COD<sub>tot</sub> for different mixing ratios, b %R.E. of COD<sub>sol</sub> for different mixing ratios, c %R.E. of TSS for different mixing ratios

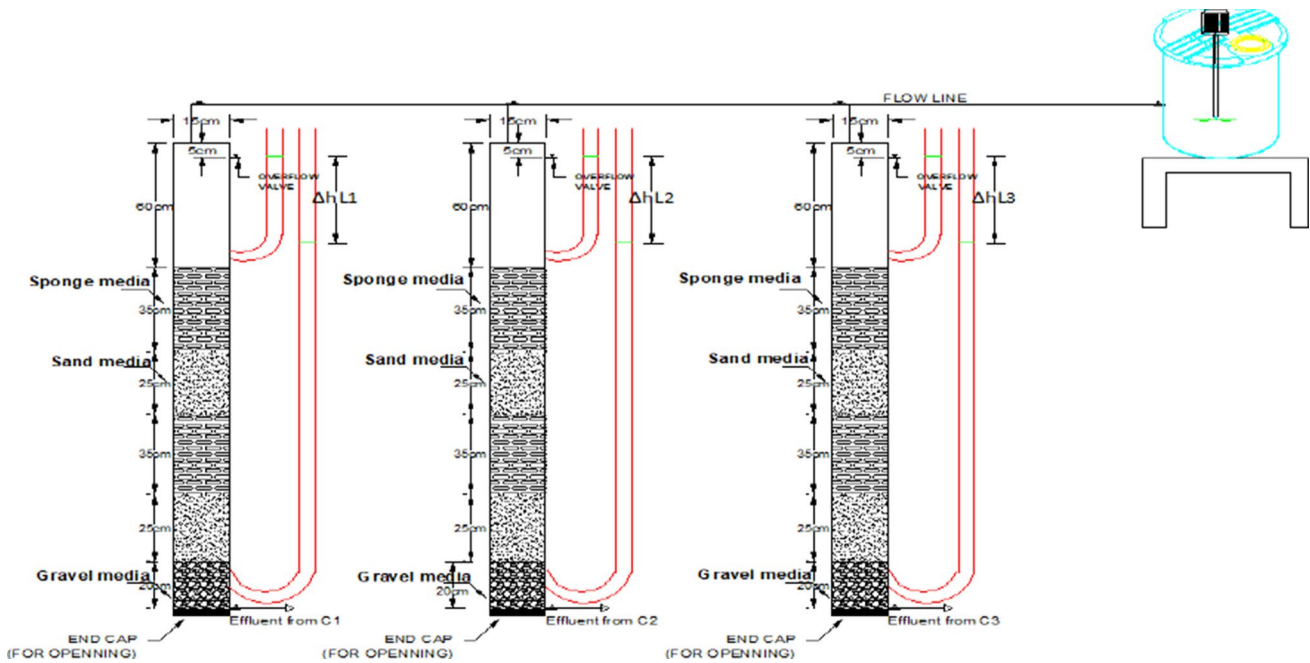


Fig. 12 The experimental setup for run (3) for optimum I.R and the head loss

Table 3 Results obtained from run (3)

	The I.R m <sup>3</sup> /m <sup>2</sup> /d	COD <sub>tot</sub> (in) (mg/l)	COD <sub>tot</sub> (out) (mg/l)	% R.E	Law 48	COD <sub>sol</sub> (in) (mg/l)	COD <sub>sol</sub> (out) (mg/l)	% R.E	Law 48	TSS (in) (mg/l)	TSS (out) (mg/l)	% R.E	Law 48	Head Loss ΔHL (cm)
Day 7	2	125	52	58	> 80	49	32	35	Undefined	148	44	70	> 50	9
	4	125	57	54		49	34	31		148	52	65		15
	6	125	61	51		49	36	26		148	56	62		18
Day 14	2	110	48	56		40	25	38		132	33	75		14
	4	110	46	58		40	25	38		132	38	71		24
	6	110	51	54		40	28	30		132	43	67		28
Day 21	2	135	42	69		59	33	44		187	35	81		23
	4	135	46	66		59	35	41		187	43	77		30
	6	135	53	61		59	37	37		187	52	72		39
Day 28	2	129	33	74		41	22	46		180	23	87		32
	4	129	37	71		41	23	44		180	32	82		40
	6	129	41	68		41	24	41		180	40	78		48



