SIMPLE BACKWASHING SYSTEM FOR A LOCALLY-DEVELOPED SCREEN FILTER

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ABSTRACT

Experiments were carried out in the Agricultural Engineering Department (Hydurlic Lab., Fac. of Agric., Ain Shams University), to design and test a simple backwashing system for a locally manufactured screen filter to be used in micro irrigation system.

The important affecting engineering and hydurlic factors, to design the screen filter with backwashing were determined and tested to get the proper dimensions for the developed filter, and to get the maximum backwashing efficiency, reduce water used in filter backwashing and conserve maximum operating irrigation time.

The main results are summarized as follows:

- *Maxima backwashing efficiencies of about (90-95%) were observed with the following cases:*
    - *a. By using 6 nozzles per rotating backwashing arm.*
    - *b. By using 6 nozzles/rotating arm at 300 kPa pressure, and backwashing time 120 sec., due to, the distribution uniformity of spray from nozzles on the rotating arm along projected area on the screen filter, and proper rotation velocity of the arm.*
    - *c. At nozzle clearance to the filter screen of 62.45 mm, by using 6 nozzles/rotating arm, and backwashing pressure of 300 kPa.*
    - *d. At 60° water cone angle from nozzle, by using 6 nozzles/rotating arm at backwashing operating pressure of 300 kPa.*
- *An increase of 26.3% in filter backwashing efficiency (from 70 to about 95 %) was obtained by raising backwashing pressure from 150 to 300 kPa.*
- *The developed filter required backwashing when pressure drop reaches to 55 kPa, every about 80m^3/cycle. After backwashing cycle, the developed filter is ready for recommended operation condition (pressure drop through the filter, 18kPa).*

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- The pressure drop through the developed filter after backwashing decreased from 25 to 18 kPa, (46%), without and with using proposed designed backwashing resp.
- Consumptive water use during backwashing cycle was decreased from 1.5 to 0.65 m^3/cycle, (28%), without and with using the proposed designed backwashing system, resp.
- Backwashing efficiency for the developed filter, increased from 65% to 95% i.e. (31.6%), without and with using proposed designed backwashing system resp.

Keywords: *Filter, backwashing, rotating arm nozzles, microirrigation*

1. INTRODUCTION

Problems from emitter clogging and filter contamination are becoming labor and arduous. At the end it becomes difficult to attain uniform pressures and discharges throughout the irrigation network. Consequently, a design of a screen filter has been developed with a backwashing rotating arm carrying flushing nozzles. A secondary filter is used to help the backflow during the backwashing to raise the overall efficiency of sediment removal.

Screen in this category functions much like cartridges and strainers, except that they are designed for much higher flow rates (about 91m^3/h or 400 U.S. gpm per housing) and are capable of greater solid retention. To accommodate higher flow rate, screen filters have more filtration surface area per inlet size than cartridges and strainers. Flushing is accomplished with little interruption to the operation of the irrigation system **(Burce, 1985)**.

Many factors affect on the function and capacity of water filtration for trickle irrigation. They include: 1) Source of water, and amount and nature of sediments and other causes of emitter-clogging carried by water; 2) Area served, plant grown, micro climatological, and soil factors; 3) type and size of filter; 4) Time between successive cleaning services; 5) Fertilizers, pesticides and other water treatment additives which may result in precipitation of solids, or from compounds that precipitate; and 6) type and size of trickler, and operation pressure **(Awady, 1991)**.

However**, El-Bagoury (1998)** reported that increasing size of suspended particles from 12 to 375 um leads to increasing filtration efficiency from 90 to 97%, 80 to 94% and 70 to 90% at concentrations of contamination 10, 250, and 750 PPM, respectively. The optimum duration between back washings was 3 hours based on load drop of 5m with 15 PPM of contamination at discharge rate 9.5 m^3/h for river water. The duration can be increased to 10 hours daily by decreasing the filter inlet discharge rate to 3.5 m^3/h.

El-Tantawy (1999) reported that screen filters are best selected for water source with low solid concentration as insurance for clean water, or as secondary filter downstream of a pre-filter. Filtration efficiency tests can be easily and effectively done under laboratory and field conditions in all filters in two different qualities water.

Moreover**, Nakayama et al., 2007**, reported that, as suspended particles are trapped by the filters, the filtration rate decreases, because the filter becomes clogged and must be cleaned to recover operational conditions. Most filters are cleaned with automatic backwashing based on a fixed head loss across the filter and/or an operation time. Both options allow for easy system automation. Automatic backwashing of filters may require a minimum flushing pressure that pumping system must supply.

Ravina et al., 1997, reported that, filters are cleaned automatically by backwashing when the head loss across the filter exceeds 50 kPa, for more than 2 min. Backwashing times were 30 and 20 s for disc and screen filters, respectively. The backwash water volume of screen and disc filters working with effluents was generally smaller than 0.5% of the total water volume passing the filter.

The filter performance in micro-irrigation systems using effluents has been studied by several

authors (**Adin & Elimelech, 1989; Ravina et al., 1997; Tajrishy & Hills, 1994; Puig-Bargués,**

Barragan, Ramirez de Cartagena, 2005; Capra & Scicolone, 2004, PuigBargués, Barragan, Ramirez de Cartagena, 2005; Ribeiro, Paterniani, Airoldi, Silvia, 2008). In these studies, inlet filter pressure was maintained between 250 and 400 kPa. However, as energy saving in the pumping system is an important issue, it is preferred to work with the minimum inlet pressure at which filtration and backwashing are effective.

