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EFFECT OF USING WASTEWATER ON THE PERFORMANCE OF MICRO-IRRIGATION SYSTEMS FOR LANDSCAPING

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ABSTRACT

The use of wastewater represents a viable option to use in agriculture. In the UAE and Egypt when, wastewater is used clogging problems are encountered in micro-irrigation systems, such as clogging of filters and emitters by physical, chemical or biological contaminants.

The objectives of this research are intended to overcome the problems of reusable wastewater for irrigation by choosing a viable filtration system (screen or disk), and viable emitters (drip, micro-jet, spaghetti or bubbler), in order to help reduce environmental pollution.

Field experiment was carried out at the Egyptian and Chinese friendship forest for youth in El-Sadat city, Egypt (El-Sadat city) using wastewater treatment and recycling in the rural areas project. Filter types were screen and disk, both with mesh 75, 120 and 150. Emitter types were: drip 4 L/h, drip 8 L/h, drip 40 L/h, micro-jet, spaghetti and bubblers 120L/h and 180L/h.

The effects of wastewater on the performance of micro-irrigation system were clearly indicated by the results. Disk filter proved to be much better (filtration efficiency and no. of operating hours) than screen filter. The most effective mesh numbers were respectively 150, 120 and 75. Also, by increasing the mesh number, there were improvements in the filtration efficiency, emitters discharge rate (with time and total discharge), emitters efficiency, emitters emission uniformity, and decreases in emitter clogging rates. Emitters which have a larger discharge are less likely to be clogged than emitters which have a lower discharge.

INTRODUCTION

Irrigated agriculture is the biggest consumer of water in the world. In arid and semiarid zones, agricultural irrigation requires from 70 to 85% of fresh water resources. As a result agriculture is the main user of water in most regions of the world particularly in the UAE and Egypt, where it is

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more difficult to meet the agricultural water demand with conventional resources, wastewater reuse represents a viable option.

Agricultural water management must be coordinated with and integrated into the overall water management of the region. Sustainability of public health and environmental protection are key factors. More storage of water behind dams and especially in aquifers via artificial recharge is necessary in order to save water in times of water surplus for use in times of water shortage. Municipal wastewater can be an important water resource but its use must be carefully planned and regulated to prevent adverse health effects and in the case of irrigation, undue contamination of groundwater.

Mara & Cairnross (1989) reported that using the recycled wastewater exemplifies a huge percentage of the UAE consumption compared with other Arab countries approximately 5.12 % of the consummated water in the nation. In addition, consumption has been rising for the last fifteen years, and is now more than 15 % of the total water production of the country (**Hamoda, 2004**).

Several researchers have reported on the application of wastewater to woody biomass plantations. Benefits from using recycled wastewater include conserving drinking water, creating an alternative water source for irrigation, and reducing fertilizing costs, because wastewater is typically rich in nitrogen and phosphorus. However, the effects of continuous irrigation using sewage effluent on soil and leachate water quality need to be evaluated (**Bahri, 1999**).

Water reuse is a cost-effective alternative in the development of water resources, since it can be provided at less than half of the cost of producing desalinated water (**Hamoda, 2004**).

The clogging of emitters is a major problem encountered in drip/trickle irrigation systems, as partial or complete clogging reduces application uniformity. The plugging of emitters can be caused by physical, chemical or biological contaminants. Physical clogging is caused by suspended inorganic particles (such as sand, silt, clay, plastics), organic materials (animal residues, snails, etc.), and microbiological debris (algae, etc.). Physical materials can also be combined with bacterial slimes (**Mara & Cairnross, 1989** and **Capra & Scicolone, 1998**). When wastewater is used, clogging problems are dependent on treatment levels and on high temporal variability (time of day, season, etc.), Suspended solids and organic matter content can cause emitter clogging (**Scischa *et al.*, 1996**).

Filtration at any conventional level can not restrain the mucous biomass growth in downstream tubing and the clogging of emitters. The order of the different types of filters (media, screen, disk) according to the level of protection afforded to the downstream check filter is: media filters (of a uniform bed of gravel with a mean size of 1 mm) are the best; second best are disk filters (120-140 mesh); the lowest level of protection was afforded by screen filters (120 - 140 mesh). Media filters of a 2 mm size gravel clogged the downstream check filter at a very fast rate. However, in general, sand filters afford the best protection to the downstream check filter, from time to time they caused rapid clogging. This was, most likely a result of coalescence of the media particles with microbial by- products. The clogging hazard of an emitter of a higher discharge rate is smaller than that of a similar emitter of lower discharge rates. Flushing through the drip laterals once every two weeks was found to be quite satisfactory when using stored effluent. It is easier to alleviate clogging problems that are detected early. Therefore, close monitoring of pressures and flow rates in the filters and drip laterals is most important when using irrigation water of sewage origin (**Ravina *et al.*, 1996**).

Clogging of drip emitters can be caused by the high iron, calcium and magnesium contents in wastewater. High bacterial counts and nutrients that promote algae growth may also contribute to clogging. Routine acid flushing of drip lines is therefore recommended (**Shatanawi and Fayyad, 1996**).

The gravel media filter guaranteed the best performance, but the disk filter, which is cheaper and simpler to manage, assured a performance similar to that of the gavel media filter. The test showed the importance of the technology used in manufacturing disk filters. Screen filters were shown to be unsuitable for use with wastewater. The theoretical discharge of filters, suggested by the manufacturers for clean water, is not adequate for wastewater of the kind used (suspended solids greater than 78 mg/1) (**Capra & Scicolone, 2004**).