**Fig. 13** Results obtained from run (3), a) %R.E. of COD<sub>tot</sub> for different I.R, b) %R.E. of COD<sub>sol</sub> for different I.R, c) %R.E. of TSS for different I.R

**The ingredients for the red ceramic cylinders**

Fifty kilograms of red clay powder (its commercial name: Aswan red clay powder for pottery) shown in Fig. 7 was mixed with 0.25 kg foam balls (1–3 mm and water).

**Water sample analysis**

Testing for the samples was conducted in the National Research Centre (NRC) water quality laboratories, in which the samples were tested for total chemical oxygen demand (COD<sub>tot</sub>), chemical oxygen demand for solution (COD<sub>sol</sub>) and TSS for the three runs. All analyses were carried out according to Standard Methods for Examination of Water and Wastewater (Mohamed and Hassan 2007). For analysis, the samples were stored in a polyethylene bottle of 1 L volume in the dark at a temperature of 4 °C.

**Results and discussion**

**Study of the most appropriate filtration media**

The target of this run is to study the optimum composite medium from the three media (sand only, sand mixed with sponge and sand mixed with activated carbon sand (L.N.A.C)).

The experimental setup was conducted as shown in Fig. 8.

From Table 1 and Fig. 9, it was found that sand mixed with sponge gave the highest removal efficiency with less price than the activated carbon.

The best mixing that gave the best efficiency was at percentage of the sponge in the mixture media. In general, all chosen mixtures have effluent quality that complied with law 48, year 82 with respect to COD<sub>tot</sub>, COD<sub>sol</sub> and TSS.

**Study of the most efficient mixing ratio between sand mixed with sponge**

As the sponge mixing with sand showed the optimum removal efficiency, the target of this run was to have the

**Table 4** Results obtained from run (4)

	Mixing ratio sand/ ceramic Cylinder	COD <sub>tot</sub> (in) (mg/l)	COD <sub>tot</sub> (out) (mg/l)	% R.E	Law 48	COD <sub>sol</sub> (in) (mg/l)	COD <sub>sol</sub> (out) (mg/l)	% R.E	Law 48	TSS (in) (mg/l)	TSS (out) (mg/l)	% R.E	Law 48
Day 7	1:zero	120	71	41	> 80	80	42	42	Undefined	183	99	46	> 50
	1:0.14	120	40	67		80	32	60		183	64	65	
	1:0.27	120	36	70		80	30	63		183	51	72	
Day 14	1: zero	120	77	46		110	53	52		200	96	52	
	1:0.14	120	40	72		110	30	73		200	62	69	
	1:0.27	120	31	78		110	24	78		200	38	81	
Day 21	1: zero	100	65	52		98	46	53		230	115	50	
	1:0.14	100	35	74		98	27	72		230	69	70	
	1:0.27	100	30	78		98	25	74		230	44	81	
Day 28	1: zero	130	534	60		94	40	57		175	11	53	
	1:0.14	130	33	75		94	21	78		175	49	72	
	1:0.27	130	25	81		94	19	80		175	32	82	