According to **Duran-Ros, et al., 2009,** an automatic filter backwashing is classified as inefficient depending on the value of the initial head loss across the filter, and found that, the number of filter backwashings required for the screen filter was reduced at 500kPa, especially due to an increase in efficient backwashing. Efficient automatic backwashing with the initial head loss was acceptable for a clean filter and allowed a normal filtration cycle. At 300 kPa, and according to the manufacturer, acceptable head loss after a backwashing was between 10 and 18 kPa for screen filter and between 18 and 28 kPa for disc filters. In the second experiment, as filters operated with greater pressure, the initial head loss across the filters increased. Therefore, acceptable head loss after a backwashings was considered to be between 15 and 24 kPa for screen filters and between28 and 36 kPa for disc filters. They also added that inefficient automatic backwashing with the initial head loss across a clean filter was greater than the head loss thresholds defined for efficient automatic backwashings. Inefficient backwashing, carried out during operational problems, such as insufficient pressure, lack of effluent or breakdown of differential pressure switches, was not considered in the analysis.

The objectives of this study are to design and test a simple backwashing system, of a locally developed screen filter used in pressurized irrigation, and to assess the performance of the developed filter under different pressures during filtration backwashing cycle. The important affecting engineering and hydurlic factors to design the screen filter of backwashing system were determined and tested to get the best dimensions for the system. Also, to get the maximum backwashing efficiency, facilitate backwashing; minimize water used in the filter backwashing and conserve maximum operating irrigation time.

2. MATERIALS AND METHODS

The experiments were carried out in the Agric. Eng. Department (Hydurlic Laboratory), Faculty of Agric., Ain Shames Univ.

2.1 Field experiments: Field experiments were carried out with sediment concentration in the surface water (average 155 mg/l), and to test parameters of the hydraulic backwashing mechanism for the designed screen filter, including:

(a) Testing the developed screen filter reliability in irrigation system,

(b) Identifying hydraulic and engineering characteristics for the developed screen filter and hydraulic backwashing mechanism for comparison and optimization.

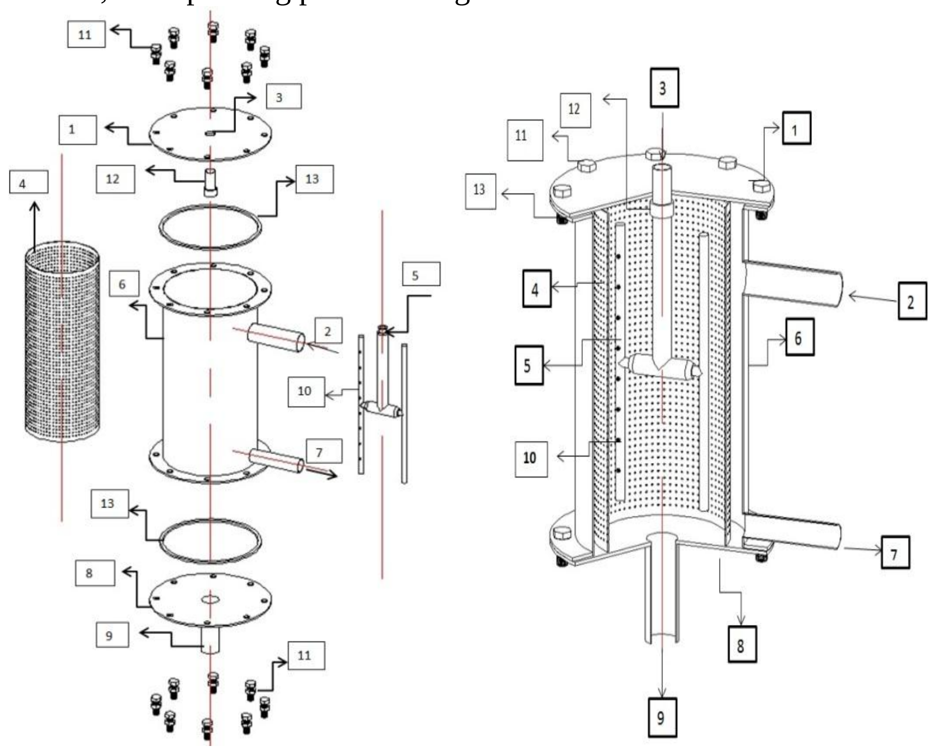
(c) Comparing backwashing screen filter operation with and without rotating arm nozzles.

The purposed screen filter unit consists of two screen filters with backwashing mechanism as shown in Fig.1 and Fig.2.

The unit consists of:

