EFFICIENCY OF ARTESIAN FILTERS TO ELIMINATE SOLIDS PRESENT IN IRRIGATION WATER[1]

J. L. B. da Silva[2], J. D. A. Oliveira[3], E. P. de Miranda[4], E. V. de Oliveira[5], P. F. S. Ortiz[6], F. A. C. Lins[7]

SUMMARY: The objective of this study was to determine the efficiency of artesian filters using different diameters in comparison with a commercial filter, using water with suspended solids sediments. The handmade sand filter was constructed from a reservoir cylindrical of gas cooking 13kg. The different sizes of gravel were used (small, medium and large: 0.2; 1.58 e 2.85 mm, respectively). It was adopted in the experiment completely randomized design with 4 treatments and 8 replications. For analysis of the results were submitted to descriptive statistics, normality test and coefficient of variation in each of the treatments and were also performed by analysis of variance. The conventional disc filter was used as control treatment. The handmade sand filter with use of gravels of different diameters, small (36.64 %), medium (35.16 %) and large (29.26 %), were more efficient than the market filter (25.57 %). Artisanal and commercial filters presented similar efficiencies, as they did not present statistical differences, so these filters with gravel use become a viable alternative for irrigated agriculture.

KEYWORDS: localized irrigation, water quality, clogging emitters.

EFICIÊNCIA DE FILTROS ARTESANAIS PARA ELIMINAÇÃO DE SÓLIDOS PRESENTES NA ÁGUA DE IRRIGAÇÃO

RESUMO: Objetivou-se determinar à eficiência de filtros artesanais com uso de cascalhos de diferentes diâmetros em comparação com um filtro comercial, utilizando água com presença de sedimentos de sólidos suspensos. O filtro artesanal foi construído a partir de um reservatório cilíndrico de gás de cozinha de 13 kg. Foram utilizados três diferentes tamanhos de cascalho:

[1] UNIVERSIDADE FEDERAL RURAL DE PERNAMUCO – UFRPE;
[2] Doutorando em Engenharia Agrícola – PGEA/UFRPE. Depto. Engenharia Agrícola, UFRPE. Av. D. Manoel de Medeiros, SN; Dois Irmãos, Recife, PE; CEP: 52171-900. Tel.: (81) 9 8424-0043. E-mail: jhonlennoigt@hotmail.com;
[3] Doutorando em Engenharia Agrícola – PGEA/UFRPE, Recife – PE. E-mail: josediorgenes@gmail.com;
[4] Prof. Doutor em Agronomia: Irrigação e Drenagem, IFCE – *Campus* Iguatu. E-mail: eu.paceli@yahoo.com.br;
[5] Mestranda em Engenharia Agrícola: Irrigação, UFC, Fortaleza – CE. E-mail: emanuellevictor@yahoo.com.br;
[6] Doutorando em Engenharia Agrícola – PGEA/UFRPE, Recife – PE. E-mail: francisko369@gmail.com;
[7] Mestrando em Engenharia Agrícola – PGEA/UFRPE, Recife – PE. E-mail: frederico.lins@ufrpe.br.

pequeno, médio e grande com os respectivos diâmetros: 0,2; 1,58 e 2,85 mm. Adotou-se no experimento o delineamento experimental inteiramente casualizado, com 4 tratamentos e 8 repetições. Para análise dos resultados foram submetidos a estatística descritiva, teste de normalidade e o coeficiente de variação em cada um dos tratamentos e também realizou-se à análise de variância. O filtro de disco foi adotado como tratamento testemunha. As variações filtrantes de areia: pequeno (36,64 %), médio (35,16 %) e grande (29,26 %), foram mais eficientes que o filtro comercial (25,57 %). Os filtros artesanais e o comercial apresentaram eficiências semelhantes, pois não apresentaram diferenças estatísticas, portanto esses filtros com uso de cascalhos torna-se uma alternativa viável para a agricultura irrigada.

PALAVRAS-CHAVE: irrigação localizada, qualidade de água, entupimento de emissores.

