Misr J. Ag. Eng., 25(3): 824-836

HYDRAULIC PROPERTIES EFFECT OF FILTER MEDIA ON EMITTER CLOGGING PROBLEMS

M.N.EL Awady, **A.M.EL Berry, ***M.A. I. Genaidy,* A.M.Zayton**

ABSTRACT

Series of laboratory experiments were conducted to investigate the filtration performance of different types of filter media under different operating conditions, and to study their influence on the emitter clogging problems. The emitter clogging problem under these different operating conditions was investigated. Five different emitter types were used. The statistical split-split- split plot design was chosen for this study. Obtained results indicated that, Sedimentation loads is the second most important factor affecting the media filter performance. Using high sedimentation loads of 50 and 100 mg/L affected drastically the removal efficiency. An improvement of the removal efficiency due to increasing filter bed depth from 30 to 50 cm was noticed. The susceptibility to clogging of the tested emitter types varied according to its emitter type, sedimentation loads, and removal efficiency. Obtained results indicated that the use of crushed silica and crushed basalt (2) media types, E-2 and Supertif emitter types under operating condition of at least 50 cm and sedimentation loads of 10 to 20 mg/L contributed to better performance of the trickle- irrigation system.

***Keywords*:** trickle irrigation, filtration, filter media, emitter, clogging

INTRODUCTION

Trickle irrigation is an attractive alternative for conserving water in Egypt, where water is scarce. The most important objective of trickle irrigation is to provide adequate water quantity to each irrigated plant. The efficiency of trickle irrigation systems depends directly on the uniformity with which water is discharged from the emission devices throughout the system. So, all emitters in the system should discharge equal amounts of water. Manufacturing variation, pressure differences, emitter plugging, temperature variations ,etc. affect negatively on uniformity.

* Prof. Emerit. of Ag. Eng., Ain Shams Univ. ** Prof. of Ag. Eng., Cairo Univ.

*** Assist. Prof. of Ag. Eng., Ain Shams Univ. ****Res,Ag. Eng. Res. Inst., A.R.C. Egypt.

Serious crop damage or economic loss can occur. (James,1993;and Hill and Tajrishy,1995). According to Mizyed and Kruse (1989), the main factors affecting drip irrigation system uniformity are:(1) manufacturing variations in emitters and pressure regulators,(2)pressure variations caused by elevation

changes, (3) friction head losses throughout the pipe network, (4) emitter sensitivity to pressure and irrigation water temperature changes, and (5) emitter clogging. Similarly, Capra and Scicolone (1998) indicated that the major sources of emitter flow rate variations are emitter design, the material used to manufacture the drip tubing, and precision. Nakayama (1993) classified the major clogging agents as physical, chemical and biological contaminants. All these constituents of clogging are carried or present in the irrigation water. These include the suspended soil material, biological organic debris, plastic cuttings, dissolved chemicals that can precipitate out under certain conditions and bacteria that can form slime or secondary precipitates following their activity on certain substances. Analysis of the irrigation water for these clogging agents plays an important role in trying to determine the type of clogging problem that can likely occur by using a particular water supply. Filtration of irrigation water is the physical treatment to prevent or reduce the physical clogging problems in trickle irrigation. Keller and Bliesner (1990) stated that recommendations by emitter manufacturers on the degree of filtration required should be followed; however, where no recommendations are available, final filtration size should be one-tenth the diameter of the emitters smallest opening. Other manufacturers recommended removing particles larger than 0.075mm or 0.15 mm. They added that where open waters are used; a complex filtration system is usually required. The system may consist of a pre-filter, such as settling basin or vortex separator, followed by a sand filter and then screen filter. Media filters are used in clarifying irrigation water for trickle irrigation where, there is a moderate to heavy load of suspended solids; there is possibility of organic contamination and when screen filter needs frequent backwashing. Three important components must be considered in performance evaluation of media filters. These include removal efficiency, pressure drop, and emitter clogging; (Nakayama and Bucks, 1986).Boman (1995) conducted an experiment over a three years period to evaluate the clogging rates of microsprinkler emitters with orifice diameters of 0.76mm, 1.02 mm, and 1.27mm. Every three months, each emitter was inspected and those that were clogged were examined to determine the cause of clogging. All fouled emitters were thoroughly cleaned and/or replaced. Overall, 46% of the clogging was due to algae, 34% was from ants and spiders, 16% was from snails, and 4% was from physical particles such as sand and bits of PVC. The total clogging rate was found to be inversely related to the orifice area of the emitters during the three- years study. The optimum characteristics of gravel media with a uniformity coefficient ranged from 1.4 to 1.6. When such conditions are not available, the value of D10 up to 2mm and Cu up to 3.5 may be accepted. (Hegazi, 1994). Farrell (1989) explained that the permeability of the filter media must be high enough to allow the flow of water with optimum pressure loss. For most common media, water flow rates through media should be in a range of 10.2 to 17 L/s.m2. A good safe flow- rate to use for moderately dirty water is 11.54 L/s.m2. Phillips (1995) stated that the sand-media filter can be a tremendously valuable tool when operated and maintained properly. The recommended flow rate of media filter ranged between (36.6-60) m3/h.m2 of filter surface area. An effective diameter of (1.4-1.6) and in sometimes to 2 mm is generally recommended. Filter media also should have a uniformity coefficient of at least 1.5 or better. Use of sharp edged and angular filter media will provide the optimum removal of suspended solids from the water source. The main objectives of this study were identifying the physical and chemical properties of the tested filter media; determining the hydraulic and manufacture characteristics of the tested emitter types and investigating the effect of the removal efficiency of tested media types on the emitter clogging ratio under different operating conditions.

