Available online at www.elixirpublishers.com (Elixir International Journal)

Pollution

Elixir Pollution 36 (2011) 3141-3147

ISSN: 2229-712X

Evaluation and optimization of drain filter performance based on available design standards

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ARTICLE INFO

Article history:
Received: 28 April 2011;
Received in revised form:
17 June 2011;
Accepted: 26 June 2011;

Keywords
Drainage,
Filters,
Geotextile,
Optimization,
Gradient ratio and
Khorram Shahr.

ABSTRACT

One of the major problems in using subsurface drain is pipe and envelope clogging by mineral materials. Such a process is the result of disturbances of soil structure during drain installation. Drain filter selection follows definite rules and neglecting them can result in project failure. Current study is based on evaluation of three kinds of synthetic filters in comparison with mineral filters. Two soil samples of northern Khorram Shahr (1.65m deep) were obtained for the study. Physical and chemical analysis on samples showed they do not have major differences in texture and particle size distribution (PSD). Original recommendations based on previous studies on synthetic filters in terms of PSD curve and soil texture was to use PP700 type. Two other types were also chosen as the upper and lower boundaries of the main choice. The performance of three types of filters (PP450, PP700 and PP900) was assessed in terms of clogging potential using ASTM-5101standard test. In addition, mineral blanket was designed according to the USBR criteria. Experiment was conducted in three treatments and completely on random. The test was conducted in laboratory, using physical model for infiltration (according to the ASTM D-5101 standard) and by creating four different hydraulic pressure head (25, 50, 75 and 100cm). In the study, changes in outflow from soil-geotextile system, hydraulic conductivity, gradient ratio and hydraulic conductivity ratio were analyzed for four filters. The results showed that 1) in terms of the gradient ratio, none of the filters were found sensitive to clogging, 2) outflow from mineral filter was 2 to 3 times greater than for geotextiles, 3) the hydraulic conductivity ratio of mineral filter for PP450, PP700 and PP900 geotextile filters were 3.47, 4.17 and 5.57 respectively, and 4) comparing outflow and hydraulic conductivity variations, geotextile filter of PP450 type was found the best. According to the optimization results, for PP450, optimum values for decision variables at different hydraulic heads (H) and drain outflows (Q) were equal to 47 cm and 0.166 cm^3/s and for PP700 were 114 cm and 0.183 cm^3/s. These values were equal to 94 cm and 0.198 cm^3/s for model PP900 and 237 cm and 0.298 cm^3/s for gravel filter, respectively.

Introduction

Many drainage system designs are often not acceptable because little attention is made towards local experiences and are mainly dependent on other studies and researches. Investigations in the Netherlands showed that nearly 80% of drainage projects failed as the result of inappropriate performance of drain filters. Mineral materials are still the most common filters used in drainage projects. Continued usage of these filters encounters major problems such as lack of gravel sources (close to the project location), transportation of the materials and executive limitations (digging wide trenches, controlling gravel PSD, etc.). Because of the reasons, the cost of drainage projects has raised. In recent years, *geotextile* filters have become more common because of lower costs, higher installation speed, less land loss (because of excavation) and some other benefits, especially in countries such as the Netherlands, the USA, Pakistan, and Egypt.

Among popular products are synthetic materials. These materials are mainly manufactured of petrochemicals and oil industry by-products. Geo-synthetics materials are being used with acceptable performance in soil and water projects worldwide. Geotextiles are one of the categories of geo-synthetics being used in drainage systems. First generation of geotextiles used in the late 1950's as an alternative for gravel envelopes.

In general, geotextile are classified based on their polymer type (polypropylene, polyethylene, and polyester), kind of threads (single thread, multi thread and cleft membrane) and texture (textile, non-textile and lumpy textile). These properties, like any other material used in engineering projects, depend on production method and the properties of final product.

Hasanoghli (1997) used an especial kind of geotextile filters on drainpipes, which was made of wicker-like textile with polyester warps and polypropylene hollow wefts. In this test, pipes were completely flexible and water could get into the pipes from small openings, which were evenly distributed throughout the pipe length. The size and distribution of these openings and of course the pipe water conductivity was controllable by changing the properties of the geotextile.

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In such a situation, provided that the pipes performance were acceptable, there was no need for gravel envelope, and trenchless installation would be possible leading to considerable reduction in expenses. Although the main positive characteristics of these pipes are their lower weight, flexibility and easy production, but their softness and flexibility may lead to some problems during installation. Therefore, the pipes tolerance against soil weight and live loads should be taken into consideration.