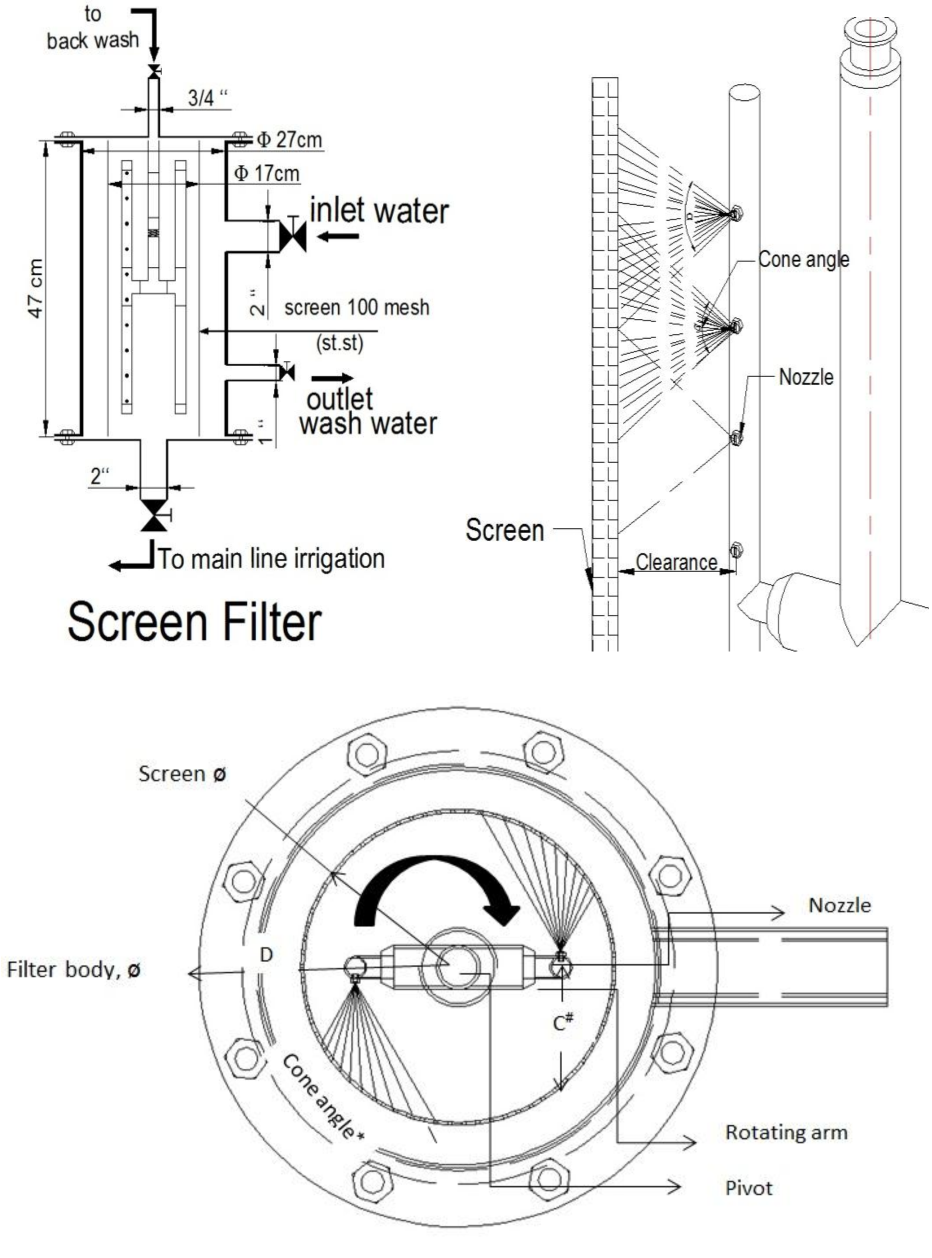
1. **Filter body:** fabricated from steel pipe coated with epoxy rating steel 40 for pressure rating 10 bar, with length 47cm, outside diameter 270mm, wall thickness 3mm, the body is welded with two flanges of 10" D. and 5 mm thickness.
2. "The filter consists of a 470 mm long steel pipe, steel 40 and 10 bar operating pressure, 270 mm outside diameter, thickness of 3mm, coating. Each flange is drilled with 12 holes to connect with top and bottom with bolts and nuts"
3. **Top and bottom filter covers:** through which a perpendicular 1" pipe is welded in center of the plate with 2" inlet, and 2" outlet diameter for pump water to the network irrigation.
4. **Screen:** Fabricated from Sst.316, 6" diameter, 40mm length, rating pressure 10 bars, and 120 mesh.
5. **Backwashing mechanism:** Consists of two P.V.C. pipes 0.5" diameter, 40 cm length. Each pipe has a number of nozzles connected with pivot joint that allows the pipes to rotate inside the screen filter by coupling torque, due to flow discharge from the nozzles.
6. **Pressure gauge:** with range from 0 to 6 bar (0-600 kPa) with an accuracy of 0.1 bar (10kPa) and flow meter with an accuracy of 0.001 m^3.

7. **Pump:** A centrifugal pump of 15 kW power, discharge 50 m^3/h, operating pressure 5 bars, and inlet/outlet diameter 3/2".
8. **Nozzles:** fabricated from cupper with orifice diameter of 1 mm grooved to adjust jet cone angle. The discharge ranged from 0.5 to 1 m^3/h, and operating pressure ranged from 150 to 500 kPa.



1. Top cover, Steel 40 **2. Water inlet, 2" D.** **3. Inlet backwashing mechanism, 1" D.** **4. Stainless steel, 316 screen filter, 6" D.** **5. Rotating arm backwashing P.V.C., 0.5" D.** **6. Steel body 11", Steel 40**	**7. Outlet water flow backwashing, 1.5" D.** **8. Steel bottom cover, Steel 40** **9. Water outlet, 2" D.** **10. Washing nozzles** **11. Steel bolts for cover assembly and body filter** **12. Pivot joint** **13. Rubber gasket**

Fig.1: Developed screen filter section details.



*Cone angles: (0, 30, 45; 60°)

(c): Changeable clearance between nozzle and filter screen

Fig.2: Section in body, screen, and nozzles.

Two rotating arms carry a number of nozzles (2, 4, 6, 8, and 10) at radii of (65, 60, 50, 40 mm) with axial distances of 73 mm each. Every nozzle emits a jet of (0, 30, 45, and 60°) cone angles as shown in (fig. 2). The clearance between the jet and screen varied according to the section geometry.