MATERIALS AND METHODS

Different media types were used, namely: coarse sand; crushed basalt, (1); crushed silica, crushed basalt, (2). The experiments aimed to: evaluating the filtration efficiency for each media type at different bed depths, flow rates, sedimentation load. A media filter was designed and constructed for the purpose of these experiments. Details description of media filter are shown in Fig. (1), and examining the performance of different emitter types and testing there susceptibility to clogging under different operating conditions. Five different emitter types were used, which were, Turbo-key, E-2, Tufftif, Katif and Supertif. The experimental setup included the filter performance testing system, and emitters testing system. Filter experiment system was based on the assumption that field conditions such as suspended material, concentrations, filtering velocity, and identical filter media could be carefully simulated. Four types of media, each in two filtration depths, 30 and 50cm, and five different sediment loads (10, 20, and 50,100) mg/L were used.

Different sedimentation compositions were used according to the (ASAE Standards, 1998) recommendations.

Experimental measurements were carried out under the condition of 200-kPa inlet pressure. The initial head loss through the clean media bed and the underdrain assembly ranged from 10 to 12 kPa for media bed depth of 30 cm, and from 14 to 16 kPa for media depth of 50 cm. The flow rate was measured over 10 kPa pressure drop increments. The experiment was terminated when the head loss through the filter reached 70 kPa. The time at which the pressure drop reaches 70 kPa is the backwashing time. The evaluation of the filter efficiency followed the measurements of the total suspended solids of water samples before and after the filter. Filter papers were used to filter the water samples. The filter papers were then completely dried in the electrical oven. The following equation was used to calculate the filtration efficiency according to ASAE standards (1998):

$$E_r = 100\ (1 - S_1/S_2)$$

Where:

E_r: removal efficiency,

S_1: outlet concentration of suspended solids in mg/L, and

S_2: inlet concentration of suspended solids in mg/L.

Laboratory measurements based on the procedure proposed by Keller and Karmeli (1975) were conducted to study the hydraulic performance of different emitter types. A total of five available models of emitters were selected to be included in the experiments. Those emitters were further categorized by flow rate. Discharge rates from different emitters were collected at different pressures from 50 to 300 and to 350 kPa for Supertif and Katif emitters. The pressure regulator and pressure gauge at the beginning of the emitter test controlled pressure. Data were collected after one hour to ensure that the reached desired -pressure remained constant. Coefficient of manufacturing variation (C_v), emitter exponent (x), and discharge coefficient (K) were computed. These parameters were used to evaluate the effect of emitter exponent, x, on the flow regime in relation to pressure and to find the emission uniformity of water for each tested emitter. The scheme of the system used for testing emitter performance following different levels of sediments in water, and by using different types of media, and different filtration bed depths is shown in Fig. (2). It consists of four laterals. The lateral tubing was 14 mm polyethylene hose. Emitters of specific make and flow rate were placed at 0.15cm spacing. Control valve, pressure gauge, and pressure regulator were provided at the system inlet to control the pressure during the test. Emitters clogging-tests were conducted parallel to the filter performance tests by using four different sediment concentrations and tap water as a control treatment. The initial operating pressure for all treatments was maintained at 100 kPa. The degree of emitter clogging was related directly to the reduction in the average flow rate for each emitter to the design flow- rate. Therefore, flowrates of individual emitters were measured. Emitters with flow reduced to less than 50 percent of the design flow were considered clogged. The degree of emitter clogging can be calculated for any emitter duration as follows:

$$\alpha = (1 - (Q_{avg.} / Q_d)) * 100.$$

Where:

