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DESIGNING AND TESTING OF A NEW PROPOSED FILTER TO IMPROVE THE FILTRATION PROCESS IN MODERN IRRIGATION SYSTEMS

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ABSTRACT: The traditional sand filter which used strictly in modern irrigation system as a gravity flow system requires at least 1.2 m hydraulic head. Designing and testing of a new proposed filter is the main objective of this study, besides comparing its performance with the performance of the traditional sand one. the study conducted with two irrigation water levels different in quality which were Nile water and the mixed agricultural drainage water at two levels of water flow rate inside the filter (5 and 7 $m^3.h^{-1}$). The new proposed filter comprises separately three types of filtration media; one contains gravel layer of 13 cm thickness and mixed gravel and sand layer of 13 cm thick, the second media contains the same two layers besides a sand layer of 13 cm thick, while the third media contains another layer of mixed gravel and resin with 11 cm thick. The highest removal efficiency of 95.7% was recorded with the new proposed filter at 5 $m^3.h^{-1}$ of Nile water flow rate, with the filtration media that contains four layers (gravel, mixed gravel and sand, sand only and gravel mixed with resin). The lowest removal efficiency of 72.04% was recorded with 7 $m^3.h^{-1}$ of mixed agricultural drainage water flow rate with the traditional sand filter. The lowest pressure drop (3.75 kPa) was recorded with the new proposed filter after 900 h of operating times at 5 $m^3.h^{-1}$ of Nile water flow rate.

Key words: Traditional sand filter; the new proposed filter; removal efficiency; pressure drop; mixed agricultural drainage water; resin; the filtration media; flow rate.

INTRODUCTION

Filtration process is the separation process of removing solid particles, microorganisms or droplets from a liquid or a gas by depositing them on a filter medium which also called a septum, that is essentially permeable to only the fluid phase of the mixture being separated. The particles are deposited either at the outer surface of the filter medium and/or within its depth. The permeation of the fluid phase through the filter medium is connected to a pressure gradient (Ripperger *et al.*, 2012).

Filtering mechanisms can be divided into screen and disc filters, classified as mechanical or surface filter elements, where the filtering process is based on the principle according to which the pores of the filtering medium are smaller than the diameter of the particles that have to be filtered; and as granular or sand filters, where the particles that must be retained are smaller than the pores of the element, but retention of these particles is achieved by physical and chemical processes (Adin and Alon, 1986).

Sand filters are frequently used in micro-irrigation especially when water contains large amounts of organic contaminants. This type has the advantage of its simplicity and that the main filtration mechanism is based on filtration depth, giving an additional removal capacity in comparison with screen or disc filters, which essentially work by surface filtration (Arbat *et al.*, 2014).

Removal efficiency varies among filtration bed layers in function of filtration rates (ratio between filtration flow and surface area of the filtration sand bed) and sand particle sizes. A filtration rate was recommended between 36 and 61.2 m^3 m^{-2} h^{-1}. Low filtration rates form preferential pathways, resulting in a low particle removal. On the other hand, high filtration rate values cause excessive fluid turbulence within

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the filter, causing surface movement of the filter bed, changing the hydraulic behavior of the equipment, and reducing filtration area and removal efficiency (Phillips, 1995).

The mixing regime of both solid and liquid is extremely good within the units providing conditions conducive to effective suspended solid and nutrient removal. Bed movement appears to be constant and represents a good mixing regime suggesting that the units will operate in an effective manner if good maintenance practices are followed. Biological treatment performance evaluation of the units is also under development (Loffill *et al.,* 2009).

Sand filter media must be cleaned properly after each filter cycle to remove all deposited matter. Inadequate cleaning leads to the accumulation of material within the filter bed in any form. "Mud balls", as one such form, are agglomerates of grains of filter material, fine silt or clay, and flocculated material that are held together with adhesive matter that may be of chemical or biological origin. Mud balls start forming when gelatinous solids accumulate on the exterior of media grains (Arendze, *et al.*, 2010).

The modified sand filter consisted of sand, course sand and activated carbon prepared from rice husk and coconut shells. After 10 weeks of treatment, the results showed that the concentration of Biochemical Oxygen Demand BOD, Chemical Oxygen Demand COD, Suspended Solids SS, Ammoniacal Nitrogen AN, turbidity and pH were reduced up to 86%, 84%, 63%, 88%, 73%, respectively while pH nearly to neutral with a value of 6.83. Moreover, the results also revealed that the sand filter added with rice husk almost complied with Standard B of Malaysia Environmental Quality (Sewage) Regulations 2009 as well as gives the highest number of Water Quality Index WQI of 36.81. Overall, WQI obtained in this study are ranged from 12.77 to 36.81 (Saad *et al.,* 2016).

The main objectives of this work were: Study the possibility of overcome the disadvantage of the traditional sand filter using a new proposed filter, Evaluate the performance of the new proposed filter from the point of view of the pressure drop, filter removal efficiency and with respect to the performance of the new proposed filter at two levels of irrigation water quality the comparison with the performance of the traditional sand filter will be carried out.

MATERIALS AND METHODS

Theoretical basis for designing the new proposed filter

The proposed filter was designed mainly to achieve a higher filtration efficiency comparing with the traditional sand filter. Besides the higher efficiency the proposed filter was designed and tested to estimate the total filtration cost for either fixed or operating cost. The filtration process with the proposed filter was based on separating the residuals that the irrigation water contains across a series of modified cylindrical plates obstructed the water flow direction. Designing of the proposed sand filter involves several steps which include:

Filter surface area

The required filter surface area (A) in m^2 was calculated using the formula below (Phillips, 1995):

$$A = \frac{Q_{one}}{F_R} \qquad (1)$$

Where;

Q_{one}= Flow into the filter, ($m^3.h^{-1}$. per filter); and

F_R. = Filtration rate, ($m.h^{-1}$).

Assuming that the optimum value of the filtration rate ($F_{.R}$) is 75 $m.h^{-1}$ according to (Phillips, 1995); at the first tested level of flow rate (5 $m^3.h^{-1}$), A= 0.066 m^2 which represented 58 cm height and 11.5 cm width, at the second tested level of flow rate (7 $m^3.h^{-1}$); A= 0. 093 m^2 which represented 71.5 cm height and 13 cm width.