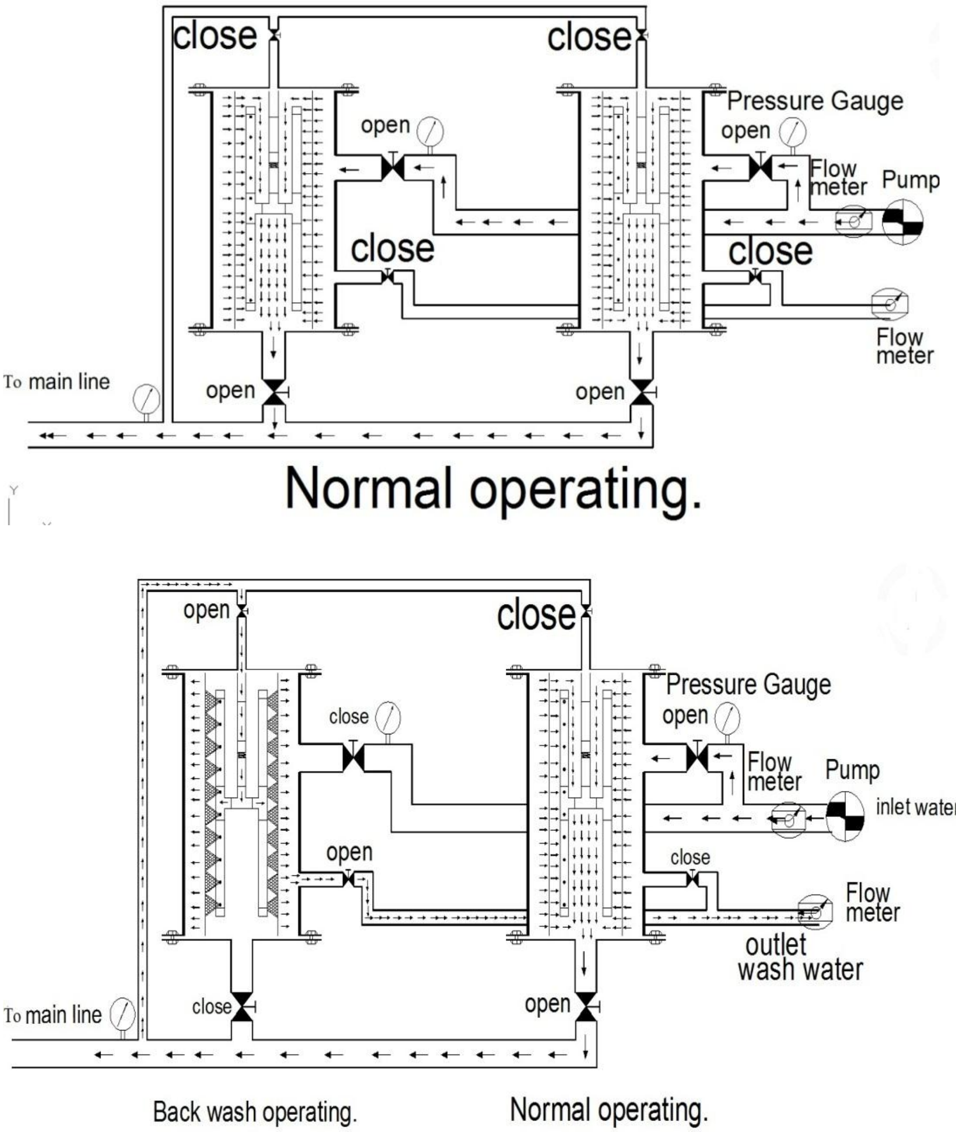


Fig.3: Normal and backwashing operation of screen filter.

Table (1): Specifications of the screen filter.			
Length of the filter body, mm	470	Construction material of the filter body	steel
Outside diameter of the filter body, mm	278	Construction material of the screen filter	St,316
Thickness of the filter body, mm	4	Length of screen filter, mm	40
Maximum pressure(bar)	10	Filtration surface area, cm^2	1914
Maximum discharge (m^3/h)	25	Filtration volume, m^3	17
Inlet and outlet pipe outside diameter, inch	2	Screen mesh size,	120
Screen filter diameter, inch	6	Inlet of backwashing system, inch	1
Arm backwashing diameter, inch	1/2	Size of nozzle on arm, mm	0.25
Backwashing valve diameter, inch	1.5	Gross volume, m^3	24.25

The purpose of the screen filter unit was to locally construct and test the backwashing filter with the following factors:

1- Number of nozzles per each rotating arm.
2- Operating pressures during backwashing (150, 300, 500 kPa).
3- Clearance from nozzle on the rotating arm to filter screen cartridge (46.64, 52.92, 62.45, 69.28 mm).
4- Water spray angles from tested nozzles of (0-30-45 - 60°).
5- Backwashing time (60, 90, 120, 150, 180 sec.).
6- Filtered volume/ backwashing cycle.
7- Action with and without rotating arm of backwashing mechanism.

2.2. Assessment of filter removal efficiency:

The removal efficiency (E) was calculated as:

$$E = \frac{N_o - N}{N_o} \times 100$$

No and N are the values of a physical or chemical parameter of the unfiltered and filtered effluent, respectively.

2.3. Water consumption in filter backwashing:

Filter backwashing consumes additional water. Data registered during the experiments show the filtered volume in every filtration cycle (V_f) and the volume used for every backwashing (V_b). The percentage of water used for filter backwashing (C_b) was calculated as:

$$C_b\% = \frac{V_b}{V_f + V_b} \times 100$$

$$\textit{Backwashing efficiency}(\ \eta\ ) = \frac{\textit{The sediment concentration in back washing water}(\frac{mg}{l})}{\textit{Total sediment concentration on the screen}\ (\frac{mg}{l})} \times 100$$

2.4. Correlation between measured and calculated data.

$$\text{Correlation}\ (R^2) = \frac{\sum (x - \bar{x})(y - \bar{y})}{n.\sigma_x.\sigma_y}$$ (Nigm, 1993 in Arabic).

2.5. Estimation of sediment load.

The sediment retained on the filter screen was estimated by washing, separation on blotting paper, drying, and weighing.