INTRODUCTION

The increase in agricultural production caused by the increase in the demand for food in the world and the limitations in production due to water scarcity require the development of new models and techniques of production. Currently, water scarcity in arid and semi-arid regions caused by irregular rainfall periods is the main limiting factor for food production, mainly in the Northeast region of Brazil. Thus, irrigation becomes an indispensable strategy for the sustainable use of water resources and favoring crop productivity in agricultural fields (Shen et al., 2013; Djaman et al., 2015; FAO, 2015).

It is estimated that agriculture is currently responsible for the consumption of approximately 70 % of all fresh water used in the world, with 23 % of the areas cultivated with irrigation systems, these areas hold 40 % of the food produced for humanity, the proper management of water resources through irrigation allows an efficient increase of agricultural production (Singh, 2014; FAO, 2015).

In view of the technological advance and the potential of the proper use of irrigated agriculture, considering mainly the cost, it stands out the localized irrigation, used in large scale due to several advantages, such as the greater economy and efficiency of water application and of fertilizers (Ribeiro & Paterniani, 2013). However, for the success of any irrigation system and for the good performance, water quality is fundamental, especially in localized systems, for example, drip irrigation, developed due to the scarcity of water. However, in these irrigation systems there are frequent problems, such as the clogging of the emitters (drippers and microsprinklers), for which some authors emphasize in their studies the direct relation with water quality and the efficiency of the filtration system (Ribeiro & Paterniani, 2013).

In this respect, the filtration of irrigation water is an effective measure in reducing undesirable contaminants (dissolved salts, suspended solids sediments, etc.), maintaining efficiency and reducing costs for maintenance and renovation of irrigation systems. Therefore, the use of commercial filter elements, such as disc, screen and sand filters, among others, has the objective of improving the physical-chemical quality of the water, aiming at the proper functioning of the system (Salcedo et al., 2011; Testezlaf et al., 2014). However, commercial filters usually have a high cost per acquisition and maintenance, low durability over time and consequently low filtering efficiency, making it less viable for rural agricultural regions (Oliveira et al., 2016).

With the need to implement the use of filters in the irrigation and to facilitate the implementation by the small farmers, the motivation appears in the development of crafts filters with low cost and facilitating the elaboration, as well as the acquisition of the filtering elements (e.g. sugarcane bagasse, activated charcoal, synthetic fabric, sand, gravel, fabric, sponge, etc.), mainly good filtration efficiency for regions with low quality water (Crozariollo Neto et al., 2011; Paterniani et al., 2011; Carmo et al., 2012; Miranda et al., 2012; Silva et al., 2012; Ribeiro & Paterniani, 2013).

In view of this context, the objective of this study was to determine the efficiency of crafts filters using different diameters in comparison with a commercial filter, using water with suspended solids sediments.

MATERIAL AND METHODS

The study was conducted at the Irrigation and Drainage Hydraulics Laboratory of the Federal Institute of Education, Science and Technology of Ceará, IFCE - Campus Iguatu, located approximately 380 km from the capital Fortaleza, at the geographical coordinates 6º 21' 34'' S and 39º 17' 55'' W, with an altitude of 214.17 meters.

The tests were performed in a hydraulic workbench, through which it was possible to install the crafts and conventional disc filters. The filter elements were installed and tested alternately. Three different sizes of gravel were used in the crafts filters: small (Figure 1A), medium (Figure 1B) and large (Figure 1C) (with respective diameters: 0.2, 1.58 and 2.85 mm).

The handcrafted filter was constructed from a cylindrical kitchen gas tank of 13 kg, with a height and diameter of 50 cm. The cylinder was cut in the middle with adaptations that allow the opening and closing of this, later the PVC pipes (2.54 cm) were installed at both ends, allowing the entrance and exit of water of the handcrafted filter. The control treatment of the experiment was the 2-inch disc filter, with rings of 13.1 cm in diameter and 230 mesh of grooves (Figure 1D).

The filtration system was supplied by a centrifugal pump, whose power of the motor-pump assembly was 2 HP. The tubing used was 1 inch (2.54 cm) and the water was deposited in a plastic tank with a capacity of 1000 L. 1 kg of soil was added to the tank with water in order to have the presence of suspended solids in the water. To measure the pressure of the system a piezometer was used, with pressure points before and after the filters. For all tests the pressures started at 200 kPa.