α :clogging ratio, (%)

Q_{avg}: average flow rate for each emitter (Lph), and

Q_d : design flow rate for each emitter type (Lph).

The statistical split-split-split plot design was chosen for this study. Four parameters were considered in the analysis, which were: five sedimentation loads, four types of media, two filtration depths and five different emitter types. These four variables were combined in the design in two replicates.

RESULTS AND DISCUSSION

Emitter characteristic data:

Values for the emitter exponent (x), discharge coefficient (K) and consequently the flow regime are presented in table (1) for all types of the tested emitters. Flow regimes for these emitters are categorized depending on their emitter exponent values. All tested emitters inhabited a coefficient of manufacturing variation (C_v) values less than 0.05 and therefore lay in the acceptable range. Turbo-key, E-2, Tufftif and Katif emitter types discharged water uniformly than Supertif emitter type.

Table (1): Some manufacture characteristics and hydraulic performance data of the tested emitters.

Type of emitter	P kPa	$Q_{avg.}$ Lph	x	K	C_v %	EU %	Flow regime
1.Turbo-key	50-300	4.0	0.5026	0.3983	1.59	95.20	Turbulent
2.E-2	50-300	4.08	0.608	0.4881	2.13	93.76	Partially turb.
3.Tufftif	50-300	1.99	0.5808	0.1416	2.93	92.33	Turbulent
4.Katif	50-100		0.4045	0.5878			Pressure comp.
	100-350	3.71	0.0512	2.9315	3.40	90.92	
5.Supertif	50-100		0.3427	1.4707			Pressure comp.
	100-350	8.02	0.0599	6.0814	4.0	88.73	

Their emission uniformity (EU) values were 95.20, 93.76, 92.33, and 90.92% respectively. For pressure compensating emitters, it was so difficult to find out a mathematical expression for the discharge- pressure, because of the complexity relation between a given pressure and the corresponding value of the discharge. Therefore, these types of emitters were tested on two stages ; (50 –100) kPa and from (100 - 350) kPa as shown in table (1) .

Emitter clogging test:

Obtained results and the statistical analysis indicated that the sedimentation load affected significantly the emitter clogging ratio in all treatments as shown in Fig.(3). Supertif emitter type had the minimum clogging ratios of 1.05 and 1.6% at 10 and 20 mg/L sedimentation loads and 50 cm filtration depth with crushed silica media type respectively as shown in Figs. (3) and (4).