WHO (1989) standards for the use of wastewater in agricultural production for export generally require a level of treatment that ensures that the Fecal Coliform Bacteria (FCB) of the wastewater is less than 1000 per 100 ml. Also it sets standards for helminth eggs and intestinal nematodes that may be a problem for agricultural workers, consumers, and the public when the wastewater is surface applied or flood irrigated. These standards do not address the risks if the wastewater is applied through a subsurface drip irrigation system

The microbiological contamination and the organic matter existing in the wastewater can produce detrimental effect on human health. The only standard has been set for total bacterial count (TBC) for irrigation purpose is to be less than 10,000 colony/ ml for no problems. Medium problems are expected when irrigated with a water of 10,000–50,000 colony/ ml of TBC, while severe problems are expected when this value exceeded the 50,000 colony/ml (**WHO, 1999**).

The objectives of this research are intended to overcome the problems of reusable wastewater for irrigation by:

a- Choosing the viable emitters (drip, micro-jet, spaghetti or bubbler) and

b- Choosing the viable filtration system (screen or disk), in order to reduce the environmental pollution.

MATERIALS AND METHODS

Experimental site:

Field experiments were carried out at the Egyptian and Chinese friendship forest for youth in El-Sadat city belonging to the Central Forestation Department in the Ministry Of Agriculture using wastewater treatment and recycling in the rural areas project.

The experimental work:

A 60 x 96 m plot area was selected for carrying out the experiment. The main project used media filter and the work research was under the sub unit of the main network.

Irrigation Systems:

Irrigation systems were installed at the experimental site of the project. The site was divided into two plots, each plot was divided into subplots under the same mesh of different types of filters (screen and disk) after sand filters. Each plot had the same irrigation systems and the network specification as shown in fig (1).

- The main filters were media with 80 – 100 mesh.
- The secondary filter types were screen (2") with mesh 75, 120 and 150 and the disk (2") with mesh 75, 120 and 150. The discharge rate of filters were 15 – 35 m^3/h
- Emitter types were:
  - Pressure-compensating online drip with discharge rate 4 L/h.
  - E-2 online drip with discharge rate about 8 L/h long-path.
  - Local online drip with discharge rate about 40 L/h flow-passage.
  - Local micro-jet half circle with discharge rate about 90 L/h.
  - Local spaghetti with 3 mm diameter.
  - Two kind of air jet bubbler with discharge rate about 120 L/h and 180 L/h.