Darbandi and Hasanoghli (2001) assessed the technical performance of non-textile geo-synthetic drain envelopes. It was revealed that average outflow through synthetic envelopes was lower than the one for pipes with gravel envelope. Also, the outflow had a decreasing trend due to soil rearrangement and translocation of smaller particles into macro pores and between larger soil and filter particles. In addition, decreasing rate of pipe outflow with gravel envelope was more than for synthetic filters which were probably due to the continued translocation of small soil particles into macro pores of gravel envelope. Moreover, entrance resistance for synthetic filter was more than of gravel filter.

Palmira and Gardouni (2002) measured the effects of different pressure on hydraulics and physical properties of geotextiles and found that for drainpipes installed deeper and increased soil pressure on pipe and envelope, the size and conductivity of filter openings would be smaller and a lower performance of drainpipe and filter would result.

Fernando et al. (2006) conducted a study on biological clogging of geotextiles and mineral materials (for filtering agricultural wastewaters in a 5-year period). This study revealed that both kinds of filters had some effects on water quality. Furthermore, they found that geotextiles are more frugal in terms of economic and technical issues.

Soubaida et al. (2008) studied woven and non-woven geotextile filters using a pressure membrane and assessed the tensions on geotextiles. They concluded that tensions and strains on drain filters have a major effect on outflow rate and filters hydraulic conductivity that depends on the density of threads used in the envelope. Again, the resistance of these filters is related to surrounding soil particle size distribution.

This study has objectives as followings: (1) Comparison of selected filters in terms of their hydraulic performance, (2) performance assessment of geotextile filters as compared with mineral filters, (3) examining hydraulic properties of mineral and geotextile filters in laboratory situations and (4) consistency assessment of filter properties with existing standards.

Genetic algorithm

GAs initially start from randomly generating a population of strings (also referred to as a chromosome), each string is composed of a series of substrings (bits or genes in other words) representing components or variables that are related or used to evaluate the fitness of the problem through objective function. One string has its own fitness value obtained from the objective function and is one solution for the problem. The entire population of such strings represents a generation. The initial population undergoes a series of genetic operators resulting in a new population with new fitness values in each string, which is the initial population for the next generation. This successive algorithm (Figure 1) is repeated for many generations until the stopping criterion is satisfied. The stopping criterion of a GA is determined by either the specific number of generations or a convergence to a single solution where the change in the fitness values is insignificant. It is expected that most of the fitness values of the later generations will be improved after a number of iterations from the earlier generations. Nevertheless, the best string with the highest fitness value is not necessary to be found from the final generation. The basic principle of GAs with review of their applications can be found from the work of Goldberg (1989) and Michalewicz (1996).

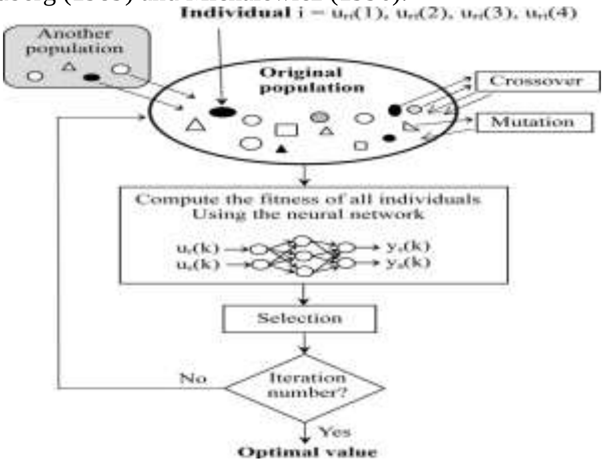

Figure 1. Flow chart of the searching process of an optimal value using genetic algorithms

Methods and Materials

Site Description

The laboratory tests were conducted using soil samples of a drainage project under construction in northern Khorram Shahr, south west of Iran (Figure 2). This drainage system is constructed as part of major agriculture development project improving water usage, providing more employment in the region and attracting university graduates. Water is supplied by the Karun River via pumping station and is carried into the region by a 7350m long concrete canal. At the end of canal, the required pressure head for irrigation network (low pressure irrigation systems) is provided by a secondary pumping station. Project area is divided into 38 51-ha and 374 5.2-ha agricultural units. In the study, 2 soil samples were provided from regions 15 and 37 and 1.65m deep (in order to being more similar to the real depth of drains) (Fig 2). Chemical and physical analysis results showed both soil samples are largely similar in terms of their particle size distribution and texture (Tables 1 and 2) and other experiments were done, using the sample from region 15 (Table 3).