The experimental design was completely randomized, 4 treatments with 8 replicates and a total of 32 water samples after filtration. The treatments were classified as: T1 = Handcrafted filter with small gravel (AFSG); T2 = Handcrafted filter with medium gravel (AFMG); T3 = Handcrafted filter with large gravel (AFLG) and T4 = Conventional disc filter (Disc).

In each of the treatments were collected 8 samples of 50 ml water and deposited in previously weighed beckers for the analysis of suspended solids. The analysis process was carried out at the Laboratory of Analysis of Soil, Water and Vegetable Tissues (LABAAS) of the IFCE - Campus Iguatu. The process of quantifying suspended solids was done by eliminating water by evaporation. This process was determined using a analytical balance for weighing the water samples, obtaining the total weight of water and solids present, then placed in an oven at 110 °C for 24 hours. With the difference between the sample weights before and after drying, the amount of suspended solids of each of the different samples was obtained; To estimate the filtering efficiency applied to Equation 1 (Miranda et al., 2012).

$$FE = \left(\frac{S_1 - S_2}{S_1}\right) 100 \qquad (1)$$

on what,

FE = Filtering efficiency (%);

S1 = Concentration of suspended solids in the input on the filter (mg / L);

S2 = Concentration of suspended solids in the output on the filter (mg / L).

For organization and analysis of the results were submitted to descriptive statistics, normality test and to verify the precision of the experiment, the coefficient of variation (CV) was applied in each of the treatments, according to Warrick and Nielsen (1980), CV < 12 % of low variability, CV between 12 to 60 % of average variability and High variability when CV >

60 %. The analysis of variance and Tukey's test were performed at the 95 % significance level for comparison of the treatments.

RESULTS AND DISCUSSION

From the results of the analysis of the suspended solids concentration in the water, it was observed that in the treatment of the handcrafted filter whit use of the small, medium and large gravel were in average terms more efficient than the conventional disc filter, with values of 36.64; 35.16; 29.26 and 25.57 %, respectively. It was also observed that T4 obtained the lowest minimum value (20.35 %) in efficiency and the maximum value in efficiency (50.11 %) was observed in T3, but a higher maximum value was observed in T2 of 59.16 %, even though it is considered outlier. These comparisons of results can be observed in Figure 2.

According to the behavior of the data the variation of the treatments are representative for the criteria proposed by Warrick and Nielsen (1980), since the values of the efficiencies in all the treatments presented low dispersion, with CV in the range between 12 to 60 %, considered of average variability, as shown in Table 1.

The statistical evaluation of the removal efficiency of suspended solids by the different filter media did not show representativeness in the variation between the treatments at 95% of significance, suggesting the lack of statistical differences between the filters, as presented in Table 2. The fact that it does not present significant differences represents the efficiency level of the crafts filters, since the capacity to improve water quality for irrigation was significant, as well as the commercial filter, proving to be a viable alternative for irrigated agriculture with benefits to the small farmer.

The small gravel and very fine sands have good filtration results in the irrigation systems, since they present a greater presence of micropores increasing the capacity of suspended solids retention (Testezlaf et al., 2014), as observed in T1, which had the small gravel as the filter element, which obtained the highest average filtration efficiency (Figure 2).

Paterniani et al. (2011) in a comparative study on different filtration systems, evaluated the efficiency in the removal of suspended solids and the results indicated that the introduction of a layer of activated carbon and the use of a synthetic blanket in the sand filter, provided greater efficiency in the with similar values (27.2 and 34.2 %) with those found in the crafts filters of this research (Figure 2). Carmo et al. (2012) also showed that the highest average filtering efficiencies were for sand-based sand filters when compared to the disc filter.

Miranda et al. (2012) analyzing the performance of alternative filters and comparing them to a disk filter of the same characteristics as the one used in this study, observed that PVC filter elements coated by different layers of synthetic fabrics obtained the highest filtration efficiencies, as Occurred in the filtering variations of this work, when compared to the disk filter (Figure 2).