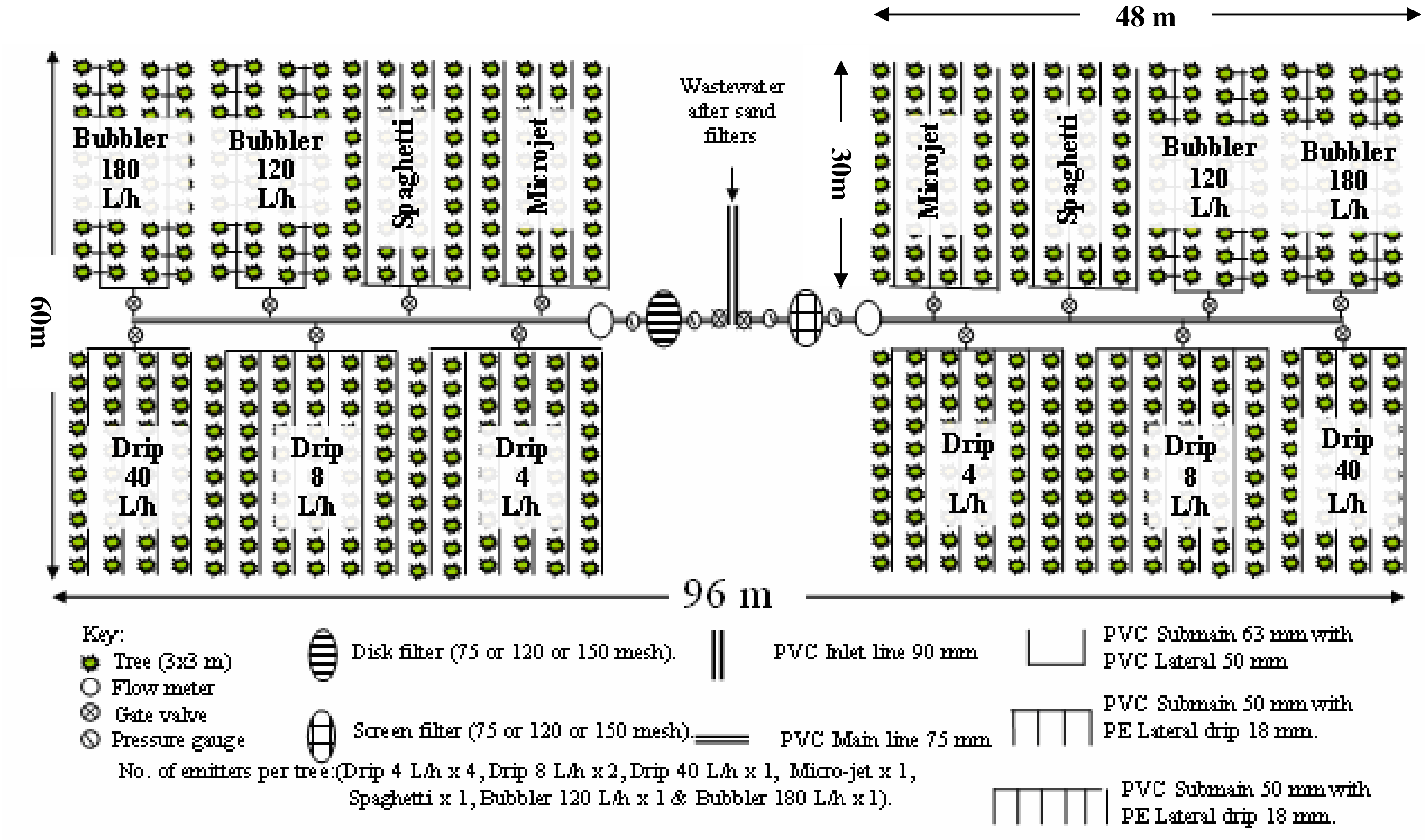


Fig (1): The Field Experiment Layout and Treatments

The irrigation system network consisted of the following:

Pump: Booster pump was installed to carry water from the polishing pond through the sand filters to the irrigation systems, 45 m^3/h discharge and 15 m head were used for the experiment.

Sub control head unit: consisted of one screen filter and one disk filter 2" with 30 m^3/h capacity, flow meter 2" with 25 m^3/h capacity, control valves and pressure gauges.

Measurement Devices:

The following devices were used for different measurement through the experimental work:

1- Calibrated cylinder for measuring water volume.
2- Stopwatch for measuring the times.
3- Flow meter 2" with 25 m^3/h capacity for measuring discharge.
4- Pressure gauges with sensitivity 0.1 bar.
5- Auger for taking soil samples.
6- Wastewater samples were taken to The Centre for Desert Research (مركز بحوث الصحراء) from outlet units of sand filters for analyses by using plastic bottles.

The operating pressure of all evaluated filters was 1.5 bar, and the trees spacing was three meters. The measurements of all filters were carried out at the beginning of each 16th hour individually without cleaning until 81 hours. The operating pressure of all evaluated emitters was one bar with daily filter cleaning. Its discharge was recorded at the beginning and each 10 days until 60 days. Each of the seven emitters was tested in this way. During the 60 days, there were about 200 operating hours per emitter.

Methods:

The following indicators are taken to evaluate the irrigation system components and to choose the preferable ones.

A- Performance of Filters:

1-Filtrations Efficiency (E_f): was estimated according equation (1):

$$E_f = \frac{S_b - S_a}{S_b} \times 100$$

Where:

S_b = total suspended solids (TSS) in water before filter (mg/L).
S_a = total suspended solids (TSS) in water after filter (mg/L).

2- Discharge Percentage Reduction (q_r): was determined by equation (2):

$$q_r = \left(\frac{q_1 - q_2}{q_1} \right) \times 100$$

Where:

q_r = discharge percentage reduction (%).
q_1 = discharge at the start (m^3/h).
q_2 = discharge after each 16^{th} hour starting (m^3/h).

B- Performance of Emitters:

Performance for different emitters (Drip 4L/h, Drip 8L/h, Drip 40L/h, micro-jet, Spaghetti, Bubbler 120 L/h and Bubbler 180 L/h) by using the following indicators:

3-Emission Uniformity (EU):

$$EU = \frac{q_m}{q_a} \times 100$$

Where:

EU = emission uniformity (%).
q_m = lowest average discharge for the 1/4 of emitters (L/h).
q_a = total average discharge of emitters (L/h).

4-Emitter Efficiency (E) by:

$$E = \frac{q_u}{q_n} \times 100$$

Where:

E = emitter efficiency (%).
q_u = emitter discharge after 200 hours (L/h).
q_n = new emitter discharge (L/h).

5-Emitters Clogging Rate (CR):

$$CR = (1 - E) \times 100$$

Where:

CR = emitters clogging Rate (%).
E = emitters efficiency (%).

6-Reduction Ratio of Average Discharge (q_r):

$$q_r = \left(\frac{q_1 - q_2}{q_1} \right) \times 100$$

Where:

q_r = reduction ratio of average discharge (%).
q_1 = discharge at the start (L/h).
q_2= discharge after starting (L/h).

7-Comparison for Emitters Efficiency (E) by:

$$E = \frac{q_u}{q_n} x \frac{total \text{ discharge of the emitter}}{the \text{ largest } total \text{ discharge of the emitters}} x100$$

8-Comparison for Emitters Clogging Rate (CR):

$$CR = (1 - \text{E}) x \frac{total \text{ discharge of the emitter}}{the \text{ largest total discharge of the emitters}} x100$$

The chemical and microbial tests of the wastewater:

Wastewater samples were taken from outlet units of sand filters for analyses as shown in tables (1, 2 and 3) and for screen filters and disk filters as shown in table (4).

RESULTS AND DISCUSSION

Laboratory analysis of wastewater:

According to **Pescod's (1992)** classification, the laboratory analysis of water samples showed that the danger of using wastewater with salinity was moderate. The toxicity of sodium was moderate. The heavy metals were still under the permitted level, though the high microbial levels indicated that the water should be treated carefully and was not suitable for human consumption as shown in tables (1, 2, & 3).