3. RESULTS AND DISCUSSION

3.1 Relation between flow rates for screen filter and pressure drop

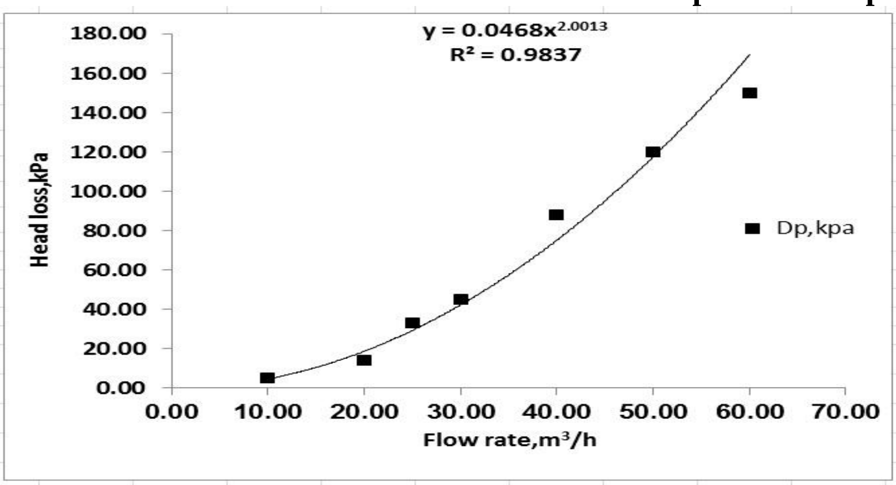


Fig.4: Hydulric characteristic of developed screen filter.

Fig.(4) shows that by increasing filter flow rate from 10 to 60 m^3/h, pressure drop increased from 10 to 120 kPa.

The recommended operating for the developed filter is at discharge range from 20 to 25 m^3/h, and pressure drop range from 18 to 25 kPa.

3.2 Effect of number of nozzles on backwashing efficiency at different operating pressures

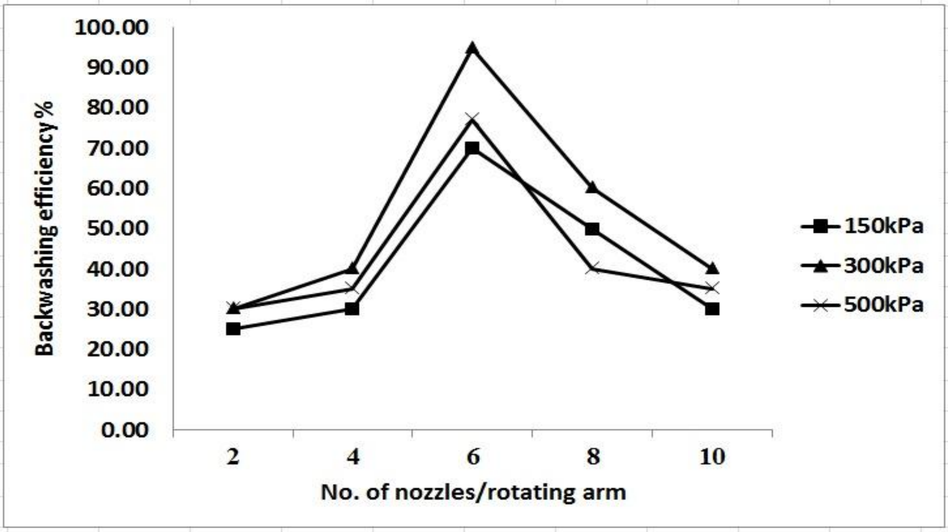


Fig.5: **Effect of number of nozzles on backwashing efficiency at different operating pressure**

Fig.(5) shows that the maximum filter backwashing efficiency was 95% by using 6 nozzles per rotating backwashing arm, and the minimum filter backwashing efficiency was 25% by using 2 nozzles per rotating backwashing arm. i.e. the same high efficiency (~ 95%) could be maintained by using a discharge of $1m^3/h$ and pressure drop of 18kPa per nozzle covering an interfered spacing of about 65-67mm along the axis of the rotating arm during the washing process.

A drop of 58% in filter backwashing efficiency (from 95 to 40 %) was obtained by increasing the number of nozzles / rotating arm from 6 to 10 nozzles. That is due to increasing rotating arm speed, which does not give sufficient opportunity to efficiently remove sediments from the screen filter.

An increasing of 26.3% in filter backwashing efficiency (from 70 to 95 %) was obtained by increasing backwashing pressure from 150 to 300 kPa, and a small drop of 5.3%, in filter backwashing efficiency was obtained by increasing backwashing pressure from 300 to 500 kPa. That is due to increasing of backwashing rotating arm speed, which does not allow efficient cleaning of the screen from sediments.

3.3 Effect of backwashing time on its efficiency at different nozzles number /rotating arm

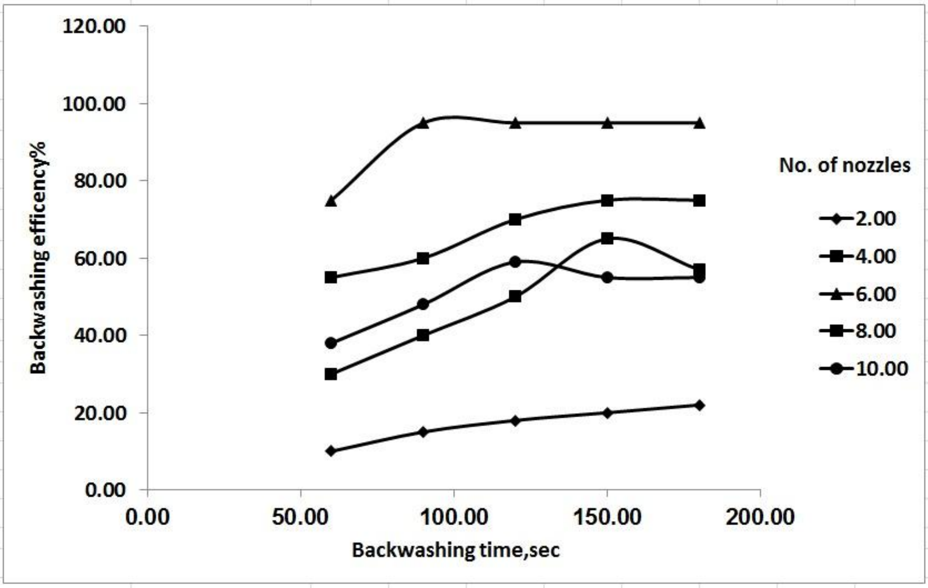


Fig.(6): Effect of backwashing time on efficiency at different nozzles number / rotating Arm.