Design steps for estimation of sand and gravel sizes

The required minimum thickness by (Hudson formula, 1948)

$$F_R \times {d_{eq}}^3 \times \frac{H}{L} = B_i \times 29323 \qquad (2)$$

Where;
d_{eq} = Sand size in (mm),
H= Terminal head loss in (m);
B_i = breakthrough index whose value ranges between $4*10^{-5}$ and $6*10^{-3}$ depending on response to coagulation and degree of pre-treatment in filter;
L = Thickness of sand or gravel bed (m); and
29323= coefficient of sand size ($m^4.h^{-1}$). (sand size = 3.94 mm and gravel size = 9.84 mm);

Using the following equation, the thickness of sand bed (L) can be derived, while the value of the equivalent diameter can be calculated from the following equation (Bové *et al.*, 2015):

$$d_{eq} = \emptyset_s \times d \qquad (3)$$

Where;

d_{eq} = the equivalent diameter(mm);

d = the measured diameter (mm) and

$\emptyset_s$ = the correction factor of diameter shape, between sharp and angular grain and it equal approximately to 0.8.

As for the calculation of the pressure drop (Δp), it describes by the Kozeny-Carman equation in a bed of granular material (Fitzpatrick and Gregory, 2003), as:

$$\frac{\Delta p}{h} = \frac{5(1-e)^2}{e^3} S^2 \mu V \qquad (4)$$

Where;
Δp is the pressure difference across a bed of depth h (Pa).
e is the porosity of the media.
S is the specific surface area per unit volume of grain = 6/d for spheres diameter d,
μ is the absolute (or dynamic) viscosity of water (Pa. s), and
V is the approach velocity of the water at the bed surface ($m. s^{-1}$).

Computation of the total length of filter tank

The total length of filter tank (T_f) in cm can be calculated by the following equation (Cleasby, 1960):

$$T_f = W_m + T_m + T_d. \qquad (5)$$

Where;
W_m= Water place movement (cm);
T_m= Thickness for all media layers (cm);
T_d= Thickness of under drain (cm).
Total designed length of filter tank is 120 cm.

Diameter of grain media

The hydraulic pore diameter (dh) is a function of both porosity (ε) and the volume of solid mass as presented in the following equation (Carman, 1937):

$$d_h = 4\,\frac{\varepsilon}{(1-\varepsilon).S_v} \qquad (6)$$

Equation (7) used in computing the volume of solid mass (S_v). Therefore, in case of a spherical particle system one can write (Ripperger *et al.*, 2012):

$$S_v = \frac{6}{d_s} \qquad (7)$$

d_s = diameter of grain media.

Total pressure and the required material

Total water pressure in the filter = static pressure + dynamic pressure come from the pump.

The static pressure can be calculated as follows (Bové *et al.*, 2015):

$$w = \gamma_w \times h \qquad (8)$$

w = static pressure ($kN.m^{-2}$);

γ_w = specific weight of water (10 $kN.m^{-3}$);

h = height of the filter based on the design (0.8 m);

w= 8 kN/m^2 and operating pressure(dynamic) = 100 $kN.m^{-2}$

Total pressure = 108 $kN.m^{-2}$

Based on the above-mentioned equation, a sheet of an iron was selected to tolerate the calculated pressure which equal to 108 $kN.m^{-2}$. Figure (1) shows pressure distribution inside the filter box.

Description and composition of the proposed filter

The proposed new filter as shown in Figure (2) consists of a pressurized vessel that is a cuboid in shape with circular bevels on all sides of the corners. Inside that vessel, four modified cylindrical plates are placed a separate bed to allow the water to be filtered through. These modified cylindrical plates have a special lane that the media was placed inside these cylindrical plates and have many opposite mesh holes. After the water passes through the cylindrical plates, it goes towards drainers which installed on a metal plate to come out through then the filtered water goes towards the irrigation network.

On the body of the external filter, pressure gauges are installed to measure the pressure after each stage of the filtration process and each layer of the proposed filter. Figure (3) showed the three sectional views besides, the movement of water inside the proposed filter. Drains which fixed in the filter have a discharge of $1m^3.h^{-1}$. It consists of rectangular slots, oriented in vertical planes and truncated conic surface.

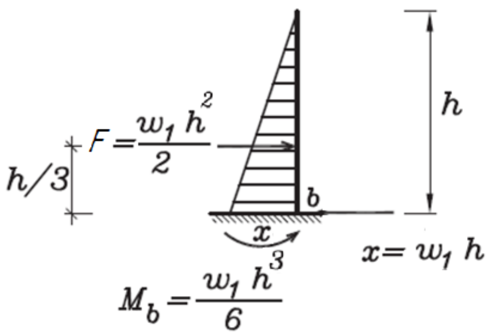

Fig (1) Pressure distribution inside the filter column.

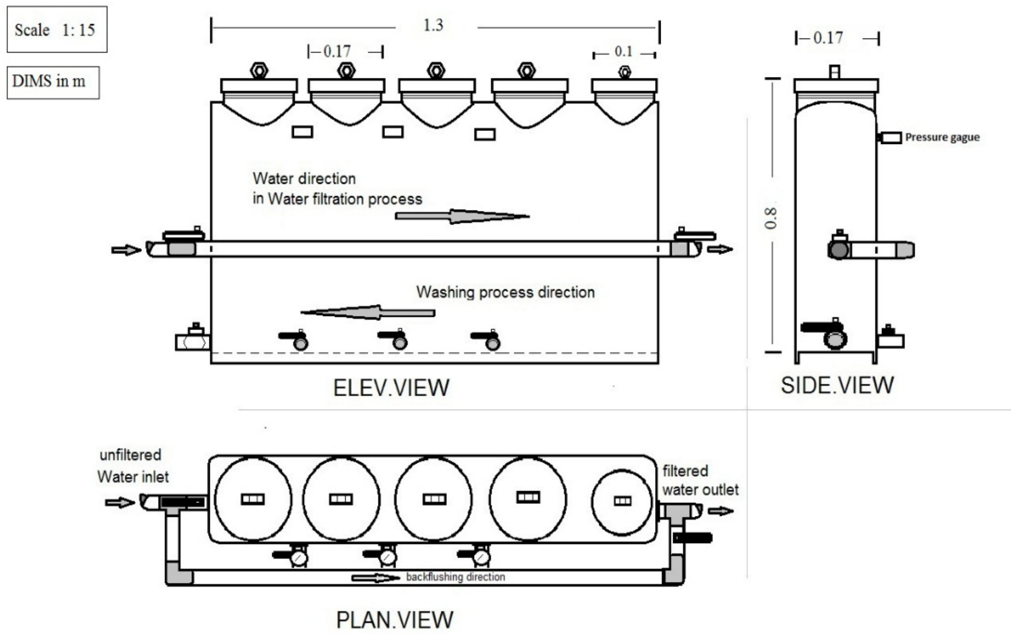

Figure (2): The three views and dimensions of the proposed filter.