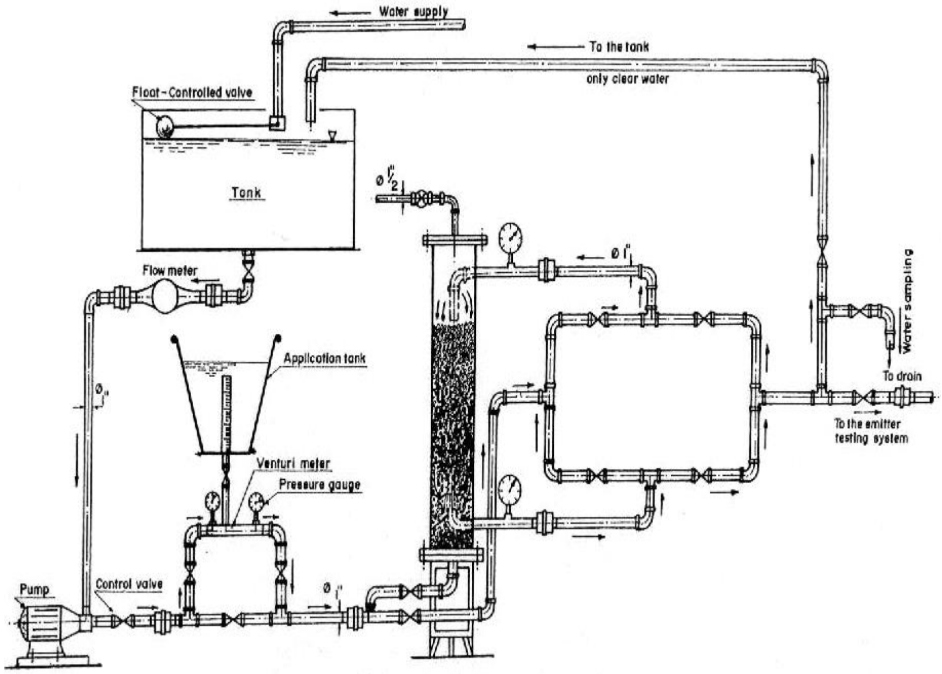

Fig. (1): Details of the filtration performance testing apparatus.

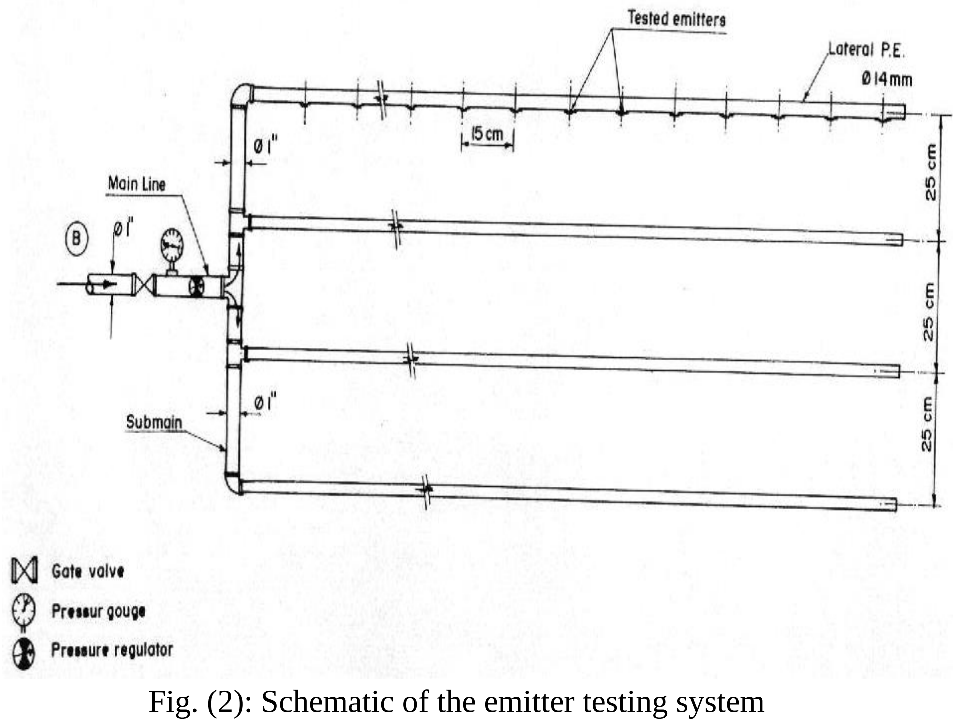

Fig. (2): Schematic of the emitter testing system

Increasing the sedimentation load to 50 and 100 mg/L influenced drastically the performance of the all tested emitters especially Supertif and Katif emitter types. The relationship between media type and the emitter clogging ratio was found to be very correlated. Filter media, which had the best filtration efficiency, contributed by reducing the emitter clogging problems.

Figs. (3) and (4) show the effect of media type on the performance of the tested emitters under different operating conditions. Crushed silica and crushed basalt, 2 media types offered the minimum clogging ratio for most treatments. The maximum clogging ratio of 1.76% was for orifice emitter type (Tufftif) by 10 mg/L, 30 cm filtration depth and crushed silica media type. Meanwhile,it was 2.30%, 2.12% and 1.93% for coarse sand, crushed basalt, 1, and crushed basalt "2" media types, respectively, as shown in Fig. (4). The same trend was found with the other emitter types and treatments.

Comparison between Figs. (3) and (4) indicates that the emitter-clogging ratio decreased by increasing the filtration bed depth from 30 to 50 cm at the same sedimentation load. Also, the statistical analysis of the emitter clogging test data confirmed that increasing the filtration bed depth from 30 to 50 cm affected the clogging ratio very significantly. This was a general observation in all treatments.