Table(1): Analysis of the total cations and anions, phosphorus and SAR in wastewater sample after media filter:

Parameter	Result	None	Slight to moderate	Severe
pH	7.4	-	6.5 – 8.4	-
Electrical conductivity (EC), dS/m	1.669	< 0.7	0.7 - 3.0	> 3.0
Total dissolved solids (TDS), mg/L	916	< 450	450 - 2000	> 2000
Calcium, mg/L	51.38	-	-	-
Magnesium, mg/L	19.11	-	-	-
Sodium, mg/L	250	< 69	69 - 207	> 207
Potassium, mg/L	26	-	-	-
Carbonate, mg/L	0	-	-	-
Bicarbonate, mg/L	433.41	< 91.5	91.5 – 518.5	> 518.5
Sulphate, mg/L	117	-	-	-
Chloride, mg/L	236.03	< 106.5	106.5 - 350	> 350
phosphorus, mg/L	1.96	-	-	-
SAR	7.52	< 3	3 - 9	> 9

All tables results analyzed by the Central Lab. of the Centre for Desert Research.

Table (2): Analysis of heavy metals in wastewater sample:

Parameter	Result	Max. Allowed Heavy metals Mg/L
Aluminum, mg/L	<0.12	5.0
Boron, mg/L	0.2394	-
Cadmium, mg/L	<0.002	0.01
Cobalt, mg/L	<0.003	0.05
Chromium, mg/L	<0.005	0.10
Copper, mg/L	<0.02	0.20
Iron, mg/L	0.1819	5.0
Manganese, mg/L	0.1018	0.20
Molybdenum,mg/L	<0.02	0.01
Nickel, mg/L	0.0124	0.20
Lead, mg/L	<0.01	5.0
Strontium, mg/L	0.6040	-
Vanadium, mg/L	0.0723	0.10
Zinc, mg/L	0.0302	2.0

Table (3): Bacteriological analysis and Total nitrogen content of wastewater sample:

Organisms	Count in tested water sample		
	result	Allowed count for forest irrigation	Allowed count for human use
Total colony count (S.P.C/ml at 37 ˚C)	1400	Less than **10000**	Less than **50**
Coliform Count (M.P.N/100ml)	975	Less than **1000**	Less than **9**
***E .coli* Count (M.P.N/100ml)**	340	-	Less than **1**
Total N content ppm	69.785	–	–

Table (4): Analysis of TSS, EC and pH of water samples after each filter:

Filter Type	TSS mg/L	EC dS/m	pH
Sand filters	40	1.669	7.4
Screen filter 75 mesh	36	1.671	7.2
Screen filter 120 mesh	32	1.670	7.0
Screen filter 150 mesh	28	1.673	7.0
Disk filter 75 mesh	32	1.680	7.1
Disk filter 120 mesh	28	1.675	7.0
Disk filter 150 mesh	26	1.673	6.9

Performance of Irrigation System:

Filters:

Filtration Efficiency:

Fig.(2) shows that disk filters were more efficient than screen filters. Also, the efficiency of filtration was increased with an increase in mesh number whether screen and disk filters. The highest filtration for disk 150 reached up to 35% efficiency, disk filter 120 reached up to 30% efficiency with screen filter 150, disk filter 75 reached up to 20% efficiency with screen filter 120, the lowest filtration reached was 10% efficiency for screen 75.

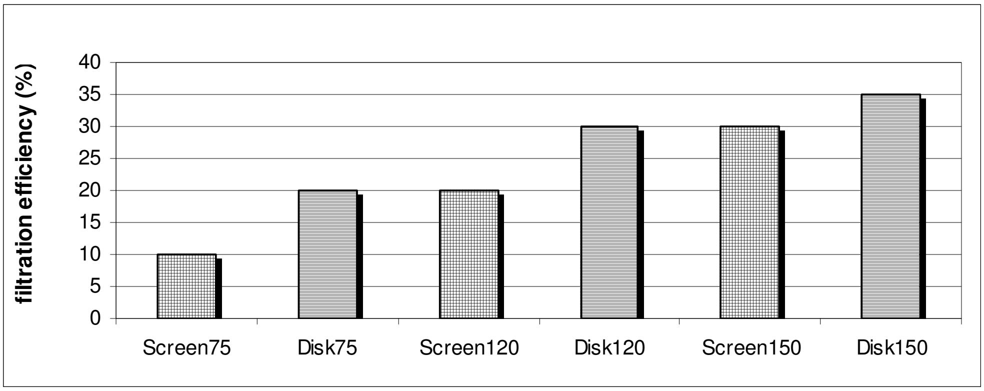


Fig. (2): The effect of filter on the Filtration Efficiency.

Reduction rate of discharge:

There was a reduction in filter discharge with the time or with the accumulation of filter discharge as illustrated in fig. (3), the screen filter had the highest reduction in discharge. The highest reduction in discharge was with mesh 150, 120 and 75 respectively, whether disk or screen filters. Also, the results indicated that the reduction rate was larger for the screen 150, followed by screen 120, 75 and disk 150, 120 and 75, respectively. The performance of filters reflects preference the disk filter than screen one in micro-irrigation system under using wastewater for irrigation.

