

ELIMINATION OF SUSPENDED MATERIALS IN IRRIGATION WATER WITH DIFFERENT MEDIA FILTERS

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ABSTRACT

Suspended materials in irrigation water are very important for the economic life of pressured irrigation systems. This study analyzed the effectiveness of pumice and sand-gravel media in removing suspended solids from irrigation water. Sand-gravel and pumice media passed through 0.05-2 mm and 2-4 mm sieve openings were used. Raw water with a sediment concentration of 250 mg/L was passed through the media filters under the operating pressure of 100 kPa. For each hour of process time, the discharge velocities measured and the sediment contents determined via the gravimetric method. Total cumulative flow volumes for sand-gravel and pumice media were 12897 L and 14035 L respectively, after the 30 h operating period. The discharge velocities were changed between 47.71 m³/m²/h and 3.22 m³/m²/h for sand-gravel medium, and 49.46 m³/m²/h and 3.44 m³/m²/h for pumice medium. Based on the analyses, we found that the sediment contents and discharge velocities decreased as the total amount of treated water increased in both sand-gravel and pumice media filters. Layers created of small size were more effective than the other layers at removing the solid particles. Based on the amount of the sediment measured of the treated water, it can be said that the sand-gravel medium was more effective than the pumice medium.

KEYWORDS:

Pumice, sand-gravel, irrigation water, media filter, suspended solids

INTRODUCTION

When water is contaminated or it needs treatment, it can become a technically and economically sustainable source with the help of natural or artificial environments. To eliminate unwanted ingredients in water, media with very different properties can be used as filter material. The treatment of water in this way has been the subject of many investigations [1]. Organic materials can be used for this purpose [2, 3, 4], as well as inorganic materials [5, 6].

Pumice is a natural material that solidified frothy lava. It is formed when the rock is violently ejected from the volcano at the high pressure and superheat conditions. Then the rapid depressurization and cooling together caused pumice to form a sponge-like structure. The pumice which has unconnected, large, and small pores, is a lightweight and inert material. The surface area is wide because of the deep and shallow cavities on the surface (Figure 1-a). It is reported that pumice is being produced in about 50 countries around the world, with Italy having the largest share. This country is followed by Greece, Chile, Spain, and Turkey [7].

Sand-gravel material, unlike pumice, has a smooth surface (Figure 1-b). Sand-gravel filters are the most well-known media used in water treatment especially physical treatment [8]. They are commonly used to remove suspended matter from irrigation water. The use of natural materials such as pumice and zeolite in water treatment technology is becoming increasingly widespread [5, 9].

Pumice, which can be found cheap and plentiful in most countries, is the subject of new research in water treatment. It was investigated the use of pumice stone as a biofilter material and found positive results [10]. Another research showed that pumice can be used as a cheap adsorbent in textile wastewater by acidic modification [11].

However, some researches show that filters composed of pumice medium also can be used and get favorable results for this purpose [5, 6, 11, 12, 13]. Because of its large surface area, the pumice is used as a biofilm material especially in wastewater treatment. The adsorption properties are well due to the cavities on the surface. Scientific researches on the use of pumice show that pumice could be an appropriate adsorbent in the removal of dye, heavy metals, and unwanted ions from wastewater [1, 11, 14].

The relationship between non-spontaneous (human-induced) production and the conservation of resources often emerges as a contrast [15]. Wastewater use and excessive use of water for crop production are dramatic examples in agriculture. One way to prevent this practice, which causes soil salinity, toxicity, and the leaching of plant nutrients from the soil, is to prefer high-efficiency pressurized irrigation methods. Only in this way can plant production

be carried out with the least damage to the environment. Especially the mixing of some elements or ions, washed from the soil with water resources, have unfavorable results in terms of crop production and biodiversity [16, 17, 18].

The problems faced by producers who have limited water resources and engaged in intensive and effective agriculture are often related to irrigation water quality and soil fertility [17, 19]. The economic life span of pressure irrigation systems used in agricultural irrigation depends on irrigation water. The physical clogging in the micro irrigation system is due to the organic and inorganic substances present in irrigation water quality [8, 20, 21]. The use of irrigation water which has more than 100 mg/L suspended solids content increases the problem of clogging. The low operating pressure in micro irrigation systems with too small water outlet openings increases the clogging problem [5, 22].

In this study, the pumice and sand gravel materials were used as the filter media. The objective of this study was to compare pumice and sand-gravel filter performance.