The differences between the levels of emitter clogging according to their types at 1% significance were found to be very significant .Figs. (3) and (4) show that the Supertif and E-2 emitters types were less sensitive to clogging than the other tested emitter types under sediment loads of 10 and 20 mg/L. Orifice emitter types (Turbo-key and Tufftif) were more sensitive to clogging than long path emitter type (E-2). Pressure compensating (Katif) and orifice (Tufftif) emitters types were more sensitive to clogging under the same operation conditions. All tested emitter types were sensitive to clogging and caused trouble when using sedimentation loads of 50 and 100 mg/L. Therefore, it was enough to demonstrate the susceptibility to clogging of the tested emitters under operating conditions of 10 and 20 mg/L only.

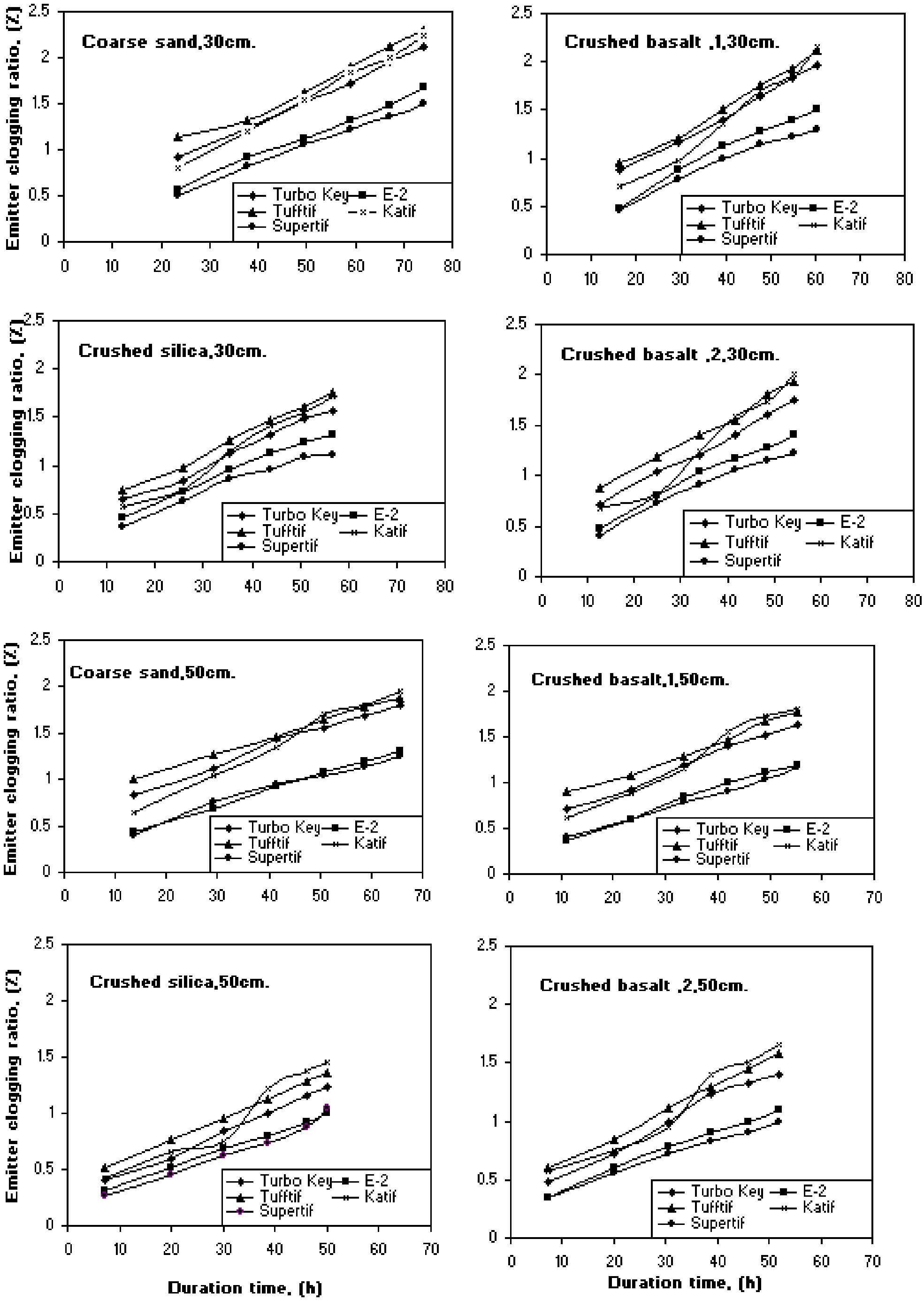

Fig. (3) : Emitter clogging ratio as affected by operating time, media types and filtration depths at 10 mg/L. sedimentation load.