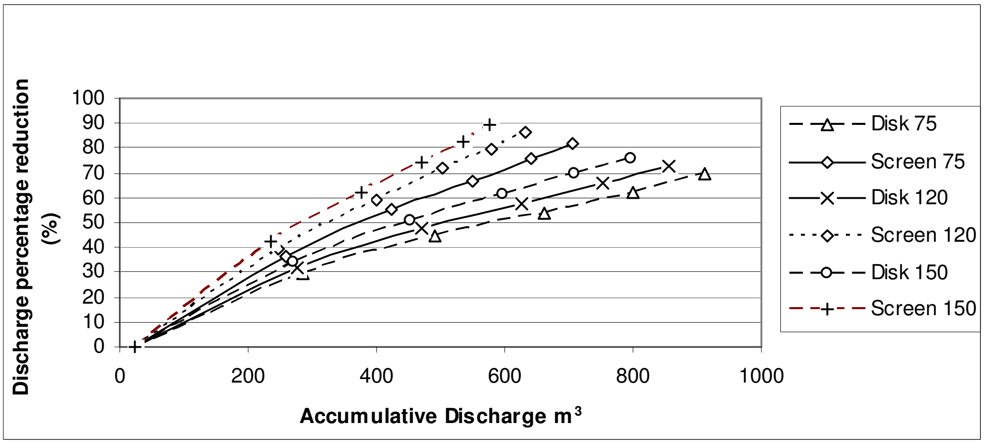


Fig.(3):The discharge percentage reduction (%) under different types of filters

Emitters:

Discharge rate:

Averages of flow rate were obtained by using 75, 120 and 150 mesh. This was done for each of the seven emitters and for both disk and screen filters. On the first operating day, the discharge rate of different emitters under different types of filters were very similar.

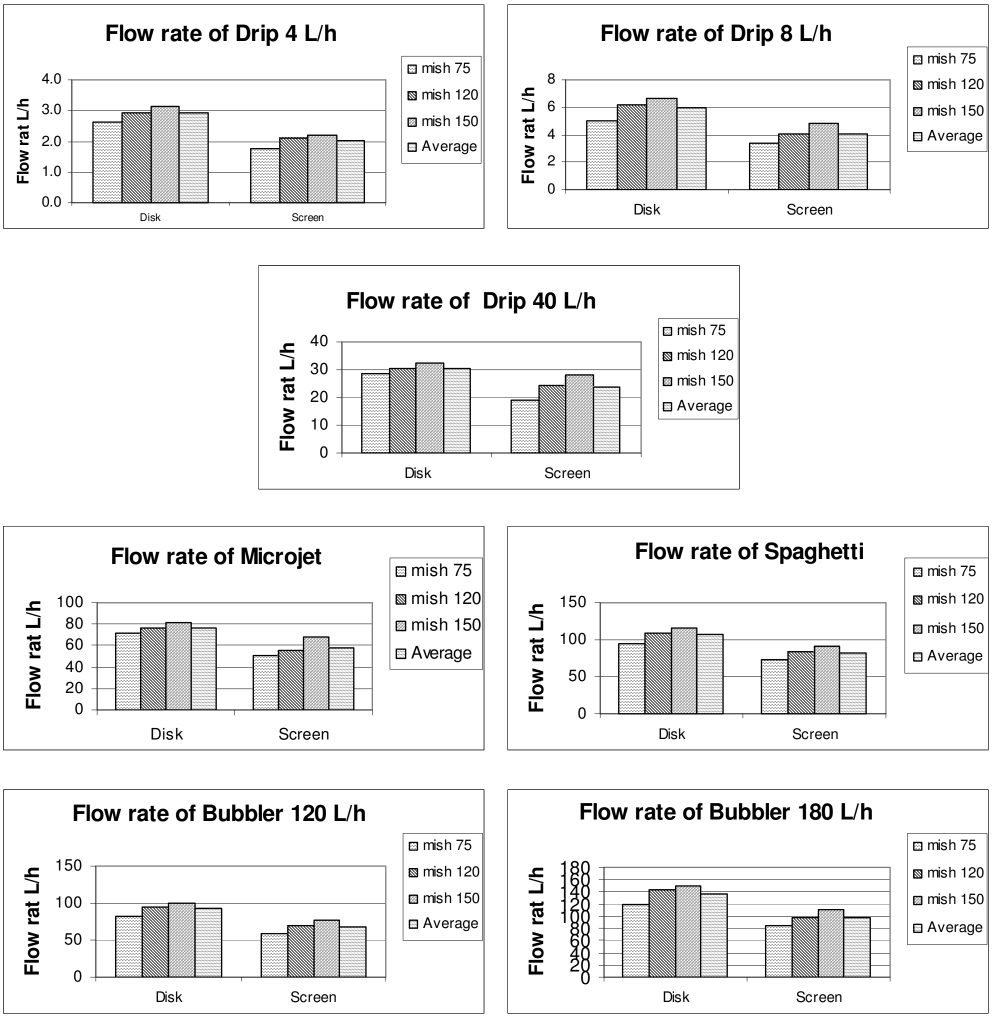
At the end of the experiment the discharge of emitters changed according to the sort of filter and mesh size used. The reason for this change in average discharge rate at the end of the experiment was that the clogging rate of emitters, it was different through the efficiency of different filters. Generally, the discharge rate of emitters at the end of the experiment was larger under the disk filter than the screen filter and for all types of emitters. Also, the average discharge rate of different emitters increased by mesh size whether disk or screen filter. The average discharge rate for emitters, when using a disk filter, was greatest for mesh 150, followed by mesh 120 and finally mesh 75, as shown in figure (4). These figures were all higher than those obtained using a screen filter.