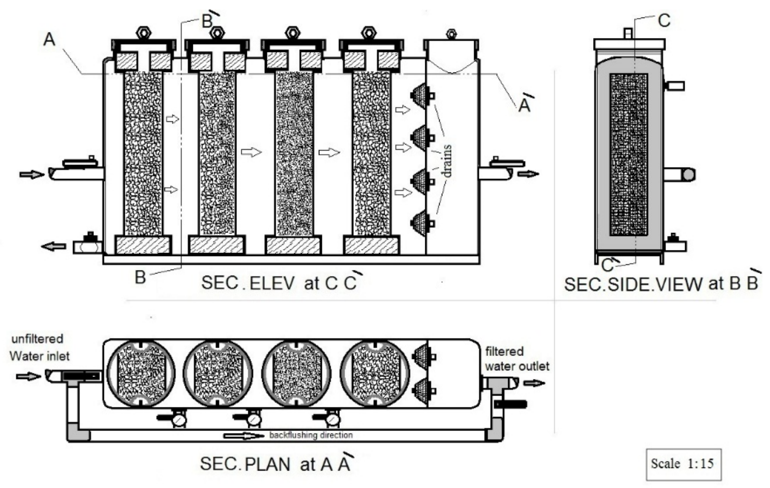

Fig (3): Sectional views of elevation, side view and plan with the water movement across the proposed filter.

Assembling of the proposed filter

The manufacturing process does not depend only on the design of the filter dimensions and the size of the media used, but on the pressure inside the filter that must be taken into account during the operation process. Consequently, there wasn't explosion or damage to the filter body, so it was necessary to choose the appropriate material and thickness to withstand the pressure inside the filter. Figure (4) represents the stage of manufacturing the new proposed filter. The manufacturing took place in the workshop attached to the Mit Khalaf station Menoufia governorate for agricultural equipment.

Filter removal efficiency (R_E)

The removal efficiency (R_E) of the total suspended solids (TSS) from the water was determined according to equation 9 (Mesquita *et al.*, 2019).

$$R_E = \left(1 - \frac{Tss_{out}}{Tss_{in}}\right) \times 100 \qquad (9)$$

R_E = removal efficiency of the total suspended solids from water (%)

Tss_{out} = outlet concentration of total suspended solids (mg L^{-1})

Tss_{in} = inlet concentration of total suspended solids (mg L^{-1})

Total suspended solids (Tss_{total}) across all duration of the filtration process can be expressed as follows:

$$Tss_{total} = F_R \times A \times t \times \overline{Tss} \qquad (10)$$

F_R = filtration rate ($m^3m^{-2}h^{-1}$);

A = filter cross sectional area (m^2);

t = duration of the filtration process (h); and

$\overline{Tss}$= average values of total suspended solids (Tss) that entered during the filtration process (mg L^{-1}).

Experimental site

The present work was conducted in the laboratory of Agricultural Engineering Department, Faculty of Agriculture, Menoufia University during 2020/2022.

Traditional sand filter

The traditional sand filter was used in this study to compare the filtration performance obtained by the new proposed filter with that obtained by the traditional sand filter. The sand filter was 70 cm high and was 30 cm in diameter. The filter bed media contains a layer of 5 cm gravel grain for a break around the nozzles, then the second layer contains 10 cm merged sand with gravel and the last layer contains only 15 cm sand. The filter included 5 and 7 nozzles one $m^3.h^{-1}$ (according to filter discharge) which made of poly vinyl chloride (PVC) with 4 cm height and 5 cm diameter with 1.5 cm water outlet in the second room and the nozzle slot is 1 mm. Figure (5) represents the three views of the used traditional sand filter.

Fig (4): Manufacturing process stages for the new proposed filter

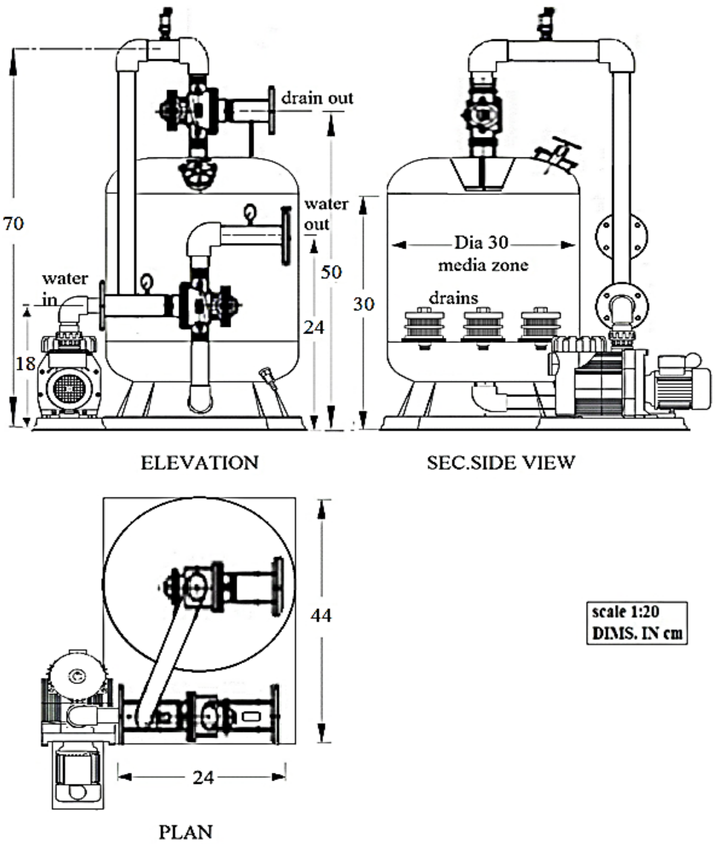

Fig (5): Elevation, plan and sectional side view of the used traditional sand filter with its components and dimensions.

Experimental treatments

Two levels of irrigation water quality were tested which were: Nile water and mixed agricultural drainage water (physical treatment by mixing by the drainage water a ratio of 1:1 with Nile water). Agricultural drainage water was taken from kafr-Elmeselha drain, Shebin el-Kom, Menoufia, Egypt. The study was carried out under two levels of water discharge inside the filter (5 and 7 $m^3.h^{-1}$), three different filtration medias were tested, the first (gravel+ mixed of sand and gravel), second (gravel+ mixed of sand and gravel + sand only) and third (gravel + mixed of sand and gravel + sand only + mixed of gravel and resin). For each treatment, the system was operated at 100 kPa pressure. Each level of the irrigation water quality included six treatments and each treatment contains three lateral lines having long path emitter (in line) with a discharge of 6 $L.h^{-1}$ as a replication as shown in Figures (6) and (7). The percent of emitter clogging will be computed according to the average value of emitter discharge for each treatment. Also, lettuce Plant with its total roots and leaves weight will be considered as an indicator of the degree of water filtration efficiency.