Fig.6 shows that, by increasing backwashing time from (60 to 150 sec.), its efficiency increased at all tested nozzles number/rotating arm, and there was no effect on backwashing efficiency by increasing its time, from (150 to 180 sec.).

The maximum backwashing efficiency was 91.4% by using 6 nozzles/rotating arm at 300 kPa backwashing pressure, and backwashing time 120 sec., due to, the distribution uniformity of spray from nozzles on the rotating arm along projected area of the screen filter, and proper rotation speed of the rotating arm. The minimum backwashing efficiency was 10% by using 2 nozzles/rotating arm at 300kPa backwashing pressure, and backwashing time 60 sec., due to stopped rotation of the rotating arm.

3.4. Effect of rotating arm speed on backwashing efficiency

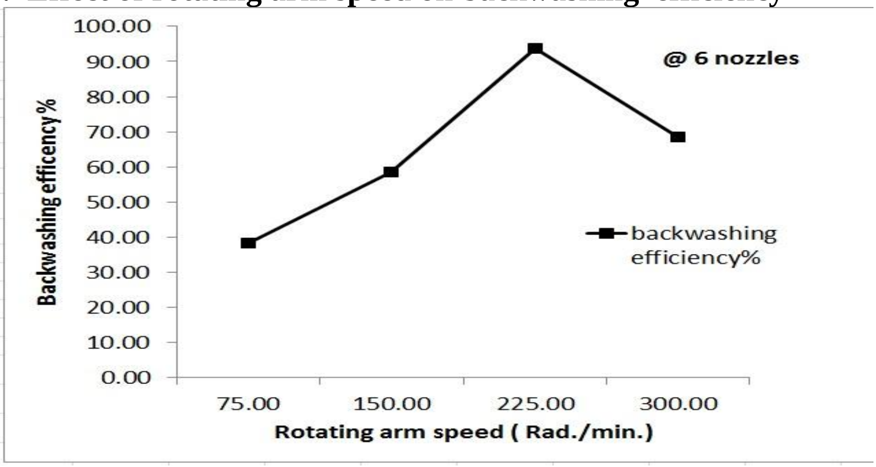


Fig.5: Effect of rotating arm speed on backwashing efficiency.

The maximum backwashing efficiency was 93.8% on 225 rad./min of rotating arm speed, that may due to the best distribution uniformity of water cone from rotating arm nozzles achieved along the projected screen cartridge of the filter, and the minimum backwashing efficiency was 38.2% on 75 rad./min. of rotating arm speed, due to the decreasing of required pressure needed for the efficient cleaning of the screen filter cartridge.

Backwashing efficiency increased from 38.3 to 93.8 %(145%) by increasing rotating arm speed from 75 to 225 rad./min. Meanwhile, by increasing rotating arm speed from 225 to 300 rad./min., the screen filter backwashing efficiency decreased from 93.2 to 68.5%, due to decreasing the required opportunity time for efficient cleaning of sediments from cartridge of the screen filter, from water cone nozzles on the rotating arm.

3.5. Effect of nozzle distance to the screen filter on backwashing efficiency.

Fig.(6) shows that the maximum filter backwashing efficiency was 93.5% at nozzle distance to the filter screen of 62.45 mm, by using 6 nozzles/rotating arm (73 mm spacing between nozzles), and backwashing pressure of 300 kPa, due to excellent uniformity distribution of spray from rotating arm nozzles along the projected screen filter area.

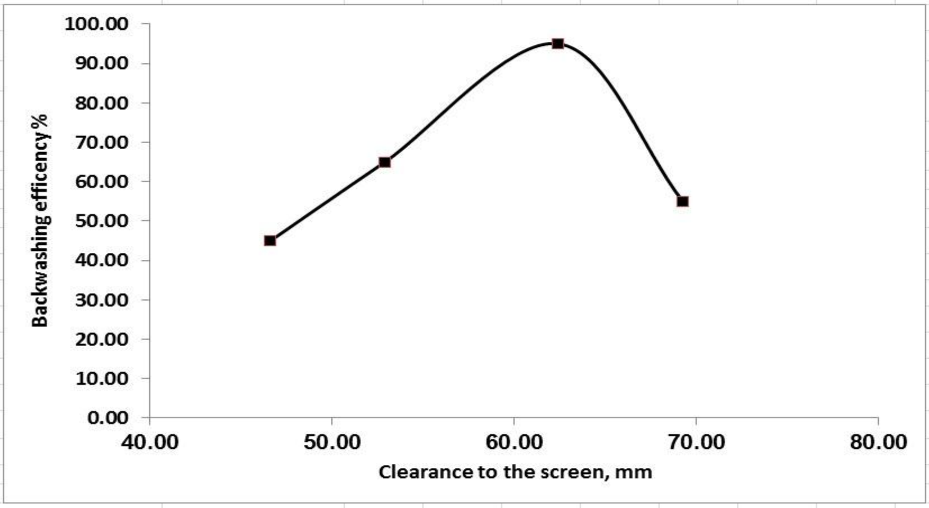


Fig. (6): Effect of nozzle clearance to the screen filter on backwashing efficiency.

The minimum filter backwashing efficiency was 45% at nozzle clearance to the filter screen of 46.64 mm, by using 6 nozzles/rotating arm(73 mm spacing), and backwashing pressure of 300 kPa. That was due to poor uniformity distribution of spray from rotating arm nozzles along the projected screen filter area. By increasing distance from nozzles on the rotating arm to the screen filter (from 69.28 to 46.64 mm), backwashing efficiency decreased from 55% to 45 %, due to increased losses of spray kinetic energy from the nozzles, as required to remove sediment from the screen filter.