Emission uniformity:

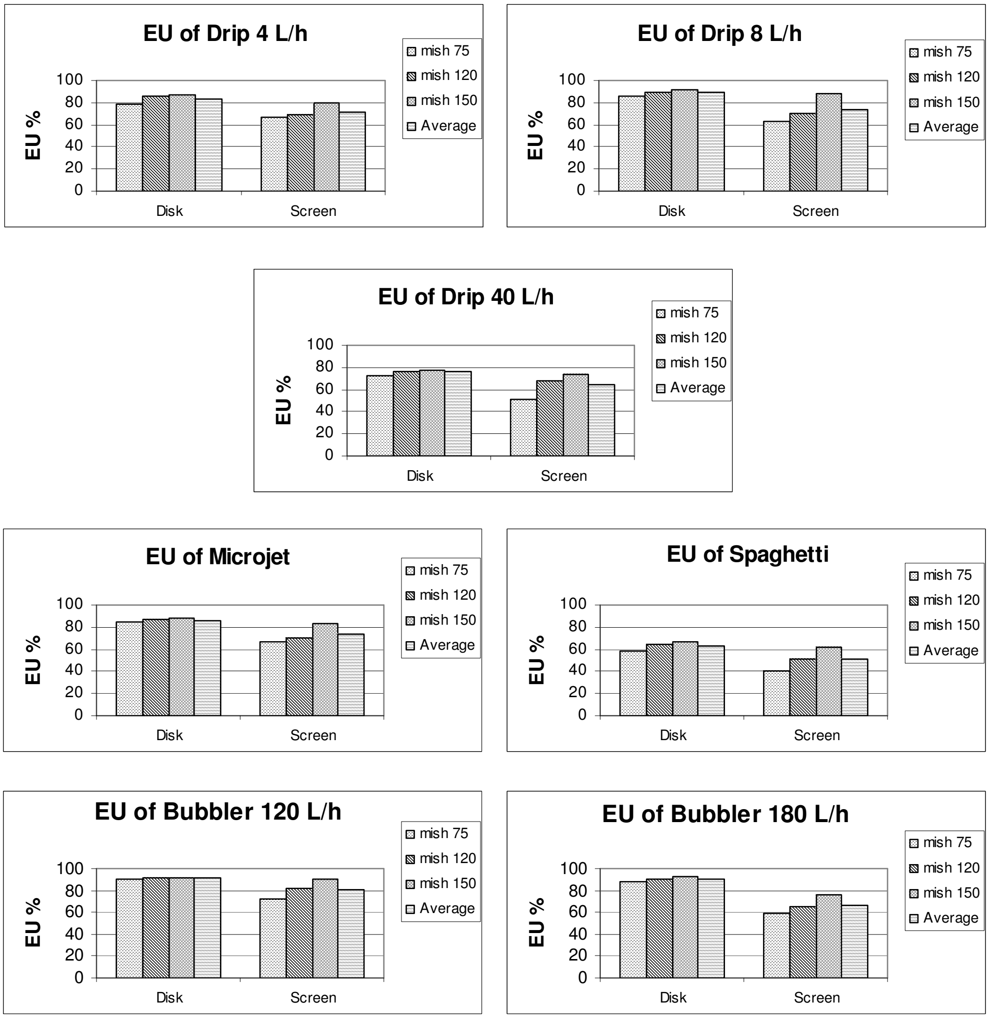
Averages of EU were obtained by using 75, 120 and 150 mesh. This was done for each of the seven emitters and for both disk and screen filters.

The results indicated that generally emission uniformity is a useful indicator between emitters. It's clear that under filters, a good indication is that mesh sizes 150 was more efficient than 120 or 75 in both disk and screen filters because clogging is not the same. Emission uniformity for different emitters at the end of the experiment were largely decreased. Through the results, the

lowest emission uniformity was for spaghetti and before that the 40L/h drip as shown in figure (5).
We can first compare the results of disk filters when using the different emitter types. Across the disks, mesh 150 produced the highest EU with bubbler 120L/h, bubbler 180L/h and drip 8L/h all showing an individual emitter average of 90%. Spaghetti had the least effective EU for the disk filter giving an average for the 3 mesh numbers of just 63%.
When we look at the mesh numbers of 75, 120 and 150 for each emitter type we can clearly see that there is little difference between the three, with mesh 150 always producing slightly higher EU and discharge than the other 2.



Fig(4):The effect of wastewater on flow rate for different type of emitters under different type of filters and mesh size



Fig(5):The effect of wastewater on the emission uniformity (EU) under different type of filters and mesh size

Finally, we can compare the use of disk filter to that of the screen filter. As previously stated, the disk filter consistently produces higher EU and discharge than screen, and this can be shown by the use of the data. The highest performing disk filters each averaged EU 90%, but with the screen filter these same 3 emitters gave results of EU 80% for bubbler 120L/h, 77% for drip 8 L/h and only 68% for bubbler 180L/h. For the discharge rate, the best performing emitter was bubbler 180L/h using a disk filter and mesh number 150.

Disk filters with the use of emitters 4L/h, 40L/h and micro-jet each produced very satisfactory EU's with drip 4L/h averaging 83%, micro-jet 86% and drip 40L/h 77% across the 3 mesh numbers.

Emitters discharge reduction rate:

As shown in figure (6) which illustrates the reduction rate percentage with the accumulative discharge, we can notice the differences which are illustrated through time. The results showed the larger discharge percentage reduction was for drip 4 L/h, then drip 8 L/h, local drip, micro-jet, bubbler 120 L/h, spaghetti and bubbler 180 L/h. Under filter screen all mesh sizes were the same.

Through the curved slope, a sharp reduction of the emitters was strong under screen 75 and decreased gradually with increased mesh size. We can say that there is the same effect as previously mentioned under disk filters. There is no difference in the reduction percentage for spaghetti and bubbler 120 and the reduction percentage for the emitters under screen 120 and 75 and disk 150, 120 or 75.