Figure 2. Shape of case study in north of Khuzestan Province

First, the D60 index was determined from soil PSD curve. Then, upper and lower boundary of filter particles was drawn according to the USBR standards (Fig 4) [1]. Two other indices in relation to mineral filters are:

$$C_u = \frac{d_{60}}{d_{10}} \quad [1]$$

[2] $$C_d = \frac{(d_{30})^2}{d_{10} \times d_{60}}$$

For mineral filters, Uniformity Coefficient must be greater than 5 and Curvature Coefficient must be between 1 and 3. For hydraulic design of synthetic envelopes, there are two different criteria: 1) O90: Voltman et al (2000) recommended that O90 must be greater than 200µm in order to prevent primary and secondary clogging and 2) There are three criteria for filter hydraulic conductivity:

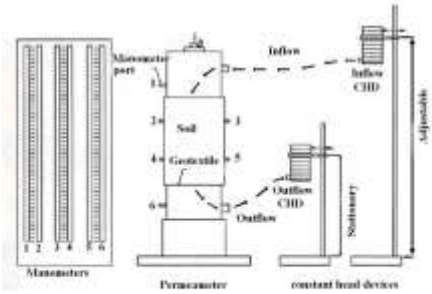

Figure 3. Geotextile Permeameter "Set Up" Diagram

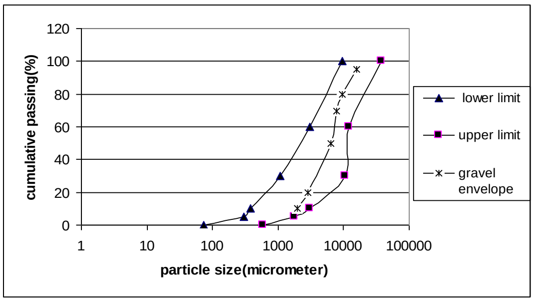

Figure 4. Particle size distribution of gravel according to the USBR standard

a. Girod (1985) suggested the criteria of $K_e \geq 0.1K_s$ where Ke is filter hydraulic conductivity and Ks is saturated hydraulic conductivity of surrounding soil (This criterion is not highly dependable).

b. The first criterion of Korner (1994) is $K_e \geq K_s$. This is suggested when critical situation (in terms of economical situation and project life-time) or extreme situation (high hydraulic gradient) does not exist. Korner recommended this criterion for use in a few states of the USA.

c. The second criterion of Korner (1994) is $K_e \geq 10\ K_s$ and is more applicable for mineral filters.

The criterion of retention of particle in synthetic filters as the following:

[3] (Filters having thickness less than 2mm)

$$1 \leq \frac{O_{90}}{d_{90}} \leq 2.5$$

[4] (Filters having thickness more than 5mm)

$$1 \leq \frac{O_{90}}{d_{90}} \leq 5$$

[5](Filters having thickness more than 2mm and less than 5 mm)

$$1 \leq \frac{O_{90}}{d_{90}} \leq 5$$

The criterion for keeping synthetic filter clogging is suggested by Dierex et al (1990):

[6] $$\frac{O_{90}}{d_{90}} \geq 1$$

In sandy soils where d90 ≥ 200µm, if geotextile O90 is lower than 200µm, the ratio of O90/d90 will be less that 1 and filter will be prone to clogging.