3.6. Effect of water cone angle from the rotating arm nozzles on backwashing efficiency

Fig.(7) shows that maximum backwashing efficiency was 92.5% at 60° water jet angle from nozzle, by using 6 nozzles/rotating arm(38.5mm spacing) at backwashing operating pressure 300kPa, while minimum backwashing efficiency was 10 %, by using same number of nozzles at backwashing operating pressure of 300kPa.

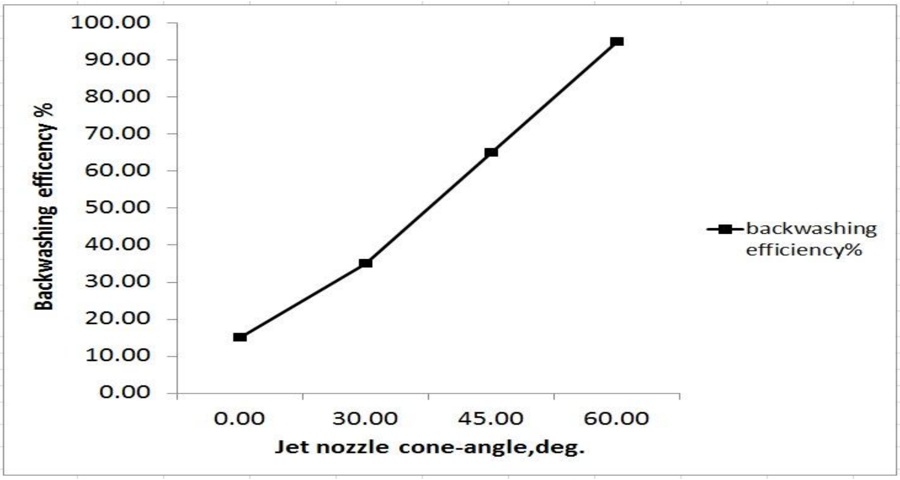


Fig.(7): Effect of water cone angle from the rotating arm nozzles on backwashing efficiency.

3.7. Backwashing cycle based on filtered volume and pressure drop

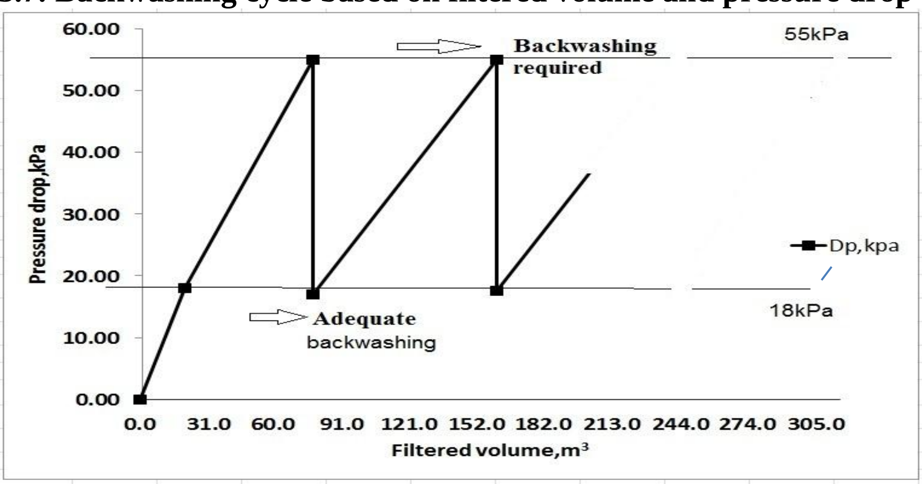


Fig.(8): Backwashing cycle based on filtered volume and pressure drop.

Fig.(8) shows the effect of filtered volume on pressure drop during filter operation.

It is clear that the developed filter required backwashing when pressure drop reaches to 55 kPa, about each 80 m^3/cycle. Backwashing cycle is required after filtered volume of 80 m^3. After backwashing cycle, the developed filter is ready for recommended operation condition (pressure drop through the filter= 18kPa).

3.8. Developed filter backwashing efficiency , pressure drop after backwashing cycle and consumptive water used/backwashing cycle, with and without rotating arm

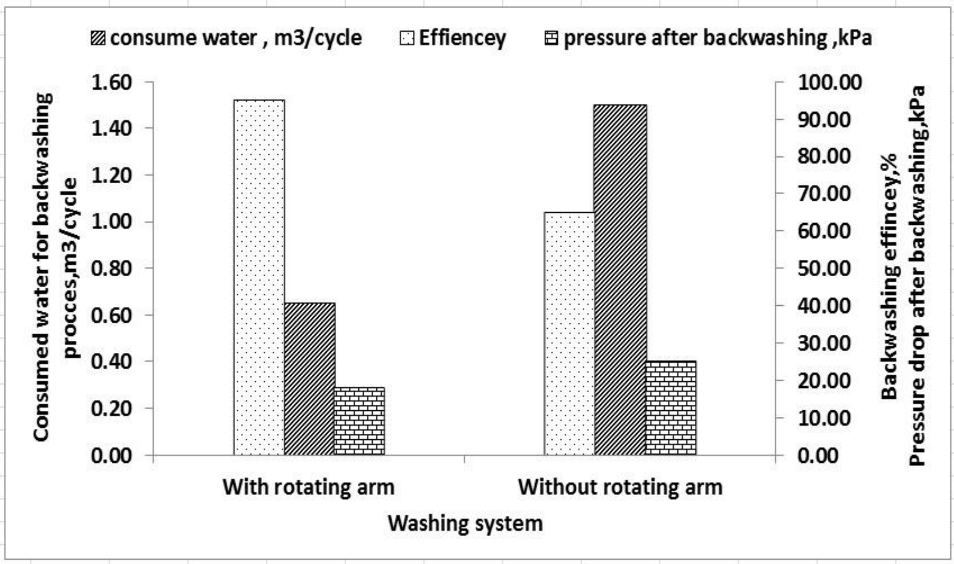


Fig.(9): Developed filter backwashing efficiency , pressure drop after backwashing cycle and consumptive water used/backwashing cycle, with and without rotating arm.