In general the best emitter results were found with bubbler 180L/h. Coupled with a disk filter and mesh 150, bubbler 180L/h produced the best actual result.

Emitters efficiency:

The emitter efficiency % after 200 hours for both screen and disk filters, for all seven emitters and for mesh 75, 120 and 150. The results as shown in fig.(7), illustrated that emitters efficiency under disk filters was larger than screen filters. Also the emitters efficiency was the largest under mesh size 150 > 120 > 75 mesh respectively. However the largest emitter efficiency was different depending on the type of filter, under disk filter it was 88% for bubbler 180L/h, but the largest efficiency under screen filter was almost 25% for spaghetti.

Clogging % of emitters:

The clogging % after 200 hours of emitters for both screen and disk filters, for all seven emitter types and for mesh 75, 120 and 150. The results, as shown in fig.(8), illustrated that the clogging rate of emitters under screen filters was larger than disk filters. Also the clogging rate was the largest under mesh size 75 > 120 > 150 respectively. The largest clogging rate of emitters was for the three drip emitters. The lowest clogging rate was found by using disk filter. Bubbler 180L/h was the most effective emitter showing a clogging rate of 12% compared to the next lowest which was bubbler 120L/h at 43% and the highest being drip 4L/h at 89%. All of these results were obtained by using mesh 150. When comparing the three different mesh numbers used with a disk filter, it was found that the various emitters performed in the same way, with bubbler 180L/h performing the best and drip 4L/h the least. With the screen filter, spaghetti emitters produced some interesting results as with all three mesh numbers as it consistently remained the best performance.

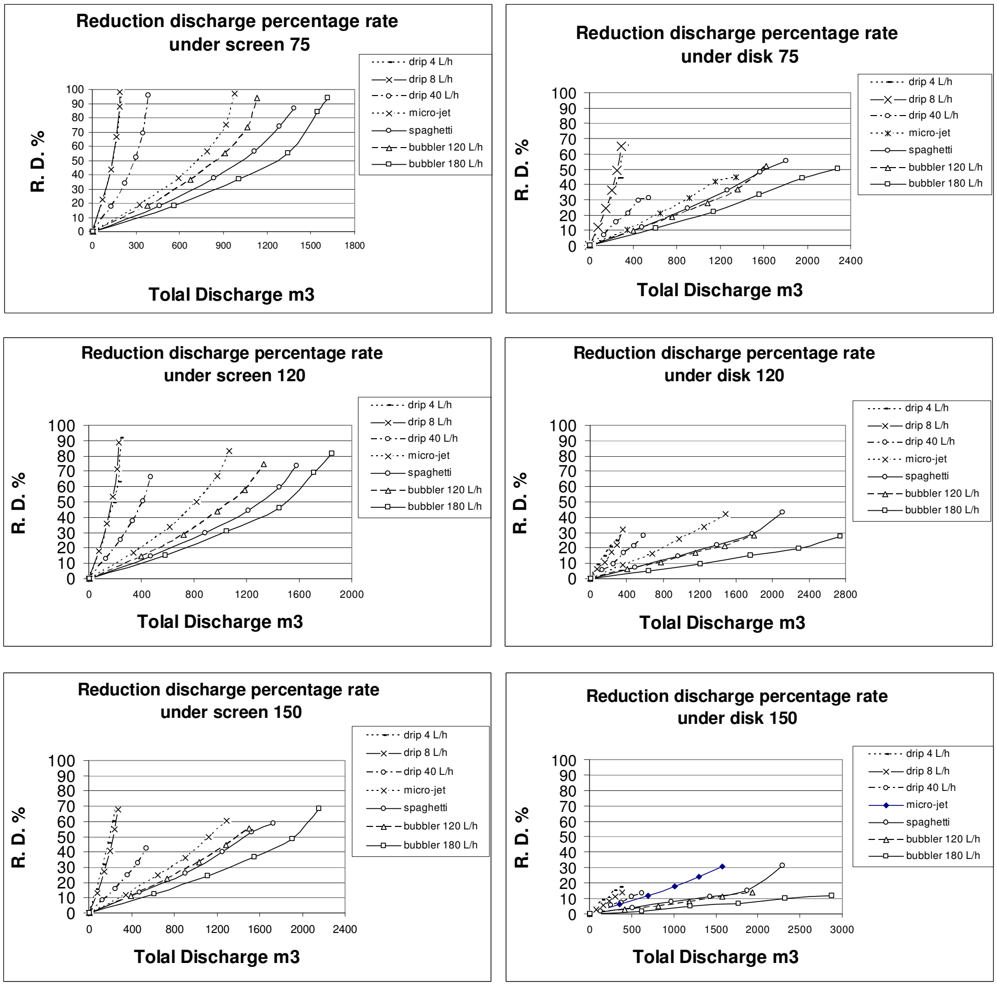


Fig.(6): Reduction discharge percentage rate with total discharge for different emitters under different meshes for different types of filters

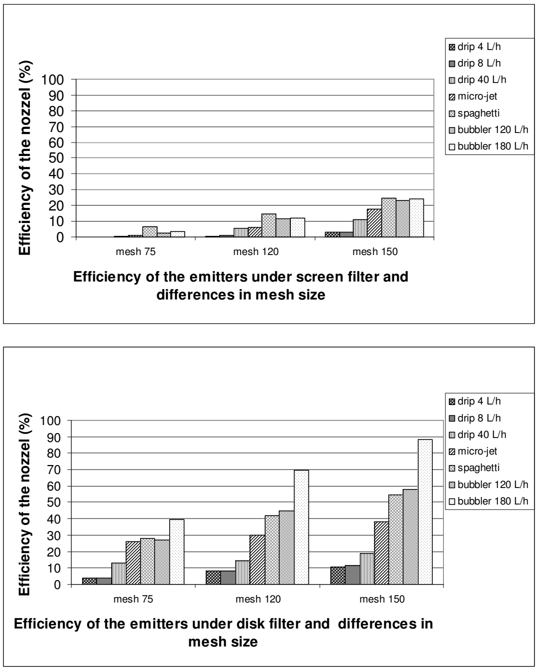


Fig.(7): The effect of filter type and mesh size on the efficiency of the emitters.