Drip irrigation system

A drip irrigation system was constructed outdoor and used to evaluate its hydraulic performance under the tested filtration medias of the new proposed filter. The used drip irrigation system had the possibility of changing the tested filtration media according to the tested treatment. The control head depends on the irrigation water resource which was a tank with one m^3 volume. Each individual type of irrigation water (Nile water and mixed agricultural drainage water) was carried out separately with its treatments. The main line was made of galvanized iron and was located between the tank outlet and the pump inlet with an inner diameter of 38.1mm. An Italian electric motor (0.88 kW and 1800 r.p.m.) with a centrifugal pump were used for sucking the water from the tank and delivered it to the drip system, which connected with the proposed filter on the pulley vinyl chloride (PVC) sub-main line, with 25.4mm diameter and 3m in length. The sub-main line was connected with three lateral lines for each treatment and each lateral line considered a replication and made of Poly Ethylene (PE) with 15m long. The diameter of the lateral line was 16mm and each lateral line had 30 emitters with nominal flow rate of (6 $L.h^{-1}$). The spacing between laterals was 0.75 m, while the spacing between emitters was 0.5m. as shown in Figure (6).

Backwashing of the experimental system

Flush valves fitted at the end of main, submain, and flush lines (if present). The flushing procedure started with the system's main lines and then proceed through the system finishing but change the laterals in each case. Also, the back washing occurs every 200 hours, and the area of the particles was derived using the pc Image Java program with pixel.

Image processing of grain media size and deposits (Image Java program)

Image J program as shown in Figure 7 is an open source image processing program designed for scientific multidimensional images. It's highly extensible, with thousands of plugins and scripts for performing a wide variety of tasks, and a large user community. It runs on any computer with a JAVA 1.8 or later virtual machine. Downloadable distributions are available for Windows, Mac OS X and Linux. Image Java program has a strong, established user base, with thousands of plugins and macros for performing a wide variety of tasks.

The suspended materials accumulated above the media surface of the proposed filter was collected by filtering the output of filter back washing using sieve with a size of 0.2 micron (0.2 meshes) then, its dried airily for one to three hours, then the sediment and organic residues weighted and photos by the electronic microscope then the photos entered to the PC Image Java program to calculate the area of the particles. This procedure was repeated more times randomly to calculate the mean area of the particles with pixel.

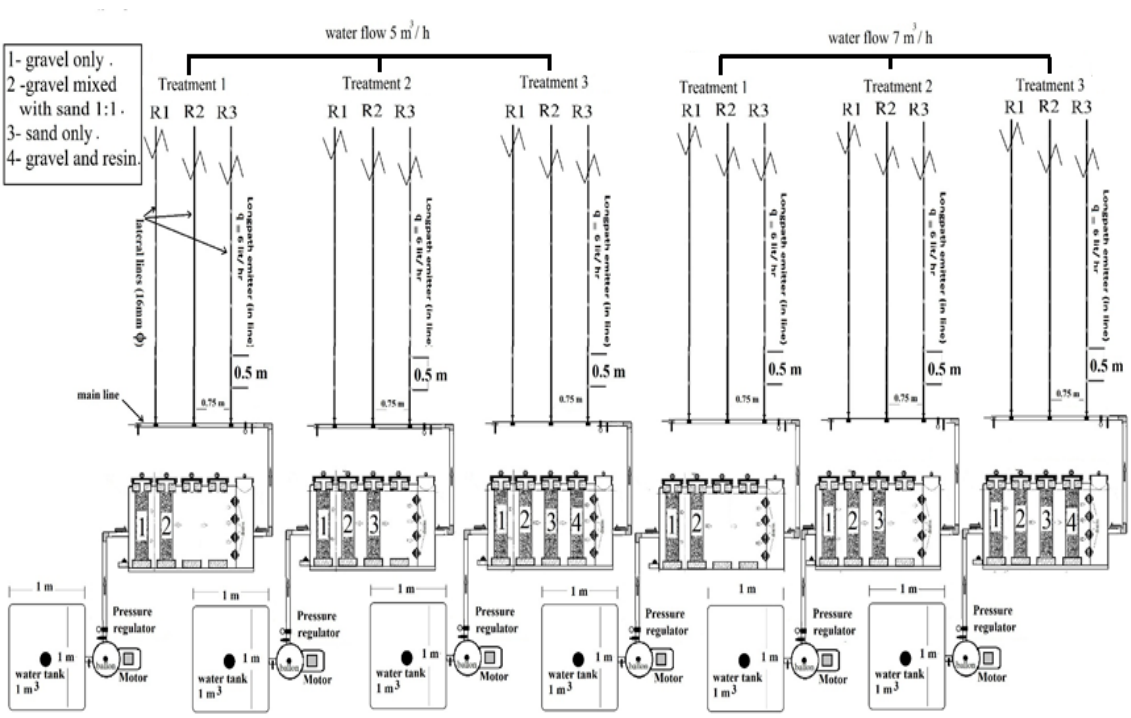

Fig (6): A schematic diagram of the tested treatments for both Nile and mixed agricultural drainage water under 5 and 7 $m^3.h^{-1}$ of water flow rate inside the new filter (6 treatments for each type of water).

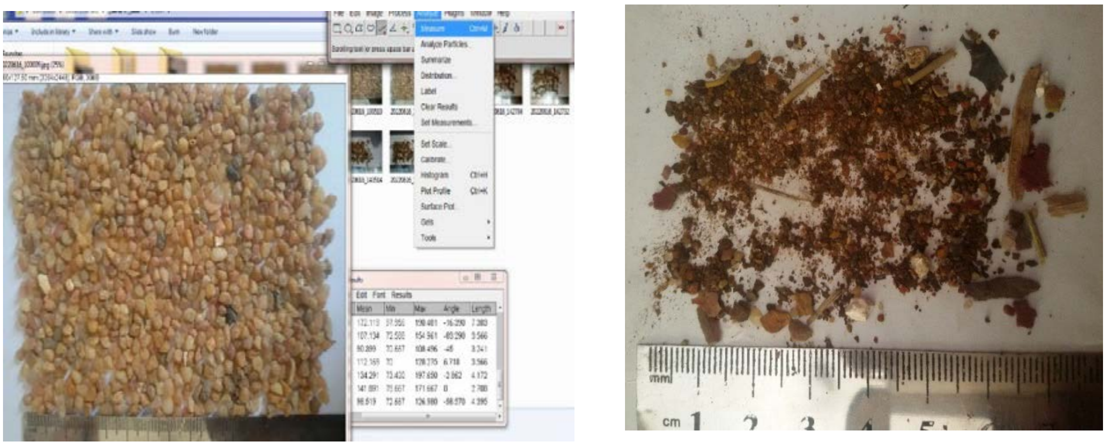

Fig. (7): Image Java Windows program used to measure grain media size and deposits before and after filtration process.