In the study, a permeameter system (according to the ASTMD-5101 standard) was used for determining hydraulic conductivity and clogging potential of the combined soil-geotextile system, as well as mineral filter. The main part of the system was a transparent cylinder made of Plexiglas with inner diameter of 100mm and wall thickness of about 5mm. At different levels, piezometers were installed to assess variability of hydraulic gradient through the soil sample and around the geotextile. This test was carried out for the three types of geotextile (PP-900, PP-700 and PP-450). The main difference between the types is related to their fiber density and weight of unit length. In the next step, the performance of these types of filters was analyzed using standard permeameter test. The suggested type, according to soil particle size distribution curve and soil texture, was PP-700 and the other two types were used as the upper and lower boundaries. A mesh steel plate (with openings of 4.76mm, mesh #4) was placed between the main part and foundation where geotextile sample was placed on. Piezometers were installed in sets of two at the same height with respect to the steel plate, i.e. Piezometer couples were at 25 and 75mm heights above the steel plate. Another piezometer was installed 143mm away from the steel plate and, contrary to other piezometers. It was placed outside the soil sample. The inlet section was 162mm above the geotextile sample. In the topmost section of the system, an air valve was installed to be used for saturating the soil sample (Figure 3). In order to prevent piping, two wall-to-wall rings were placed horizontally in the system casing. After installation, by creating different hydraulic gradient (25, 50, 75 and 100), the values of permeability and hydraulic conductivity of soil-geotextile system, outflow and hydraulic conductivity of the geotextile were measured. Another similar system was built using gravel filter with 4 piezometers for comparison to the previous system. At first, system was saturated by an upward flow (to prevent the air from entering) and increasing total head. After 24hr, the test began. Both tests were conducted simultaneously.

Hydraulic Gradient Calculation

Hydraulic gradient is calculated as:

[7] $$G = \frac{\Delta h}{l}$$

Where Δh is Difference between piezometers readings and l is the length or thickness of soil sample.

[8] $$\Delta h_{es} = \frac{M_2 + M_3 - 2M_6}{2}$$

[9] $$G_{es} = \frac{\Delta h_{es}}{l_{es}}$$

[10] $$\Delta h_s = \frac{M_2 + M_3 - M_4 - M_5}{2}$$

[11] $$G_s = \frac{\Delta h_s}{l_s}$$

[12] $$\Delta h_e = \frac{M_4 + M_5 - 2M_6}{2}$$

[13] $$G_e = \frac{\Delta h_e}{l_e}$$

$\Delta h_{es}, \Delta h_s, \Delta h_e$: Head loss in soil-geotextile column, soil column and geotextile, respectively.

l_{es}, l_s, l_e: The length of soil-geotextile column, soil column and geotextile, respectively.

G_{es}, G_s, G_e: Hydraulic gradient of soil-geotextile column, soil column and geotextile, respectively.

M_x : The values of **x**th piezometer (cm).

Gradient Ratio

Gradient ratio is calculated as the ratio of hydraulic gradient of the soil-geotextile system to soil hydraulic gradient:

[14] $$GR = \frac{i_{es}}{i_s}$$

Where GR is Gradient Ratio, i_{es} is hydraulic gradient of soil-geotextile system and i_s is soil hydraulic gradient. In this case, the filter will be prone to mineral clogging if gradient ratio is greater than unit.

Result

The test of flow rate was carried out on three types of synthetic envelopes and one type of mineral filter. The volume of drain water, temperature of water inside the tank and the height of water in all piezometers were measured.

The results showed that flow rate from permeameter decreased by time. Decrease of flow rate was due to soil particles displacement into filter blanket, and also because of decrease in hydraulic conductivity of soil-filter system. The results of the test revealed that under all created hydraulic heads, flow rate from mineral filter was 2 to 3 times higher than the ones from synthetic filters.

Regarding to Table 4, it is clear that flow rate values at the beginning of the test was 0.061427 cm3/sec and at the end was equal to 0.08381 cm3/sec which varied by 26.7% for PP450 type filter. Such a variation is considered to be significant.

The amounts of flow rate for PP700 at the beginning of the test (25cm hydraulic head) was 0.05381 cm3/sec, and at the end of the test was about 0.082857 cm3/sec and with flow variations of nearly 35.05% for PP700 synthetic filter. The last value is very high as compared with the one for PP450 and is advantageous for PP450 synthetic filters (low flow variations in small scales). Flow variations will be certainly more at larger scales.

The values of flow rate for PP900 synthetic filter ranged from 0.049048 to 0.07238 cm3/sec at the beginning and the end of the test duration, respectively, and with flow variations of nearly 32.23%, which were more as compared with PP450 type. If flow variation is less, outflow can be controlled better because downstream drainage structure is usually designed on the basis of average flow rates (with a certain return period). Management of extensively varied flow rates would be more challenging and may result in environmental consequences.

The values of flow rates for mineral filter were ranged from 0.16238 to 0.2238 cm3/sec with 27.44% variations (Table 4). These values are much lower than the ones for PP900 and PP700 synthetic filters. These results show the advantage of synthetic filters. In general, however, it seems that synthetic filters don't have efficiency and high performance of mineral envelopes. The reason for choosing synthetic filters would be their lower expenses, higher accessibility and transportation issues as compared with mineral materials (Table 4).