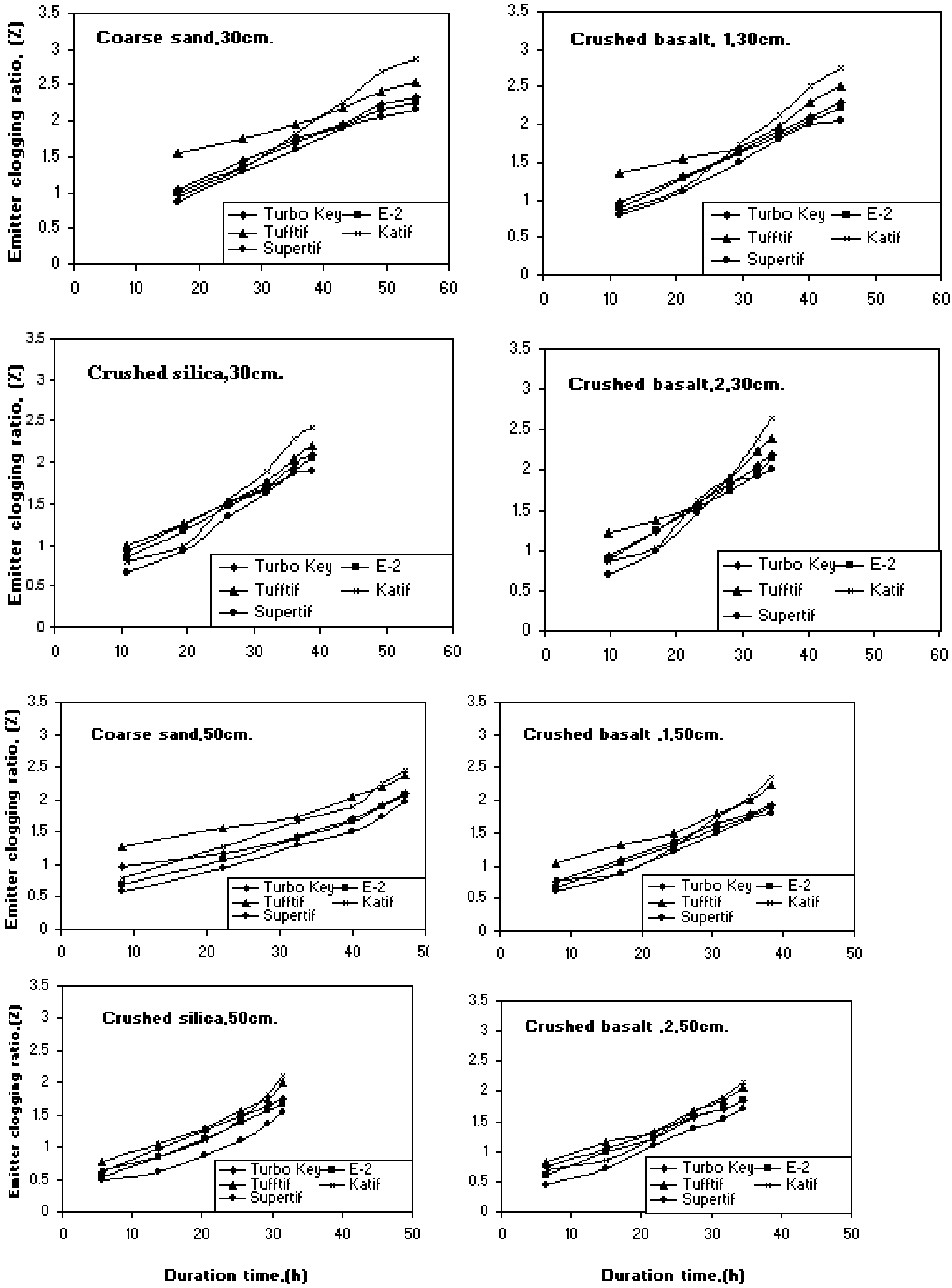

Fig.(4): Emitter clogging ratio as affected by operating time, media type and filtration depth at 20 mg/L sedimentation load.