MATERIAL AND METHODS

For the filtration, pumice obtained from the Pasinler-Erzurum region in Turkey and natural river sand were used as the media materials. The filtration experiments were carried out in the drainage laboratory of Atatürk University Agricultural Faculty Agricultural Structures and Irrigation Department.

The filters were formed three layers and two different grain-sized as 0.5-2 mm and 2-4 mm (Figure 2).

The length and the diameter of the filter column were 850 mm and 200 mm respectively. The thickness of layers was arranged the same form both of the pumice and the sand-gravel filters. The central (second) layer of the filters was created from 0.5-2 mm diameter material and 50% of the total length of the filter column. Also, the inlet (first) and the outlet (third) layers of the filters were constituted from 2-4 mm grain-sized material and 25% of the total length of the filter column. For the filtration process, the

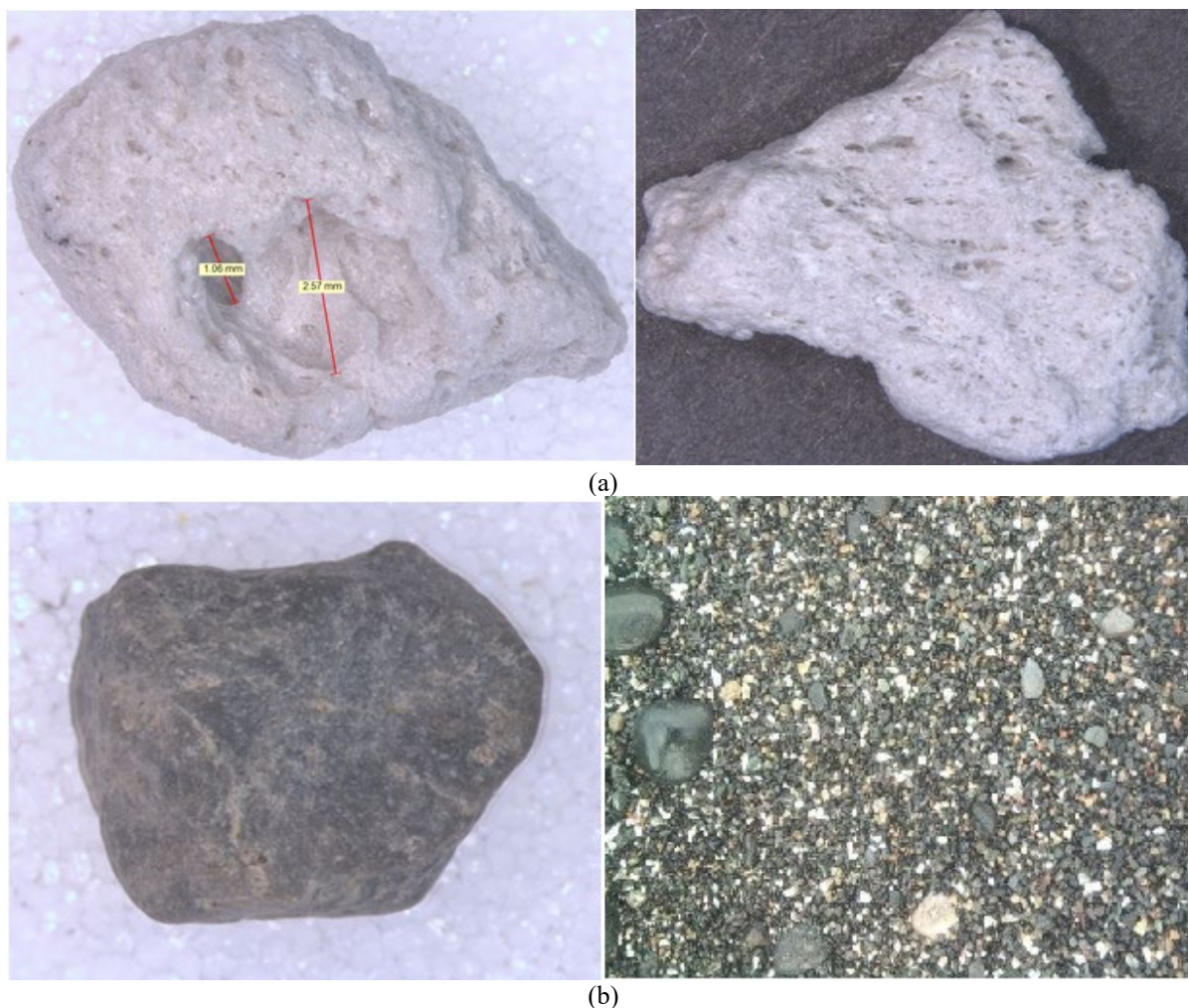


FIGURE 1

Microscope image of pumice and sand-gravel materials and their surface structure

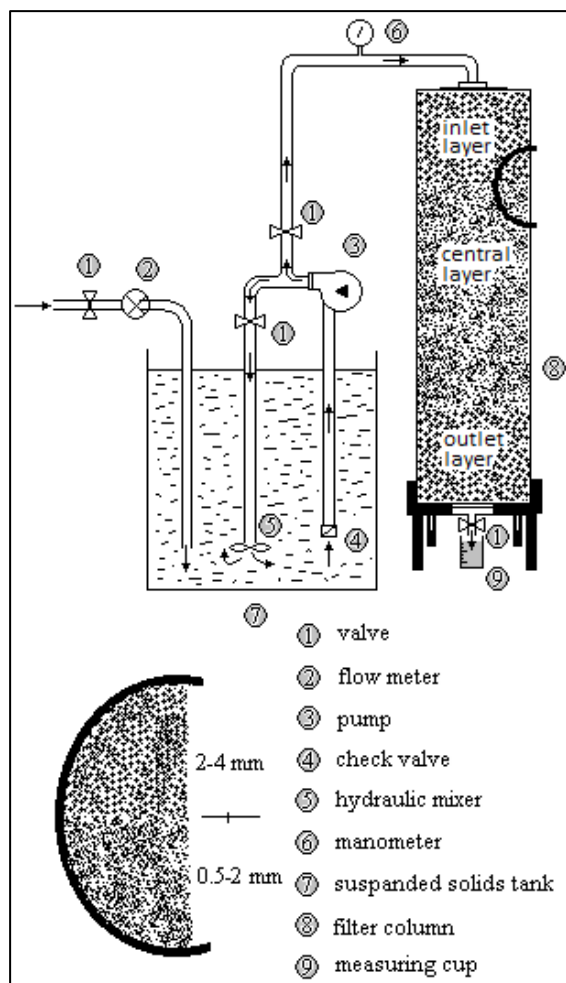


FIGURE 2

The experimental design of the filtration system

soil was sieved with 75 μm aperture and used as a suspended solid material. This material was mixed with the city water main, and raw water was prepared. The temperature of the water and the electrical conductivity (EC) of the water were $10 \pm 1^\circ\text{C}$ and 0.24 ± 0.01 dS/m respectively.

In this study, operating pressure was selected as 100 kPa based on the inlet flow for each filter type [23]. Because the particles accumulate in the filter media, the increase of the operating pressure is obvious. To reduce the pressure, the inlet flow volume entering the filter was decreased, and the backflow volume into the suspended solid tank was increased by using valves. So, the operating pressure of the system was kept stable through