Analysis of the results on variations of hydraulic conductivity for PP450, PP700, PP900 and gravel filters under various hydraulic heads showed hydraulic conductivity variations were 1.22%, 1.8%, 53.2% and 8.07%, respectively, and average variations for PP900 synthetic filters are high which could pose greater clogging potential as compared with two other synthetic filters i.e. PP700 and PP450. In a comparison between PP450 and PP700, variations in hydraulic conductivity of soil-filter system showed that PP450 was lower and it indicates that PP450 has less clogging potentials as compared with PP700 type (Table 5).

Calculation of gradient ratio showed that none of the tested filters were sensitive to clogging because gradient ratios were less than 1 in all the tests (Figure 6). According to the thickness of synthetic filters which were 2 to 5 mm (3.2, 3.5 and 3.5 mm for PP450, PP700 and PP900 respectively) and the values of O90 (450, 700 and 900 micrometer for PP450, PP700 and PP900 respectively) and based on equations 3 to 5, the ratios of O90 to d90 were found to be 3.6, 5.6 and 7.2 for PP450, PP700 and PP900, respectively. Since this ratio should be between 1 and 5, just PP450 passes the criterion and PP700 and PP900 cannot prevent soil particles from getting into drain pipes. According to Woltman et al (2000) that recommended O90 ≥ 200 µm, all these synthetic filters can pass this criterion and none is prone to primary and secondary clogging.

Equation 6 sets the criterion for synthetic filter clogging. Therefore, it is concluded that all three tested filters meet the standard and should not have clogging problems.

The ratio of filter hydraulic conductivity (Ke) and soil hydraulic conductivity (Ks) for all filters were found to be greater than 1. All three synthetic filters fulfilled the criterion of Girod (Ke/Ks > 0.1) and the first criterion of Korner (which is recommended for some of the U.S states) and none of them can passed the second criterion of Korner (Ke/Ks > 10).

In order to choose the best synthetic envelope for available types, PP450, as compared with other two types, provides higher performance from the viewpoints of hydraulic conductivity, flow rate variations, gradient ratio, and the criterion of retention of particles, mineral clogging, mechanical stability and the values of hydraulic conductivity ratios. Comparison of hydraulic conductivity test for PP450, PP700 and PP900 filters confirms decrease in hydraulic conductivity. According to Darcy's law, the value of hydraulic gradient is increased by an increase in hydraulic head so does the value of Q. However, since the increase in hydraulic gradient was more than the rate of increase in Q, it is concluded that hydraulic conductivity decreased (Table 5).

Tests on PP450 synthetic filter showed that hydraulic conductivity at the head values of 50, 75 and 100cm have no considerable fluctuations. At 25cm head, hydraulic conductivity had the lowest value. But its fluctuation is inappreciable at all hydraulic head values. For PP700 type, hydraulic conductivity variations were found to be irregular with the greatest value at the head of 75cm. This may be because, according to Darcy's law, the amount of flow is more than existing gradient, so hydraulic conductivity increases. But for other values of hydraulic head, system follows its normal trend. The observed trend of PP900 is nearly a specific trend and it can be seen that the observed hydraulic conductivity have dramatic variations

(Figure 5). According to Figure 5, the values of hydraulic conductivity of PP450 are more than the ones for PP900, because of more threads (fibers) used in PP900 which reduce hydraulic conductivity.