The large gravel and the coarse sand support successive operations and facilitate the washing of the filter element, and can be reused for future operations, a fact observed in this study. In the case of small and medium gravel, the opposite happens, making it difficult to wash the material and in some occasions, making it impossible to reuse these elements, in agreement with the statements of Salcedo et al. (2011) and Testezlaf et al. (2014). However, the small and medium gravels have a higher capacity of retention of suspended solids in the water, obtaining a higher filtration efficiency, as observed in this study (Figure 2).

Ribeiro and Paterniani (2013) in a research with the purpose of obtaining better water for a drip irrigation system through the use of a filter (manta filter), observed that over time, this filter had more expressive results Which emphasizes the importance of researches that develop alternative filtration systems of its use in small-scale irrigated agriculture, mainly in irrigation projects in the northeastern semi-arid region.

According to Salcedo et al. (2011) and Testezlaf et al. (2014), it is extremely necessary to know the characteristics of filters for irrigated agriculture, in which the correct choice and proper handling of the filter media can guarantee the efficiency in the removal of undesirable contaminants in the irrigation system.

Among the many studies (Crozariollo Neto et al., 2011; Paterniani et al., 2011; Carmo et al., 2012; Miranda et al., 2012; Silva et al., 2012; Ribeiro & Paterniani, 2013; Oliveira et al., 2016) in the development of alternative filters emphasize the importance of good results for irrigation, due to its low cost and easy acquisition of the filtering material, being able to be incorporated within the agriculture irrigated by the small farmer and allowing to attend small projects of localized irrigation, providing quality water and favoring optimal operation throughout the irrigation system.

CONCLUSION

Crafts and commercial filters had similar efficiencies, as they did not present statistical differences, so these filters with gravel use become a viable alternative for irrigated agriculture.

The use of small gravel in the handcrafted filter had a higher average filtration efficiency in the removal of suspended solids in water, 36.64% compared to the other filter elements.

BIBLIOGRAPHIC REFERENCES

CARMO, F, F.; MIRANDA. E. P.; MARTINS. G. S.; LIMA. L. D. P.; SILVA. M. G.; LÊDO. E. R. F. Eficiência de filtragem utilizando um filtro artesanal de areia. In: I INOVAGRI INTERNATIONAL MEETING & IV WORKSHOP INTERNACIONAL DE INOVAÇÕES TECNOLÓGICAS NA IRRIGAÇÃO, Fortaleza – CE. Anais... Fortaleza – CE, 2012.

CROZARIOLLO NETO, V. S. C.; DE FREITAS, P. S. L.; REZENDE, R.; DOLL, M. M. R.; BRANDÃO, D. Retenção da carga orgânica e de cátions em filtros operando com águas residuárias da suinocultura. Irriga, Botucatu, v.16, n.2, p.134-144, 2011.

DJAMAN, K.; BALDE, A. B.; SOW, A.; MULLER, B.; IRMAK, S.; N'DIAYE, M. K.; MANNEH, B.; MOUKOUMBI, Y. D., FUTAKUCHI, K.; SAITO, K. Evapotranspiration methods under sahelian conditions in the Senegal River Valley. Journal of Hydrology: Regional Studies, v.3, p.139-159, 2015.

FAO. Organização das nações unidas para agricultura e alimentação. Statistical Pocketbook, world food and agriculture. 2015. Disponível em: <http://www.fao.org/3/a-i4691e.pdf>. Acesso em: 02 de jun. 2017.

MIRANDA, E. P.; OLIVEIRA, E. V.; SILVA, J. L. B.; DA SILVA, M. G.; LAVOR, J. M. P.; GOMES, F. E. F. Eficiência de filtragem utilizando dois filtros artesanais de tela. Irriga, Botucatu, Edição Especial, p.133-144, 2012.

OLIVEIRA, C. F.; TEIXEIRA, M. B.; RAMOS, A.; SILVA, R. M.; RIBEIRO, P. H. P.; FRIZZONE, J. A. Portable Sand Filter For Small Drip Irrigation Systems. Irriga, v.21, n.1, p.90-103, 2016.

PATERNIANI, J. E.; DA SILVA, M. J.; RIBEIRO, T. A.; BARBOSA, M. Pré-filtração em pedregulho e filtração lenta com areia, manta não tecida e carvão ativado para polimento de efluentes domésticos tratados em leitos cultivados. Engenharia Agrícola, Jaboticabal, v.31, n.4, p.803-812, 2011.