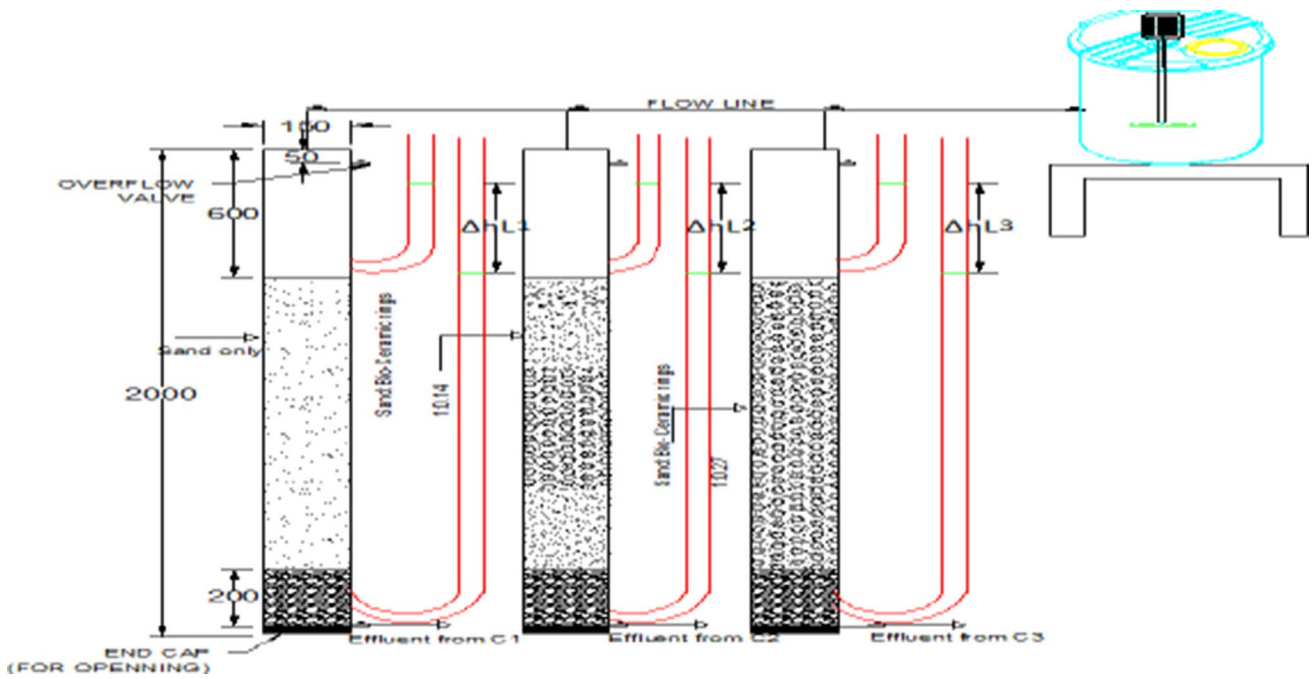


Fig. 14 The experimental setup for run (4) for efficiency mixing ratio between the sand media and ceramic cylinders