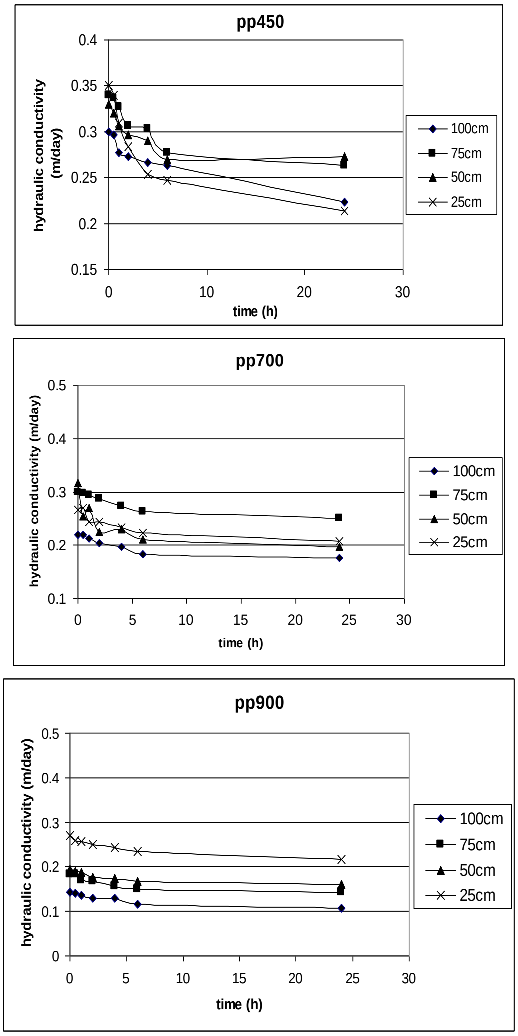

Figure 5. Hydraulic conductivity of soil-filter system at different heads for PP450m PP700 and PP900

The results of statistical analysis (Table 6) for different treatments (PP450, PP700, PP900 and gravel), and for different properties showed that flow rates for all treatments at different times were significant (in the level of 0.01). In addition, the results of flow rate tests showed that head bilateral effects at different times were not significant.

The bilateral effect of time in all treatments, and the bilateral effect of hydraulic head in different treatments were meaningful (in the level of 0.01). The counter effect of three factors including time, head and filter type was not significant. Also, the variation coefficient and correlation coefficient were 10.4% and 97% respectively. Besides, the results of hydraulic conductivity of soil-filter system showed that the effect of different parameters follows the same trend as flow. But variation coefficient and correlation coefficient are 12.55% and 98% respectively. Moreover, the results of soil hydraulic conductivity and filter hydraulic conductivity follow the same trend, but the amount of variation coefficient and correlation coefficient for soil hydraulic conductivity and filter conductivity are 14.42%, 98%, 31.56% and 86% respectively.

Optimization

In optimization process, firstly by means of parametric regression software (Sigma Plot) hydraulic conductivity and gradient ratio equations for all envelopes were obtained, then two goal functions were defined as below (H is pressure head and Q is outflow):

$$MAX : Ke = \sum_{t=1}^{n}\left(a_1 + a_2 H_t + a_3 Q_t + a_4 H_t^{2}\right) \quad [15]$$

$$MIN : GR = \sum_{t=1}^{n} c_1 + c_2 \ln abs\left(\left(\frac{(a_1 + a_2 H_t + a_3 Q_t + a_4 H_t^{2})}{(b_1 + b_2 H_t + b_3 Q_t + b_4 H_t^{2})}\right) - c_3\right) \quad [16]$$

Subject to:

$$20cm \le H \le 250cm$$

$$0\frac{cm^3}{\sec} \le Q \le 2\frac{cm^3}{\sec}$$

Where a1 to a4 are coefficients from filter hydraulic conductivity equation (different for each filter), b1 to b4 coefficients from soil hydraulic conductivity equation, c1 to c4 coefficients from gradient ratio equation (different for each filter). According to the optimization results (Table 7), the values of decision variables (outflow and water table variations) for each model of filters were determined. For PP450, optimum values for decision variables are equal to 47 cm and 0.166 cm^3/s and for PP700 are 114 cm and 0.183cm^3/s. These values are equal to 94 cm and 0.198 cm^3/s for the model PP900 and 237 cm and 0.298 cm^3/s for gravel filter, respectively. With regard to these values, it can be concluded that in case of using any one of these filters, the values of water table variations and drain outflows should be kept near these values to have optimum drainage conditions.

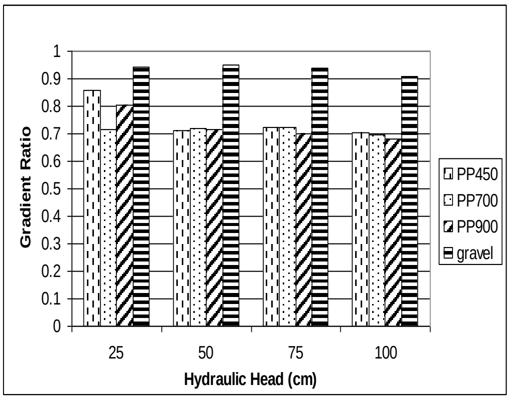

Figure 6. Gradient ratio of soil-filter system at different heads for PP450m PP700 and PP900