Affected parameters

The affected parameters which can be changed due to the changing level of each tested factor were:

Pressure drops across the filter

Pressure drop is the difference between the measured inlet and outlet pressure. Its value was recorded every five hours during the filtration process of the system (i.e. 5,10,15,20 h. etc).

Pressure drop between filter inlet and gravel layer outlet; and the pressure drop between gravel layer outlet and gravel &sand bed outlet, in case of the first treatment.

For the other treatments the pressure drop for each treatment was measured by the same way.

Weight of accumulated residuals

JAVA computer program (Image Java) was used in measuring the accumulated weight of residuals deposits that removed every 200 hours. The value of this weight for each treatment will be considered specially when comparing between both traditional sand filter and the new proposed one.

RESULTS AND DISCUSSION

Removal efficiency

The filter removal efficiency as mentioned prior can be calculated according to equation (9), Table (1) shows the calculated filter removal efficiency for all the tested treatments with all the tested levels of water quality and water flow rate. Generally, higher values of the removal efficiency (RE) were observed with the new proposed filter comparing with that obtained with the traditional sand filter. It is also obvious that the value of the flow rate of water effected strongly on the value of removal efficiency (R_E). Increasing water flow rate from 5 $m^3.h^{-1}$ to 7 $m^3.h^{-1}$ decreased the value of the removal efficiency for both Nile and mixed agricultural drainage water. When the flow rate increased, the filtration process occurred rapidly which caused lifting a slightly amount of deposits without removing from the water during flow. On the other hand, at each level of water flow rate the removal efficiency with Nile water was greater than that recorded with the mixed agricultural drainage water, which confirmed with (AMINI, 1996).

The highest value of the removal efficiency (95.70%) obtained with Nile water was recorded by the new proposed filter with the filtration media includes (gravel + mixed gravel and sand + sand only + gravel with resin) at 5 $m^3.h^{-1}$ water flow rate. In case of the mixed agricultural drainage water, the highest removal efficiency of (91.23%) was recorded also by the new proposed filter at 5 $m^3.h^{-1}$ of water flow rate with the same media.

The traditional sand filter recorded the lowest value of removal efficiency at each level of water flow rate either with Nile water or with mixed agricultural drainage water.

The lowest removal efficiency (72.04%) was observed when the mixed agricultural drainage water with the traditional sand filter at 7 $m^3.h^{-1}$ of water flow rate.

The higher value of the removal efficiency recorded with the new proposed filter can be attributed to the thickness of the sand layer. Where this media included two layers each contains a large amount of sand which resulted in more effective filtration with this treatment. This result confirmed with (Kannan *et al.,* 2020).

The relationship between the concentrations of the retained residuals in ($g.m^{-3}$) for the two tested filters and the level of water flow rates are listed in Table (1). Generally, the input concentration of residuals in case of mixed agricultural drainage water is greater than in case of Nile water. Therefore, the higher retained residuals concentration (0.99 $g.m^{-3}$) and (1.97 $g.m^{-3}$) were existed with the Nile water and mixed agricultural drainage water at 7 $m^3.h^{-1}$ water flow rate respectively. These two values were recorded with the new proposed filter treatments with the same media. In addition, the lower concentrations of the retained residuals (0.89 $g.m^{-3}$) and (0.85 $g.m^{-3}$) which obtained with Nile water were at 5$m^3.h^{-1}$ and 7 $m^3.h^{-1}$ water flow rate respectively with the traditional sand filter media. With the mixed agricultural drainage water, the lower concentrations of the retained residuals were (1.63 $g.m^{-3}$) and (1.58 $g.m^{-3}$) at 5 $m^3.h^{-1}$ and 7 $m^3.h^{-1}$ of water flow rate respectively, with the traditional sand filter treatment media.

Table (1): Filter removal efficiency (R_E) for all the tested treatments at two levels of water flow rate and water quality.

Water quality	Water flow rate ($m^3.h^{-1}$)	Filtration media		Concentration of total suspended solids (T_{ss}) (g. m^{-3})			Removal efficiency %
				input	retained	output	
Nile water	5	Proposed filter	T1	1.05	0.91	0.14	86.72
			T2		0.95	0.10	90.83
			T3		1.00	0.05	95.70
		Traditional sand filter			0.90	0.15	85.39
	7	Proposed filter	T1		0.87	0.18	82.95
			T2		0.93	0.12	88.95
			T3		0.99	0.06	94.61
		Traditional sand filter			0.85	0.19	81.58
Mixed agricultural drainage water	5	Proposed filter	T1	2.19	1.73	0.46	78.99
			T2		1.85	0.34	84.38
			T3		2.00	0.19	91.23
		Traditional sand filter			1.63	0.56	74.65
	7	Proposed filter	T1		1.68	0.51	76.80
			T2		1.82	0.37	83.07
			T3		1.97	0.22	89.85
		Traditional sand filter			1.58	0.61	72.04

T1= (gravel + mixed gravel and sand)

T2= (gravel + mixed gravel and sand+ sand only)

T3= (gravel + mixed gravel and sand+ sand only+ gravel with resin)

Surface area of residuals

After the filtration process has done the residuals divided into two parts, one retained inside the filter and the other part mixed with the filtrated water. Table (2) represents the average surface area of the residuals and relation to the filter removal efficiency. It showed that the higher the filter removal efficiency the smaller the surface area of the retained residuals at the lower level of water flow rate (5 $m^3.h^{-1}$), this was observed with both Nile and mixed agricultural drainage water. With Nile water the smallest average surface area of the retained residuals (17.83mm^2) resulted in the highest filter removal efficiency which was 95.70 %, with the new proposed filter at the filtration media of gravel layer and a mixed gravel and sand layer plus a layer of sand only and gravel layer mixed with resin. In case of mixed agricultural drainage water, the smallest retained residuals area was 26.69 mm^2 resulted in 91.23% of filter removal efficiency occurred with 5 $m^3.h^{-1}$ of water flow rate with the new proposed filter at the same filtration media. The largest average surface area of the residuals was observed at the mixed agricultural drainage water with the traditional sand filter, was 58.30 mm^2 and 63.31 mm^2 at 5 $m^3.h^{-1}$ and 7 $m^3.h^{-1}$ of water flow rate respectively confirmed with (Shirk and Dick, 1997).