the process. It was ensured that the discharge volume of the filter is equal to the flow volume into the suspended solid tank. Therefore, the water level in the suspended solid tank remained stable. The hydraulic mixer was also used in the tank using water backflow. The solid concentration for the water entering the filter system was applied to be 250 ppm. During the process, 0.50 mg of soil was added continually into the tank in response to the passing of two liters from the water

meter. Water with suspended solid was applied to the top of the filter column by using a pump. The flap was used to prevent backflow from the suspended solid tank.

The filtration process was carried out for 5 hours per day with two parts of 2 and 3 hours. There was not any intermixture between adjacent layers during the experiment. Every valve was closed just before the system was stopped. Before the starting process, the suspended solid tank was mixed and then valves were opened. Processing was continued for a total of 30 hours and three replications.

The discharge velocities and outlet solid concentrations were measured for each hour of filtered water. Also, the filter performances were determined for each filter media. The outlet concentrations of suspended solids were determined by gravimetric analysis. After the filtration process was completed, a liter volume of each layer in bed material was washed and the accumulation of solid amounts was found by gravimetric analysis.

The removal efficiency was calculated with Equation 1 [24]:

$$Er = \left(1 - \frac{S_{outflow}}{S_{inflow}}\right) \times 100 \quad (1)$$

Where:

E_r = Removal efficiency, %

$S_{outflow}$ = Outlet concentration of suspended solids, mg/L

S_{inflow} = Inlet concentration of suspended solids, mg/L

RESULT AND DISCUSSION

The equations obtained as a result of statistical analysis are given in Table 1 collectively as well as in the graph.