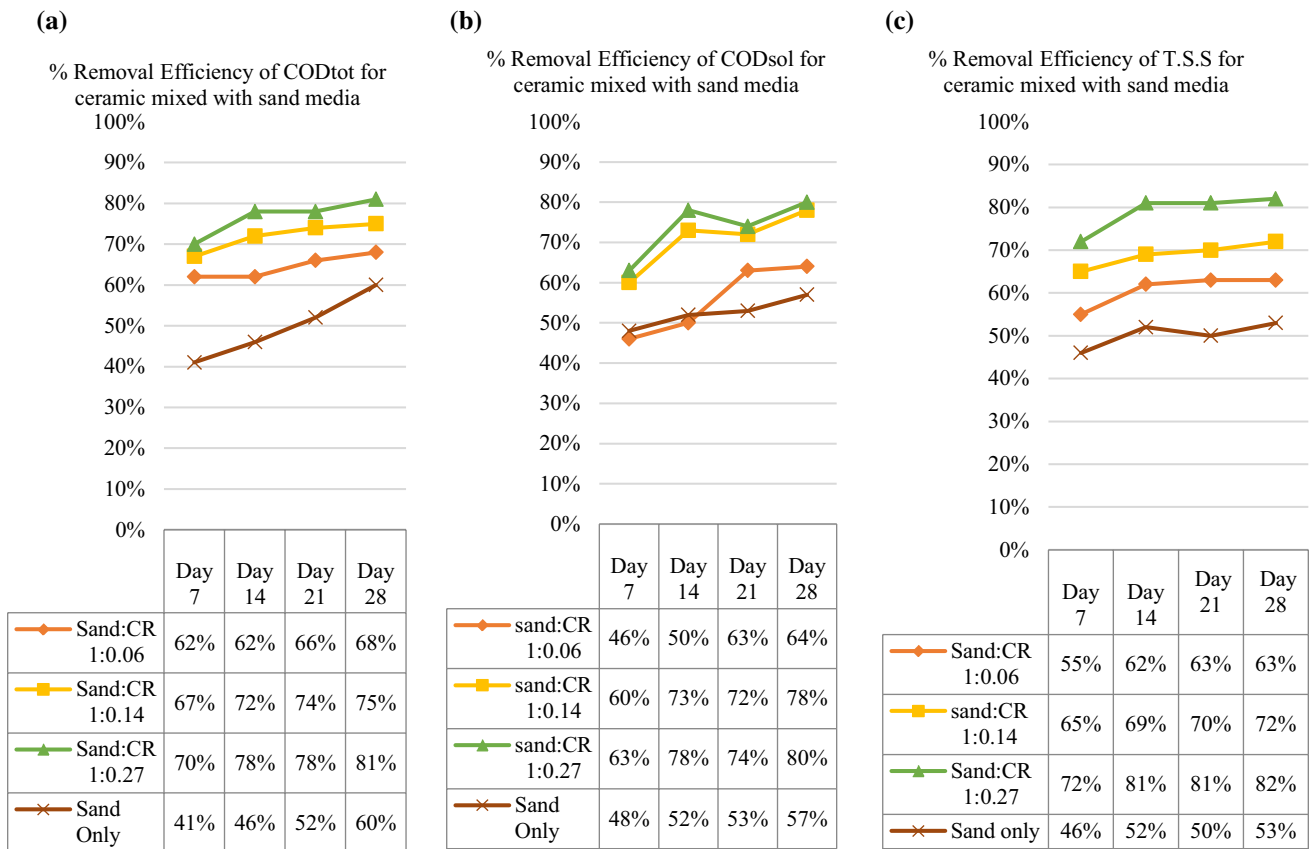


Fig. 15 Results obtained from run (4), a %R.E. of COD<sub>tot</sub> for sand and ceramic cylinder mixture, b %R.E. of COD<sub>sol</sub> for sand and ceramic cylinder mixture, c %R.E. of TSS for sand and ceramic cylinder mixture

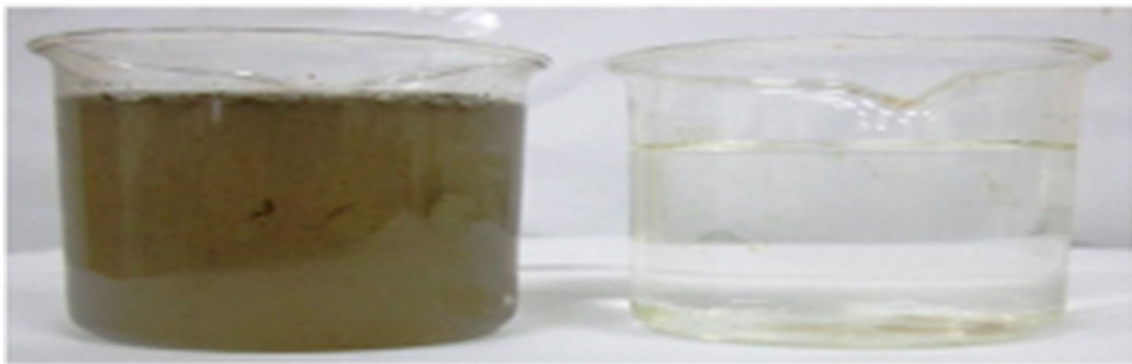


Fig. 16 Color reduction using sand/ceramics cylinders (1:0.27)

The relation between the head loss(cm) and time(days) for various mixing ratio between Sand: Ceramic