The average surface area of the output residuals that mixed with the filtered water was extremely smaller than the surface area of the retained residuals, and it took the same trend with the filter removal efficiency as in retained residuals. The smallest average surface area of the output residuals (1.48 mm^2) was observed with filtration media that contained a gravel layer plus a mixed gravel and sand layer and only sand layer and a gravel with resin layer at Nile water with 5 $m^3.h^{-1}$ of water flow rate. The largest average surface area of the output residuals (10.56 mm^2) was observed with the traditional sand filter at the mixed agricultural drainage water with 7 $m^3.h^{-1}$ of water flow rate.

Table (2): Average surface area of the output and retained residuals with the filter removal efficiency at all the tested filtration media.

Water quality	Water flow rate ($m^3.h^{-1}$)		Filtration media	Average surface area of residuals in (mm^2)		Removal efficiency %
				output	retained	
Nile water	5	Proposed filter	T1	6.32	31.53	86.72
			T2	4.17	22.65	90.83
			T3	1.48	17.83	95.70
		Traditional sand filter		6.57	45.41	85.39
	7	Proposed filter	T1	7.02	35.30	82.95
			T2	4.89	26.68	88.95
			T3	2.06	20.20	94.61
		Traditional sand filter		7.34	51.06	81.58
Mixed agricultural drainage water	5	Proposed filter	T1	9.12	40.43	78.99
			T2	6.07	33.40	84.38
			T3	4.23	26.69	91.23
		Traditional sand filter		9.67	58.30	74.65
	7	Proposed filter	T1	10.23	45.06	76.80
			T2	6.97	37.37	83.07
			T3	4.99	29.08	89.85
		Traditional sand filter		10.56	63.31	72.04

Pressure drop

Table (3) represents the inlet and outlet pressures and the pressure drop as related to the operating hours across each tested media with Nile water at 5 $m^3.h^{-1}$ of water flow rate. The value of the pressure drop (ΔP) for each treatment depended strongly upon the number of filtration layers which the flow passes through it with the new proposed filter. Generally, the pressure drop increased with operating hours with both the new proposed filter treatments and the traditional sand filter treatment. After 900 hours of operating, the highest pressure drop was 13.65 kPa achieved by the media contains (gravel + mixed gravel and sand + sand only + gravel with resin) of the new proposed filter. On the side, after 900 hours the lowest pressure drop (ΔP) was (3.75 kPa) recorded by the first media in the new proposed filter (gravel + mixed gravel and sand). The recorded pressure drop (ΔP) with the traditional sand filter treatment after 900 hours was (9.26 kPa), and it considered higher than the first treatment of the proposed new filter. Consequently, the obtained results concluded the new proposed filter with (gravel + mixed gravel and sand) as a filtration bed. The lowest value of pressure drop (ΔP) means that the system can be operated safely for a long hours before causing unsatisfied clogging of the emitters which led to carrying the required filter back flow process.

Table (3): Pressure drop across each tested treatment as related to operating hours at 5 $m^3.h^{-1}$ of water flow rate with Nile water.

Operating hours, h	Pressure drop for all Filtration treatments at 5 $m^3.h^{-1}$ with Nile water (kPa)											
	T1			T2			T3			Traditional sand filter		
	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP
0	100	99.99	0.01	100	99.97	0.03	100	99.93	0.07	100	99.98	0.02
100	100	99.91	0.09	100	98.88	1.12	100	98.65	1.35	100	98.95	1.05
200	100	98.75	1.25	100	96	4.00	100	95.5	4.50	100	96.76	3.24
300	100	99.25	0.75	100	97.25	2.75	100	97	3.00	100	97.05	2.95
400	100	97.85	2.15	100	94.10	5.90	100	92.35	7.65	100	95.55	4.45
500	100	98.24	1.76	100	95.04	4.96	100	93.69	6.31	100	95.72	4.28
600	100	97.13	2.87	100	91.63	8.37	100	89.23	10.77	100	93.05	6.95
700	100	97.44	2.56	100	92.44	7.56	100	90.09	9.91	100	93.11	6.89
800	100	95.95	4.05	100	89.20	10.80	100	85.44	14.56	100	90.78	9.22
900	100	96.25	3.75	100	89.80	10.20	100	86.35	13.65	100	90.74	9.26
1000				100	85.30	14.70	100	80.95	19.05			
1100				100	85.75	14.25	100	81.10	18.90			
1200				100	83.11	16.89	100	77.86	22.14			
1300							100	77.31	22.69			

T1 = gravel only + mixed gravel and sand
T2 = gravel+ mixed gravel and sand + Sand only
T3 = gravel+ mixed gravel and sand + sand only+ gravel and resin

Table (4) showed the obtained value of inlet (P_{in}), outlet (P_{out}) and pressure drop (ΔP) for all treatments at 7 $m^3.h^{-1}$ of Nile water flow rate with operating hours. After 800 hours of operating time the more efficient treatment with 7 $m^3.h^{-1}$ of water flow rate was the first treatment (gravel + mixed gravel and sand) of the new proposed filter but with slightly higher value of the pressure drop (4.75 kPa). The third treatment (gravel + mixed gravel and sand + sand only + gravel with resin) gave the highest value of the pressure drop (15.88 kPa) after this time of operating. Therefore, it can be concluded the first treatment of the new proposed filter to be operated at two levels of water flow rates, either at 5 $m^3.h^{-1}$ or at 7 $m^3.h^{-1}$ in Nile water because of the smallest values of pressure drop that obtained with this treatment. It can also have noticed that increasing water flow rate from 5 $m^3.h^{-1}$ to 7 $m^3.h^{-1}$ decreased the allowable operating hours before the clogging of emitter be occurred. Where, the operating hours was 900 hours before the clogging at 5 $m^3.h^{-1}$ of water flow rate but reached to 800 hours only at 7 $m^3.h^{-1}$.

The results of the pressure drop which obtained with the mixed agricultural drainage water at 5 $m^3.h^{-1}$ of water flow rate were listed in Table (5). At this type of water quality, the critical operating hours were 400 hours from beginning, and the first treatment of the new proposed filter (gravel + mixed gravel and sand) achieved the lowest pressure drop where it was 7.9 kPa. The third treatment of the new proposed filter achieved the highest value of the pressure drop, where it was 17.43 kPa. Hence, the filtration process of the mixed agricultural drainage water did not completely achieve although the operating hours continued and reached to 900 hours from the beginning. Therefore, the results concluded the first treatment of the new proposed filter to be used to improve the filtration process of the irrigation water in modern irrigation systems.