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Table 1. Chemical Properties of Two Soil Samples

Sample Name	pH	EC dS/m	Anions (meq/lit)				Sum of Anions	Cations (meq/lit)				Sum of Cations
			SO_4^{2-}	Cl^-	HCO_3^-	CO_3^{2-}		K^+	Na^+	Ca^{2+}	Mg^{2+}	
15	7.51	100.78	-	3.2	1100	34	1137.2	174	60	896.61	-	1130.61
37	7.58	100.4	-	2.2	1000	30	1032.2	178	72	778.94	-	1028.94

Table 2. Physical and chemical properties of two soil samples

Sample Name	Clay%	Silt%	Sand%	Texture	Gypsum %	Lime T.N.V%	SAR	Organic Carbon OC%	Density
15	33.71	61.29	5	Silty clay loam	-	45.25	82.89	0.0585	2.79
37	43.81	41.09	15.1	Clay silty	-	40.50	69.67	0.0333	2.78

Table 6. Physical properties of examined soil and mineral filter

Sample Name	d_{10} μm	d_{60} μm	d_{90} μm	Uniformity Coefficient	Curvature Coefficient	Hydraulic Conductivity m/day
Soil	1.1	60	125	54.5	1.09	0.413
Envelope	2000	7500	-	3.75	2.3	7.44

Table 5. Average flow rate at different heads for 3 types of synthetic and gravel filters

Hydraulic Head (cm)	Flow Rate (cm^3/sec)			
	pp450	pp700	pp900	gravel
25	0.0614	0.0538	0.049	0.1623
50	0.0786	0.059	0.0619	0.1919
75	0.0848	0.078	0.0723	0.2133
100	0.0838	0.0828	0.0723	0.2238
Average	0.0771	0.0684	0.0639	0.1978
Variation (%)	26.7	35.05	32.23	27.44

Table 4. Hydraulic Conductivity of Soil-Filter System at Different Heads for gravel, PP450, PP700 and PP900 filters

Hydraulic Head (cm)	Hydraulic Conductivity (m/day)			
	PP450	PP700	PP900	Gravel
25	0.2933	0.2546	0.2699	1.053
50	0.3671	0.2902	0.178	0.9593
75	0.3406	0.2945	0.1933	0.9155
100	0.2897	0.25	0.1261	1.138
Average	0.3226	0.2733	0.1918	1.016
Variation (%)	1.22	1.8	53.2	8.07

Table 3. Variation analysis for tested treatments and different counter effects

Variables	Mean square error				
	Q	Kse (Soil-Filter)	Ks (Soil)	Ke (Filter)	Ke/ Ks
Time	0.005 **	0.0953**	0.0748 **	5.33**	0.779 n.s
Hydraulic Head	0.019 **	0.0163 **	0.0134**	2.708**	29.9**
Filter Kind	0.34 **	12.66 **	13.024**	1123.55**	433.82 **
Hydraulic Heads in Different Times	0.00002 n.s	0.0005 n.s	0.0005 n.s	0.295 n.s	0.314 n.s
Filter Kind in Different Times	0.0006 **	0.022 **	0.024 **	3.97**	1.478 n.s
Filter Kind in Hydraulic Head	0.0014 **	0.0273**	0.0156**	2.9**	16.96 **
Filter Kind in Hydraulic Head in Different Times	0.00003 n.s	0.0005 n.s	0.0004 n.s	0.341 n.s	1.095 n.s
Error	0.0001	0.0029	0.0028	0.589	1.749
Variation Coefficient	10.4	12.55	14.42	31.56	27.13
Correlation Coefficient	0.97	0.98	0.98	0.96	0.81

** : Meaningful in the level of 1%
* : Meaningful in the level of 5%
n.s : Not-Meaningful.

Table 7. Optimum values for decision variables

Filter Model	H (cm)	Q (cm^3/sec)	Ke (m/day)	Ks (m/day)	Kse (m/day)	Ke/ Ks	GR
PP450	47	0.166	0.935	0.483	0.657	1.934	0.71
PP700	114	0.183	1.513	0.39	0.555	3.87	0.64
PP900	94	0.198	1.365	0.335	0.472	4.07	0.702
Gravel	237	0.298	28.74	2.62	2.97	10.96	-