Fig.(9) shows that, the pressure drop through the developed filter after backwashing decreased from 25 to 18 kPa, with (46%) , without and when using proposed designed backwashing resp.

Consumptive water use during backwashing cycle decreased from 1.5 to 0.65 m^3/cycle, with (28%), without and when using proposed designed backwashing resp.

Backwashing efficiency for the developed filter, increased from 65% to 95% with (31.6%), without and when using proposed designed backwashing resp.

CONCLUSION

The maximum backwashing efficiency was (~95%) by using 6 nozzles on rotating arm (73 mm spacing between nozzles) with clearance to screen cartridge of 62.45 mm, water cone angle of 60°, backwashing time 120 sec., and 225 rad./min. of rotating arm speed.

The developed filter required backwashing when pressure drop reaches to 55 kPa, each about 80m^3/cycle. After backwashing cycle, the developed filter is ready for recommended operation condition (pressure drop through the filter, 18kPa).

A saving of consumptive water required for filter cleaning of (28%), by using the proposed designed backwashing system compared without using backwashing system.

Backwashing efficiency for the developed filter, increased from 65% to 95% i.e. (31.6%), without and with using proposed designed backwashing system resp.

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<u>الملخص العربى</u>

" نظام غسيل عكسى بسيط مطور لمرشح شبكى محلى"

***أسامة محمد أحمد بدير**

أجريت التجارب في قسم الهندسة الزراعية (مختبر الهيدورليا، كلية الزراعة، جامعة عين شمس)، لتصميم واختبار نظام بسيط للغسيل العكسي لمرشح شبكى محلى الصنع ، يستخدم في نظم الري الضغطى. وتم تحديد واختبار أهم العوامل الهندسية والهيدروليكية التي تؤثر على تصميم الفلتر الشبكى لنظام الغسيل العكسي للحصول على ابعاده المناسبة ، وللحصول على أقصى كفاءة للغسيل العكسي، وتحديد أقل كمية مستهلكة فى عملية الغسيل العكسي للمرشح والحفاظ على أقل فقد فى طاقة الضغط المستخدمة فى الغسيل، وبالتالى توفير أقصى كمية مياه فى شبكة الرى الضغطى.

وتتلخص النتائج فيما يلي:

- كان الحد الأقصى لكفاءة غسيل المرشح ٩٥٪ باستخدام ٦ فوهات لكل ذراع تدوير للغسيل العكسى(مسافات فوهات بينية ٧٣ مم) .
- تم الحصول على زيادة قدرها ٢٦.٣٪ في كفاءة غسيل المرشح العكسي (من ٧٠ إلى ٩٥٪) من خلال زيادة الضغط العكسي من ١٥٠ إلى ٣٠٠ كيلو باسكال.
- كان الحد الأقصى من كفاءة الغسيل العكسى ٩١.٤٪ باستخدام ٦ فوهات / ذراع دوران، بضغط يساوي ٣٠٠ كيلوباسكال، ووقت الغسيل العكسي ١٢٠ ثانية، وذلك بسبب انتظامية التوزيع للرش من الفوهات على الذراع الدوارة على طول المنطقة المسقطة على شمعة المرشح الشبكى، وسرعة الدوران المناسبة للذراع الدورنية.
- كان الحد الأقصى لكفاءة الغسيل العكسى ٩٣.٥٪ عند مسافة فوهة ٦٢.٤٥مم من شمعة المرشح ، وذلك باستخدام ٦ فوهات / الذراع الدورنية، والضغط العكسي المستخدم ٣٠٠ كيلو باسكال.

***مدرس الهندسة الزراعية، زراعة عين شمس، القاهرة- مصر.**

- كان الحد الأقصى من كفاءة الغسيل العكسي ٩٢.٥٪ عند ٦٠ درجة زاوية المياه الخارجة من فوهة الرش، وذلك باستخدام ٦ الفوهات / الذراع الدورانية في عملية الغسيل العكسى ، وضغط التشغيل ٣٠٠ كيلوباسكال.
- كانت كمية مياه حوالي ٨٠ م ٣ / دورة للمرشح المطور المطلوب للغسيل العكسي عندما يصل الضغط إلى ٥٥ كيلو باسكال بعد المرشحات، وعندها تبدأ دورة الغسيل العكسي للمرشح لحالة التشغيل الموصى بها، وتستمر عملية الغسيل العكسى حتى يصل انخفاض الضغط من خلال المرشح الى ١٨ كيلوباسكال ، ثم تبدأ دورة جديدة للرى .
- انخفض الضغط من خلال المرشح المتطور بعد الغسيل العكسي من ٢٥ إلى ١٨ كيلو باسكال، وبنسبة (٤٦٪)، بدون استخدام ذراع الدوران فى الغسيل العكسى ، وباستخدام نظام الدوران العكسى لتصميم المرشح المقترح.
- انخفض استخدام المياه المستهلكة خلال دورة الغسيل العكسي من ١.٥ إلى ٠.٦٥ م ٣ / دورة، (٢٨٪)، بدون استخدام ذراع الدوران فى الغسيل العكسى ، وباستخدام نظام الدوران العكسى لتصميم المرشح المقترح.
- ارتفعت كفاءة الغسيل للمرشح المقترح من ٦٥٪ إلى ٩٥٪ وبنسبة مئوية (٣١.٦٪)، بدون استخدام ذراع الدوران فى الغسيل العكسى ، وباستخدام نظام الدوران العكسى لتصميم المرشح المقترح.