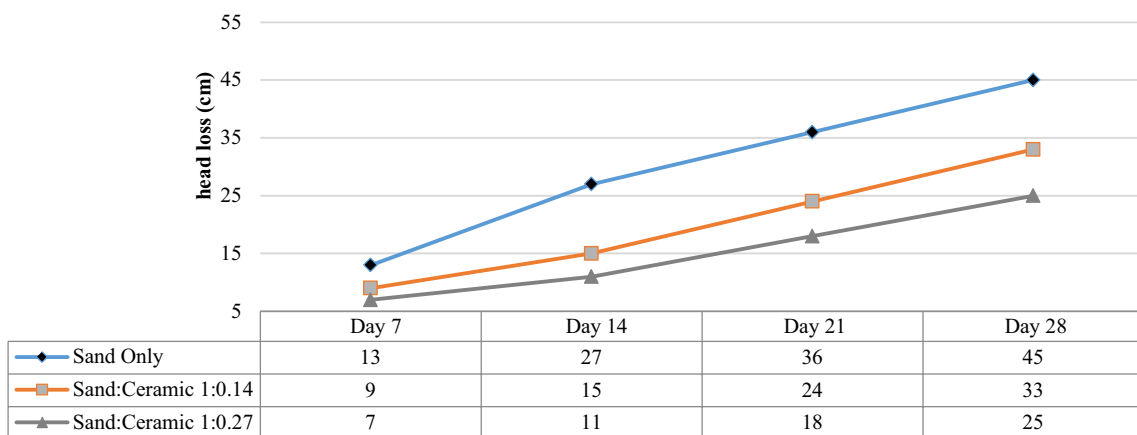


Fig. 17 The relation between the head losses in run 4

Table 5 Comparison among different media mixed with sand

The parameters	Media			
	sand only (%)	Sand/ ceramic cylinders (1:0.27) (%)	Sand/SP (1:0.85) (%)	Sand/ L.N.A.C (1:0.06) (%)
COD <sub>tot</sub>	50	77	70	68
COD <sub>sol</sub>	53	74	46	39
TSS	50	79	89	86

best mixing ratio between sand and sponge media (the sand effective size is:  $D_{10} = 0.8 \sim 1.2$  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 Fig. 10.

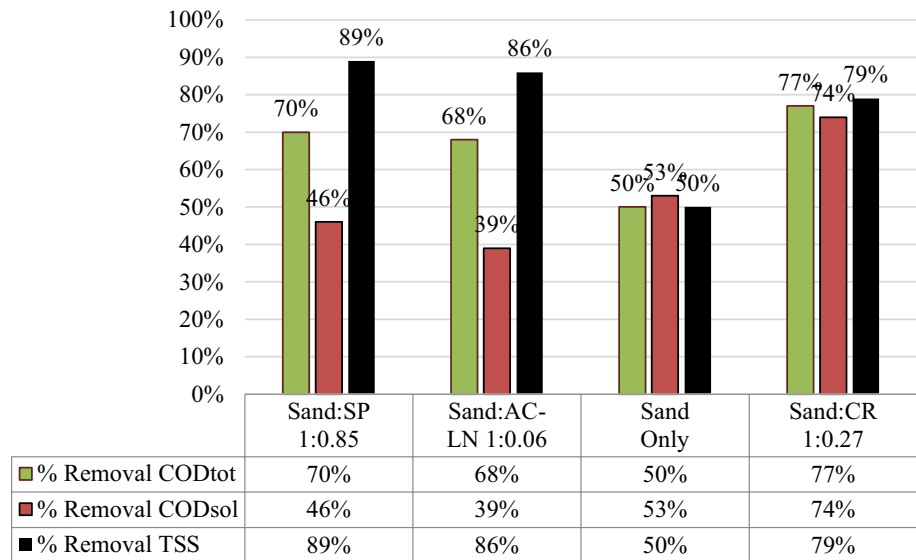
The run was conducted on (28) consecutive days, and sampling was collected and analyzed every (7) days (one sample every week). The results are shown in Table 2.

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 ratios have effluent quality that complied with law 48, year 82 with respect to COD<sub>tot</sub>, COD<sub>sol</sub> and TSS. However, the removal efficiencies were increased as the sponge in the mixing ratio was increased as well (Fig. 11).

Also, it was found that sand mixed with sponge with mixing ratio (1:0.35) gave removal efficiency that complied with law 48, year 82 with respect to COD<sub>tot</sub> and TSS but with less price than the mixing ratio sand/sponge was 1:0.85. So the targeted of the next run was to study the varying infiltration rates 2, 4 and 6 m<sup>3</sup>/m<sup>2</sup>/d (0.096, 0.144 and 0.192 L/m<sup>2</sup>/hr) on the mixing ratio between sand and sponge medium of 1:0.35.