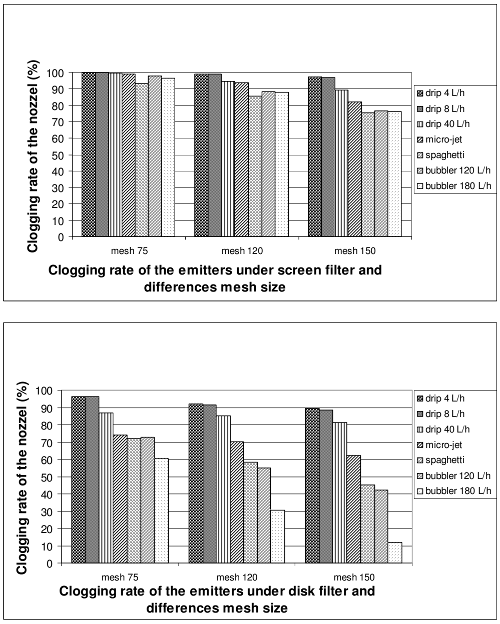


Fig. (8): The effect of type filter and mesh size on clogging % of the emitters

CONCLUSION

The results strongly indicated the effect of wastewater on the performance of micro-irrigation system through the following marks:

1- Disk filter is much better (filtration efficiency and number of operating hours) than screen filter.

2- The best No. of mesh is 150 then 120 and 75. Also increasing No. of mesh improves the following points:

- **a-** Filtration efficiency.
- **b-** Emitters' discharge rate with (time and total discharge).
- **c-** Emitters' efficiency.
- **d-** Emitters' emission uniformity.
- **e-** Decreases emitters' clogging rate.

3- Emitters which have larger discharge are less likely to be clogged than emitters which have a lower discharge (bubbler 180 L/h < bubbler 120 L/h < spaghetti < micro-jet < drip 40 L/h < drip 8 L/h < drip 4 L/h).

4- There are not obvious differences for emitters' emission uniformity under the same filter and mesh number. Nevertheless, the emission uniformity has been improving gradually through the screens 75, 120, 150, and disks 75, 120, and 150.

5- Emission uniformity was weak when using spaghetti emitters.

6- The best emitter was bubbler 180 L/h in emission uniformity and efficiency.

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الملخص العربي

تأثير استخدام مياه الصرف الصحي على أداء نظم الري الدقيق للمسطحات الخضراء

[١] عزمي محمود البري [٢] جمعه عبدربه بكير [٣] عصام واصف [٤] سمير علي الضالعي

لما كانت مياه الصرف الصحي إحدى الموارد المائية الواعدة في ري المسطحات الخضراء والأشجار في كل من مصر ودولة الإمارات العربية المتحدة، وتمشيا مع السياسة العلمية المتبعة في كلا البلدين لترشيد استخدام مياه الري من خلال أتباع نظم الري الضغطي، لذلك هدفت الدراسة إلى قياس تأثير استخدام مياه الصرف الصحي على أداء مكونات الشبكات لتحديد واختيار أنسبها طبقا لمختلف الظروف.

أجريت التجارب العلمية في مزرعة الصداقة الصينية المصرية للشباب بمدينة السادات لتحقيق هدف الدراسة باستخدام نوعين من المرشحات الشبكي والقرصي بدرجات ٧٥، ١٢٠، ١٥٠ ثقب من كل نوع مع موزعات ري بتصرفات مختلفة هي ٤ لتر/ ساعة – ٨ لتر/ ساعة – ٤٠ لتر/ ساعة – ميكروجت – الإسباجتي- الفقاعات ١٢٠لتر/ ساعة، ١٨٠ لتر/ ساعة.

- أظهرت النتائج تأثيرات واضحة على أداء مكونات النظام، ثبت من خلالها تميز المرشحات القرصية على المرشحات الشبكية فيما يختص بكفاءة الترشيح وعدد ساعات التشغيل، في نفس حالات درجات الترشيح المختلفة ٧٥، ١٢٠، ١٥٠ ثقب.
- اتضح أن استخدام المرشحات بدرجات ترشيح أكبر (ثقب أدق) يزيد كل من كفاءة الترشيح، ومعدل تصرف الموزعات ويقلل من معدل إنسدادها.
- توصلت النتائج إلى التوصية بتفضيل استخدام موزعات ذات تصرفات كبيرة مع المرشحات القرصية عند الري بمياه الصرف الصحي عن الموزعات ذات التصرفات الصغيرة مع المرشحات الشبكية.

[1] أستاذ هـ. ز. - ك. الزراعة – ج. القاهرة.
[2] أستاذ هـ. ز. - ك. الزراعة – ج. القاهرة.
[3] باحث أول بمعهد بحوث هـ. ز. - و. الزراعة.
[4] مهندس ز. – بلدية أبوظبي – دولة الإمارات العربية المتحدة.