RIBEIRO, T. A.; PATERNIANI, J. E. Comparação de elementos filtrantes no grau de obstrução em irrigação por gotejamento. Engenharia Agrícola, Jaboticabal, v.33, n.3, p.488-500, 2013.

SALCEDO, J. C.; TESTEZLAF, R.; MESQUITA, M. Processo da retrolavagem em filtros de areia usados na irrigação localizada. Engenharia Agrícola, v.31, n.6, p.1226-1237, 2011.

SHEN, Y.; LI, S.; CHEN, Y.; QI, Y.; ZHANG, S. Estimation of regional irrigation water requirement and water supply risk in the arid region of Northwestern China 1989-2010. Agricultural Water Management, v.128, p.55-64, 2013.

SILVA, J. L. B; OLIVEIRA, E. V; LAVOR, J. M. P; MIRANDA, E. P; NASCIMENTO, F. A. L; SILVA, F. F. Eficiência de filtragem utilizando um filtro artesanal de esponja. In: I INOVAGRI INTERNATIONAL MEETING & IV WORKSHOP INTERNACIONAL DE INOVAÇÕES TECNOLÓGICAS NA IRRIGAÇÃO, Fortaleza – CE. Anais... Fortaleza – CE, 2012.

SINGH, A. Conjunctive use of water resources for sustainable irrigated agriculture. Journal of Hydrology, v.519, p.1688-1697, 2014.

TESTEZLAF, R.; DEUS, F. P.; MESQUITA, M. Filtros de areia na irrigação localizada. Campinas, SP: Unicamp/Faculdade de Engenharia Agrícola, 2014. 56p.

WARRICK, A. W.; NIELSEN, D. R. Spatial variability of soil physical properties in the field. In: HILLEL, D., ed. Application of soil physics. New York: Academic Press, cap.13, p.319-344, 1980.

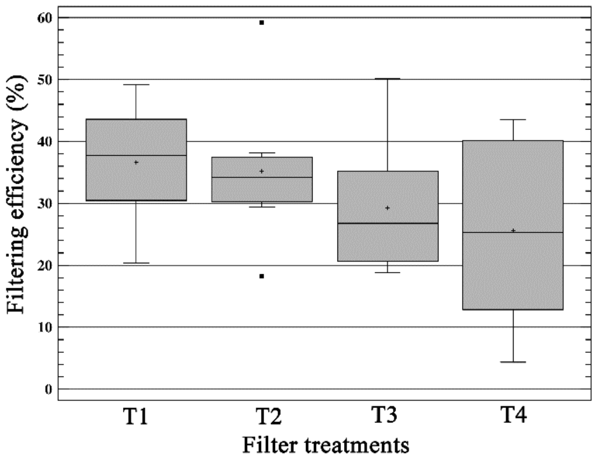
A. Small gravel

B. Medium gravel

C. Large gravel

D. Disc Filter

Figure 1. Handcrafted filters using different sizes of gravels and a disc filter



■ = *Outlier*;

T1 = Handcrafted filter with small gravel (AFSG);

T2 = Handcrafted filter with medium gravel (AFMG);

T3 = Handcrafted filter with large gravel (AFLG);

T4 = Conventional disc filter (Disc).

Figure 2. Distribution of filtering efficiencies (%).

Table 1. Standard deviation and coefficient of variation of the efficiencies (%) of the crafts (gravel) and disc filters.

Treatment	Standard deviation	*CV (%)
[1]AFSG	9,03	24,66
[2]AFMG	10,78	30,65
[3]AFLG	10,08	34,46
Disc	13,88	54,29

*CV – Coefficient of variation; [1]AFSG – Handcrafted filter with small gravel; [2]AFMG – Handcrafted filter with medium gravel; [3]AFLG – Handcrafted filter with large gravel.

Table 2. Analysis of variance at the 95 % level of significance.

Source of variation	GL	SQ	QM	P_{cal}	P-value
Treatment	3	639,88	213,29	1,51	0,232
Residue	28	3.939,56	140,69	-	-
Total	31	4.579,44	-	-	-