Table (4): Pressure drop across each tested treatment as related to operating hours at 7 $m^3.h^{-1}$ water flow rate with Nile water

Operating hours h	Pressure drop for all Filtration treatments at 7 $m^3.h^{-1}$ with Nile water (kPa)											
	T1			T2			T3			Traditional sand		
	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP
0	100	99.98	0.02	100	99.94	0.06	100	99.89	0.11	100	99.95	0.05
100	100	99.87	0.13	100	98.72	1.28	100	98.34	1.66	100	98.85	1.15
200	100	98.58	1.42	100	95.43	4.57	100	94.67	5.33	100	96.33	3.67
300	100	99.06	0.94	100	96.71	3.29	100	96.28	3.72	100	96.66	3.34
400	100	97.53	2.47	100	93.48	6.52	100	91.5	8.5	100	95.35	4.65
500	100	98.05	1.95	100	94.63	5.37	100	93.15	6.85	100	95.38	4.62
600	100	96.96	3.04	100	91.21	8.79	100	88.59	11.41	100	92.68	7.32
700	100	97.26	2.74	100	91.99	8.01	100	89.5	10.5	100	92.65	7.35
800	100	95.25	4.75	100	88.1	11.9	100	84.12	15.88	100	89.11	10.89
900				100	89.21	10.79	100	85.56	14.44			
1000				100	84.59	15.41	100	80.08	19.92			
1100							100	80.13	19.87			

Table (5): Pressure drop across each tested treatment as related to operating hours at 5 $m^3.h^{-1}$ of water flow rate with mixed agricultural drainage water

Operating hours h	Pressure drop for all Filtration treatments at 5 $m^3.h^{-1}$ with mixed agricultural											
	T1			T2			T3			Traditional sand		
	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP
0	100	99.82	0.18	100	99.61	0.39	100	99.54	0.46	100	99.77	0.23
100	100	97.25	2.75	100	93.5	6.5	100	92.65	7.35	100	96.85	3.15
200	100	94.43	5.57	100	89.48	10.52	100	87.93	12.07	100	93.11	6.89
300	100	95.11	4.89	100	90.86	9.14	100	89.52	10.48	100	93.05	6.95
400	100	92.1	7.9	100	85.32	14.68	100	82.57	17.43	100	90.15	9.85
500				100	86.05	13.95	100	83.5	16.5	100	88.77	11.23
600				100	81.28	18.72	100	78.16	21.84			
700				100	81.5	18.5	100	78.46	21.54			
800				100	76.02	23.98	100	71.1	28.9			
900							100	71.46	28.54			

Table (6) represents the obtained results of the pressure drop for various treatments at 7 $m^3.h^{-1}$ of mixed agricultural drainage water flow rate. Similarly, the occurred operating hours from the beginning were 400 hours as at 5 $m^3.h^{-1}$ but with a higher pressure drop (8.16 kPa) which obtained in this case. The same trend was observed with the third treatment of the new proposed filter, where the operating hours were also 400 h from the beginning but with a higher value of the pressure drop (18.03 kPa) compared with 5 $m^3.h^{-1}$ of the mixed agricultural drainage water flow rate. Another observation was existed where the operating hours became shorter with 7 $m^3.h^{-1}$ (800 hours) comparing with its value with 5 $m^3.h^{-1}$ where it was 900 hours. Therefore, with the mixed agricultural drainage water the first treatment of the new proposed filter treatment can also be recommended only due to the lowest value of the pressure drop but with early occurring of emitter clogging.

Table (6): Pressure drop across each tested treatment as related to operating hours at 7 $m^3.h^{-1}$ of water flow rate with mixed agricultural drainage water

Operating hours h	Pressure drop for all Filtration treatments at 7 $m^3.h^{-1}$ with mixed agricultural drainage water (kPa)											
	T1			T2			T3			Traditional sand		
	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP	P_{in}	P_{out}	ΔP
0	100	99.76	0.24	100	99.57	0.43	100	99.41	0.59	100	99.72	0.28
100	100	96.8	3.2	100	92.68	7.32	100	91.65	8.35	100	95.87	4.13
200	100	94.22	5.78	100	89.08	10.92	100	87.43	12.57	100	92.55	7.45
300	100	94.51	5.49	100	89.48	10.52	100	87.94	12.06	100	90.91	9.09
400	100	91.84	8.16	100	84.92	15.08	100	81.97	18.03	100	87.86	12.14
500				100	85.42	14.58	100	82.66	17.34			
600				100	79.31	20.69	100	75.97	24.03			
700				100	79.55	20.45	100	76.2	23.8			
800							100	70.58	29.42			

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تصميم و اختبار فلتر جديد مقترح لتحسين عملية تنقية المياه في نظم الري الحديث

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الملخص العربي

أجريت هذه الدراسة بقسم الهندسة الزراعية والنظم الحيوية بكليه الزراعة- جامعة المنوفية بمدينه شبين الكوم في الفترة من عام 2020-2022 وإستهدفت تصميم واختبار وتقييم آداء فلتر جديد مقترح و مقارنة آدائه بآداء الفلتر الرملي التقليدي الشائع الاستخدام في نظم الري الحديث و استخدم في تصميم الفلتر المقترح جميع المعادلات اللازمة للتصميم و تم تصنيعه و تركيبه بورش محطة ميت خلف للميكنة الزراعية و بأحد الورش الخارجية بمحافظة المنوفية وفقاً للابعاد المتحصل عليها من معادلات التصميم.

وأجريت الاختبارات لكلا الفلترين عند مستويين لجودة مياه الري هما مياه النيل ومياه الصرف الزراعي المخلوط بنسبة 1:1 لتنقية مياه الري في نظم الري الحديث بهدف الوصول الى امكانية حل أحد أهم مشاكل الفلتر الرملي التقليدي وهي بالاضافة الى الترتيب الغير جيد للطبقات المكونة لوسط التنقية للفلتر الرملي التقليدي والذي يؤثر بدرجة كبيرة على تدني قيمة كفاءة التنقية و درجة تنقية مياه الري في نظم الري الحديث.

و تضمنت عناصر تقييم الفلتر الجديد المقترح وتقييم الفلتر الرملي التقليدي قياس وحساب متغيرات التقييم لكلا الفلترين والتي تمثلت في المتغيرات الآتية:-

1- قياس وحساب كفاءة التنقية "Removal efficiency" وعلاقتها بعدد ساعات التشغيل.
2- قياس قيمة فاقد الضغط وعلاقته بعدد ساعات التشغيل عن طريق الفرق بين ضغط الدخول وضغط الخروج للفلتر الجديد المقترح والفلتر الرملي التقليدي عند كل معاملة من معاملات الدراسة.
3- قياس متوسط مساحة سطح الشوائب المحجوزة بواسطة كلاً من الفلتر الرملي التقليدي والفلتر الجديد المقترح باستخدام برنامج "Image Java" و مقارنتها بكفاءة التنقية.