CONCLUSION

Media size is the main factor affecting removal efficiency and pressure loss development. Sedimentation loads is the second most important factor affecting the media filter performance. Using high sedimentation load of 50 and 100 mg/L reduced drastically the removal efficiency. An improvement of the removal efficiency due to increasing the filtration depth from 30 to 50 cm was noticed. Greater filter bed depth is required to achieve the same removal efficiency as that by finer media at the same operating conditions. Head loss development across the filter media is directly proportional to the bed depth sedimentation loads and accumulated filtration time and inversely with media size. The susceptibility to clogging of the tested emitters varied according to their types, sedimentation loads, and removal efficiency. Obtained results indicated that the use of crushed silica and crushed basalt (2) media types with an effective diameter of 1.30 and 1.31 mm respectively, E-2 and Supertif emitter types under operating condition of at least 50 cm and sedimentation loads of 10 to 20 mg/L may contribute to better performance of the trickle irrigation system. Additional filtration processes are recommended to maintain the system at acceptable performance especially at sedimentation loads of 50 mg/L and more. Emitter design should be carefully considered before making water treatment recommendations.

REFERENCES

ASAE standards. 1998. Media filters for irrigation- testing and performance reporting. ANSI/ASAE S 539 OCT 95. : 953-958.

Boman, B.J. 1995.Effects of orifice size on microsprinkler clogging rates. Applied-engineering- in Agricultural. 11: (6): 839-843.

Bucks, D. A., and F. S. Nakayama. 1985. Guidelines for maintenance of a trickle irrigation system, Proc. of the 3rd Inter. Drip/Trickle Irrig. Cong. Cal. USA. : 119-126.

Capra, A and B. Scicolone. 1998. Water quality and distribution uniformity in drip/trickle irrigation systems. J. Agric. Eng. Res., 70: 355-365.

Farrell, D. M. 1989. Filtration: The key to successful micro-irrigation systems. Irr. J., Nov.-Dec. : 4-7.

Hegazi, M. M. 1994. Evaluation of local gravel media for filtration of new-irrigation systems. Misr J. Ag. Eng., 11 (2): 338-352.

Hill, D. J., and M. Tajrishy. 1995. Treatment requirements of secondary effluent for microirrigation, Proc. of the 5th. Inter. Microirrigation cong. Orlando, Florida. : 887-892.

James, G. Larry. 1993.Principles of farm irrigation system design, Krieger Publishing Company Malabar, Florida.

Keller, J. D., and D. Karmeli. 1975. Trickle irrigation design.1 St Ed. Rain Bird Manufacturing Corporation, Glenotora, Cal.: 133.

Keller, J, D., And R. S. Bliesner. 1990. Sprinkler and trickle irrigation, van N. Reinhold, : 441-445.

Mizyed, N and E.G. Kruse. 1989. Emitter discharge evaluation of subsurface trickle irrigation systems. Transactions of the ASAE, 32: 1223-1228.

Nakayama, F. S.1982. Water analysis and treatment techniques to control emitter plugging. Technical conference proc. The Irrigation Association, Portland, Oregon. : 97-112.

Nakayama, F. S. 1993. Managing water quality, drip irrigation. Management. of subsurface drip irrigation, theory, practices, and application. Visalia Cal. : 27-41.

Nakayama, F. S., and D. A. Bucks. 1986. Trickle irrigation for crop production. Design, Operation, and Management. Developments in Agricultural Engineering. 9. Elsevier. N.Y.: 164-188.

Phillips P. Kenneth. (1995). Long- term operation of Microirrigation filtration systems, successes, falilures and operational solutions. Proc. of the 5th. Inter. Microirrigation cong. Orlando, Florida. : 579-585.

Zayton ,A.M.2001. Effect of hydraulic properties of filter media on the design of trickle irrigation network. Ph. D. Ain Shams Univ. Cairo , Egypt: pp 241.