**Fig. 18** Comparison among different media mixed with sand

% Average relation between all parameters for the three medias



CR: Ceramic rings or Ceramic Cylinders  
 SP: Sponge pieces  
 AC-LN: Liyang Nanfang Activated Carbon

**Study of the optimum infiltration rate and the head loss for sand/sponge (1:0.35)**

The target of this run is to study the optimum infiltration rate from three various infiltration rate (I.R) which were 2, 4 and 6 m<sup>3</sup>/m<sup>2</sup>/d (0.096, 0.144 and 0.192 L/m<sup>2</sup>/hr).

Two piezometers were added to each column as shown in Fig. 12 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).

This experiment was conducted to study the head loss in each column and the time needed for backwashing the filter to avoid media clogging.

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 Table 3.

It was found that I.R = 2 m<sup>3</sup>/m<sup>2</sup>/d has the best removal efficiency by (2%) and with the least head loss by (59%) from 6 m<sup>3</sup>/m<sup>2</sup>/d.

**Study of the most efficient mixing ratio between the sand media and ceramic cylinders**

The main purpose of the current run is to test the use of ceramic cylinders for improving the performance of the filtration and removal of pollutants from drain water.

In this run, three mixing ratios of ceramics and sand were tested in addition to the control which includes sand only.

The tested mixing ratio were: sand/ceramics cylinders (1:0.06), (1:0.14), (1:0.27) on volume basis. Operating conditions including rate of filtration and sampling frequencies and procedure were similar to that used in run (2). Also in run 4, piezometers were used to measure the head loss in the filter with as in the schematic diagram in Fig. 13.

It was found that sand mixed with ceramic cylinders with mixing ratio (1:0.27) gave removal efficiency that complied with law 48, year 82 with respect to COD tot and TSS (Table 4, Fig. 14).

It was found that sand mixed with ceramic cylinders with mixing ratio (1:0.27) gave removal efficiency that complied with law 48, year 82 with respect to COD tot and TSS (Fig. 15).

The mixing ratio showed high efficiency in reducing color and odor of the effluent sample (Figs. 16, 17).

**Conclusion**

From pervious experiments, it was found that sand mixed with sponge gave the highest removal efficiency compared with sand only and sand mixed with activated carbon sand (L.N.A.C).

In addition, it was found that sand mixed with sponge with mixing ratio (1:0.35) gave removal efficiency that complied with law 48, year 82 with respect to COD tot and TSS but with less price than the mixing ratio sand/sponge of 1:0.85. So the target of the next run was to study the

varying infiltration rates 2, 4 and 6 m<sup>3</sup>/m<sup>2</sup>/d (0.096, 0.144 and 0.192 L/m<sup>2</sup>/hr) on the mixing ratio between sand and sponge medium of 1:0.35.

Also, it was found that I.R = 2 m<sup>3</sup>/m<sup>2</sup>/d has the best removal efficiency by (2%) and with the least head loss by (59%) from 6 m<sup>3</sup>/m<sup>2</sup>/d.

Finally, sand mixed with ceramic cylinders with mixing ratio (1:0.27) gave removal efficiency that complied with law 48, year 82 with respect to COD<sub>tot</sub> and TSS.

From the last comparison in Table 5 and Fig. 18, it was noticed that although the sand/ceramic cylinders (1:0.27) had the highest removal than other media combination with respect to COD<sub>tot</sub> and COD<sub>sol</sub>, the sand/SP (1:0.85) had higher removal with respect to TSS. This can be attributed to the following:

- (1) The components (ingredients) of the ceramic increase the solid particles in the water as it was made from red clay powder; this is maybe the reason for increase in the TSS in the collected water samples which used ceramic cylinder media.
- (2) The solid shape of the ceramic cylinder with sharp edges increases the ability of channeling around the ceramics which decreases the TSS removal.
- (3) Bacteria formation can clog the small bore size in the sponge which reduces the biological activity than that in the ceramic.

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## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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