واجريت التجربة عند مستويين لتصرف المياه الداخلة للفلتر هما المستوى الأول 5 م^3/ س باستخدام عدد 5 مصرفات (Drainers) بتصرف 1 م^3/س والمستوى الثاني 7 م^3/ س باستخدام 7 مصرفات وبنفس التصرف وقيست البارامترات السابقة عند كل مستوى من مستويات تصرف المياه وتمت مقارنة آداء الفلتر الجديد المقترح بآداء الفلتر الرملي التقليدي من خلال استخدام طبقات مختلفة لوسط التنقية للفلتر الجديد المقترح موضوعة في اوعية مجهزة تم ترتيبها وتصنيفها الى ثلاثة مستويات كالآتي:

<u>المستوى الاول</u> وسط مكون من (طبقة من الحصى بسمك 13 سم+ طبقة خليط من الحصى والرمل بنسبة 1:1 بسمك 13سم)

<u>المستوى الثاني</u> وسط مكون من (طبقة من الحصى بسمك 13 سم+ طبقة خليط من الحصى والرمل بنسبة 1:1 بسمك 13 سم+ طبقة من الرمل فقط بسمك 13سم)

<u>المستوى الثالث</u> وسط مكون من (طبقة من الحصى بسمك 13سم + طبقة خليط من الحصى والرمل بنسبة 1:1 بسمك 13سم + طبقة من الرمل فقط بسمك 13 سم+ خليط من الحصى و الريزن "resin" و هي عبارة عن بلورات صمغية بسمك 11 سم).

وعليه يكون عدد المعاملات للفلتر المقترح 12 معاملة.

و باستخدام مستوى واحد للفلتر الرملي التقليدي وهو عبارة عن وسط مكون من (طبقه سفلى من الحصى بارتفاع 5 سم فوق المصرفات مباشرة فوقها طبقة خليط من الحصى والرمل بارتفاع 10 سم تعلوها طبقة من الرمل بارتفاع 15 سم) و بذلك يكون عدد المعاملات للفلتر الرملي التقليدي اربع معاملات.

وتوصلت الدراسة الى النتائج الآتية

1. أظهرت النتائج أن أكبر قيمة لكفاءة التنقية و مقدارها 95.7% مع مياه النيل باستخدام الفلتر الجديد المقترح مع وسط تنقية مكون من (طبقة حصى + طبقة خليط حصى و رمل + طبقة من الرمل فقط+ طبقة خليط من الحصى و الريزن) عند تصرف 5 م^3/س و كانت % 94.61 عند تصرف 7 م^3/س لنفس الوسط بينما تحققت أقل قيمة و مقدارها 82.95% عند تصرف 5 م^3/س و كانت % 81.58عند 7 م^3/س للفلتر الرملي التقليدي .
2. كانت أكبر قيمة لكفاءة التنقية ومقدارها 91.23% مع مياه الصرف الزراعي المعالج باستخدام الفلتر الجديد المقترح مع وسط تنقية مكون من (طبقة حصى + طبقة خليط من الحصى و الرمل + طبقة من الرمل فقط+ طبقة خليط من الحصى و الريزن) عند تصرف 5 م^3/س و كانت 89.85% عند تصرف 7 م^3/س بينما تحققت أقل قيمة و مقدارها 74.65% عند تصرف 5 م^3/س و كانت 72.04%عند 7 م^3/ س للفلتر الرملي التقليدي .
3. وجد أن أعلى قيمة في فاقد الضغط ومقدارها 13.65 كيلو باسكال تحققت مع مياه النيل عند تصرف 5 م^3/س بعد 900 ساعة تشغيل باستخدام الفلتر الجديد المقترح مع وسط تنقية مكون من (طبقة حصى + طبقة خليط من الحصى و الرمل + طبقة من الرمل فقط+ طبقة خليط من الحصى و الريزن) بينما كانت أقل قيمة و مقدارها 3.75 كيلو باسكال تحققت مع وسط تنقية مكون من (طبقة حصى + طبقة خليط من الحصى و الرمل) لنفس الفلتر.
4. تحققت عند تصرف 7 م^3/س أقل قيمة لفاقد الضغط و مقدارها 4.75 كيلو باسكال مع مياه النيل في الفلتر الجديد المقترح بعد 800 ساعة تشغيل مع وسط تنقية مكون من (طبقة حصى + طبقة خليط من الحصى و الرمل) عند نفس التصرف بينما تحققت أعلى قيمة و مقدارها 15.88 كيلو باسكال باستخدام الفلتر الجديد المقترح مع وسط تنقية مكون من (طبقة حصى + طبقة خليط من الحصى و الرمل + طبقة من الرمل فقط+ طبقة خليط من الحصى و الريزن).
5. أقل قيمة لفاقد الضغط و مقدارها 7.9 كيلو باسكال تحققت مع مياه الصرف الزراعي المعالج مع الفلتر الجديد المقترح مع وسط تنقية مكون من (طبقة حصى + طبقة خليط من الحصى و الرمل) بينما تحققت أعلى قيمة و مقدارها 17.43 كيلو باسكال باستخدام الفلتر الجديد المقترح عند تصرف 5 م^3/س باستخدام الصرف الزراعي المعالج وبعد 400 ساعة تشغيل مع وسط تنقية مكون من (طبقة حصى + طبقة خليط حصى و رمل + طبقة من الرمل فقط+ طبقة خليط من الحصى و الريزن).
6. عند تصرف 7 م^3/س تحققت أعلى قيمة لفاقد الضغط ومقدارها 18.03 كيلو باسكال مع مياه الصرف الزراعي المعالج بينما تحققت أقل قيمة و مقدارها 8.16 كيلو باسكال مع الفلتر المقترح مع وسط تنقية مكون من (طبقة حصى + طبقة خليط من الحصى والرمل) عند نفس التصرف بعد 400 ساعة تشغيل.
7. تبين وجود علاقة عكسية بين كفاءة التنقية ومتوسط المساحة السطحية للشوائب المحتجزة داخل جسم الفلتر حيث وصلت إلى 17.83 مم^2 مع اعلى كفاءة للتنقية (% 95.7) بينما كانت قيمتها 1.48مم^2 للشوائب الهاربة.
8. تحقق أكبر متوسط للمساحة السطحية للشوائب المحجوزة والهاربة 63.31 مم^2 و 10.56 مم^2 على الترتيب مع اقل كفاءة للتنقية ومقدارها 72.04% .