ا لملخص ا لعر بي

الخواص الهيدروليه لأوساط الفلا تـر الحصـويــه و تأثيرهـا على مشاكل إنسداد المنقطات

محمد نبيل العوضى* عزمي محمود البرى محمد عبد المجيد جنيدى*** عبد الحليم زيتون******

يهدف هذا البحث إلى دراسة الخواص الهيدروليه لبعض أوساط الترشيح الحصوية و تأثيرها على مشاكل انسداد المنقطات في شبكه الري بالتنقيط.وتم تحديد الخواص الهيدروليه لبعض أنواع المنقطات المستخدمة في البحث و التي تتمثل في ثابت خاص بنوع نمط السريان(x) , ثابت خاص بنوع المنقط (K), معامل الاختلاف(Cv) و معامل انتظامية البث (CU).

دراسة أداء أوساط الترشيح تحت ظروف تشغيل مختلفة من تركيز الشوائب (١٠ ، ٢٠ ، ٥٠، و ١٠٠ ملليجرام / لتر) و أعماق الترشيح (٣٠ ، ٥٠ سم) . دراسة ظاهره انسداد المنقطات تحت هذه الظروف. هذا و قد شملت الدراسة خمسه أنواع من أوساط الترشيح : الرمل الخشن ، البازلت المجروش – ١، السليكا المجروشه، البازلت المجروش-٢. بالإضافة إلي خمسه أنواع مختلفة من المنقطات: (Turbo-key, E-2, Tufftif, Katif and Supertif) .

صممت التجارب المعملية إحصائياً كتصميم مناسب للتجربة حيث اختيرت القطع المنشقة بمستويات ثلاث (split-split-split plot design). وكانت أهم النتائج كما يلي:

١- أظهرت أوساط الترشيح الدقيقة كفاءة ترشيح أعلى من تلك للأوساط الخشنة وذلك عند نفس عمق الترشيح و نفس المحتوى من الشوائب. و لقد تميز وسط الترشيح(السليكا المجروشة) ذو القطر الفعال (١,٣ مم) بأعلى كفاءة ترشيح (٧٦,١٩٪) عند مستوى(١٠ ملليجرام/ لتر) من الشوائب و ٥٠ سم عمق ترشيح.

٢- أكدت نتائج التجارب أن تركيز الشوائب العالقة بمياه الري تأتي في المرتبة الثانية من حيث التأثير على كفاءة أداء أوساط الترشيح. فعلى سبيل المثال سجل وسط الترشيح (السليكا المجروشة) كفاءة ترشيح ابتدائية قدرها (٧٣,٣٢، ٦٩,٠٨، ٦٣,١٥ و ٦١,١٣٪) وذلك عند مستويات من الشوائب (١٠،٢٠،٥٠ و ١٠٠ملليجرام / لتر) على الترتيب و عند عمق ترشيح قدره ٥٠ سم. هذا و لقد لوحظ أن جميع أوساط الترشيح تبدى كفاءة ترشيح مرفوضة عند مستويات الشوائب (٥٠ و ١٠٠ ملليجرام/لتر).

٣- أدى زيادة عمق الترشيح من ٣٠ الى٥٠ سم إلي زيادة ملحوظة في كفاءة الترشيح. على سبيل المثال أظهرت أوساط الترشيح(البازلت المجروش-٢ و السليكا المجروشة) زيادة في الكفاءة الترشيحيه قدرها ٥٪ و ٥,٤٢٪ على الترتيب عند مستوى من الشوائب قدره (٢٠ ملليجرام/لتر) و ذلك عند زيادة عمق الترشيح إلى ٥٠ سم.

٤- أظهر نوع المنقط (E-2) أداء طيباً خاصة مع مستويات الشوائب (١٠و ٢٠ملليجرام/لتر). كذلك فقد أظهر مستوى متوسط من الأداء عند المستويات الأعلى من الشوائب مقارنةً بالأنواع الأخرى من المنقطات المختبرة. هذا و قد أظهر المنقط (Supertif) أداءاً حسناً مع مستويات الشوائب(١٠و ٢٠ملليجرام/لتر. الأنواع الأخرى من المنقطات المختبرة تحتاج إلى إجراءات ترشيح إضافية للمياه للوصول بها إلى مستوى مرضى من الأداء.

*أستاذ الهندسة الزراعية غ المتفرغ–جامعة عين شمس ** أستاذ الهندسة الزراعية المتفرغ –جامعة القاهرة

*** مدرس الهندسة الزراعية–جامعة عين شمس **** باحث– معهد بحوث الهندسة الزراعية