The flow and the cumulative flow volumes during the filtration process for each filter type are shown in Figure 3 and Figure 4 respectively. For each filter type, the flow volumes were decreasing, while the cumulative flow volumes were increasing with time. According to the recorded data, it was said that the total discharge volume of the pumice media filter is higher than the sand-gravel at the same experimental conditions. This is explained by the higher porosity and the macropores ratio of the pumice media [5,12].

The discharge velocities for each filter type are shown in Figure 5. The figure shows that the discharge velocity is decreasing with time for the pumice and sand-gravel filters. It is said that the discharge velocity of pumice media filters is higher than the sand-gravel because of pumice's highly porous and rough nature. The flow velocity gets lower as the pore size smaller. Therefore, the filter bed resistance increases with decreasing in pore size of filter material [5, 12, 13].

TABLE 1

The relationship between the test period and flow volume per hour, cumulative volume, discharge velocity, and solid concentrations in discharge water, and some of the process statistics

Parameters	Media type			
	Sand-gravel	Pumice		
Flow volume per hour (L)	Equations	$y = 3.0579x^2 - 136.35x + 1579.5$ $R^2 = 0.9544$	$y = 3.2511x^2 - 145.37x + 1696.5$ $R^2 = 0.9404$	
	Maximum	1498	1553	
	Minimum	101	108	
	Average	429.90	467.83	
Cumulative volume (L)	Equations	$y = 3595.8\ln(x) + 828.01$ $R^2 = 0.9925$	$y = 3926.6\ln(x) + 820.07$ $R^2 = 0.9943$	
	Total	12897	14035	
Discharge velocity (m³/h/m²)	Equations	$y = 0.0974x^2 - 4.3423x + 50.304$ $R^2 = 0.9544$	$y = 0.1035x^2 - 4.6297x + 54.028$ $R^2 = 0.9404$	
	Maximum	47.71	49.46	
	Minimum	3.22	3.44	
	Average	13.69	14.90	
Solid concentrations in out-flow (mg/L)	Equations	$y = 0.1903x^2 - 8.7238x + 132.68$ $R^2 = 0.9633$	$y = 0.2157x^2 - 9.1051x + 134.02$ $R^2 = 0.898$	
	Maximum	125	137	
	Minimum	34	40	
	Average	57.43	60.87	
Sediment accumulation (for per liter of a layer)	Inlet	g	81.43	53.79
	layer	%	32.60	20.89
	Central	g	130.05	182.07
	layer	%	52.06	70.71
	Outlet	g	38.32	21.63
	layer	%	15.34	8.40

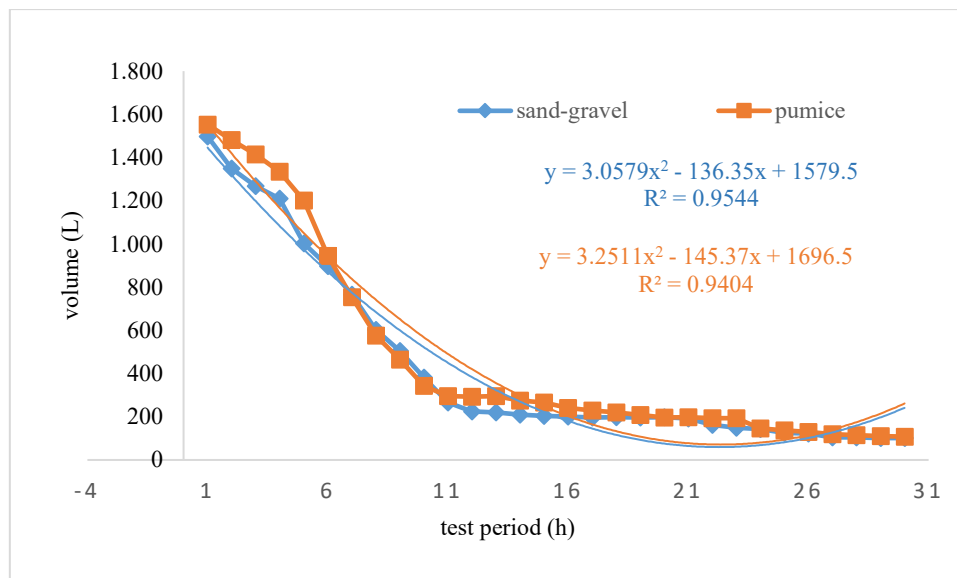


FIGURE 3

The discharge volumes for sand-gravel and pumice media filters

Figure 6 shows that the solid concentrations in discharge water for all types of filter media. The solid concentrations of discharged water decreased with an increase in the filtration test period. It can conclude that the solid concentrations in discharged water of pumice media filters are higher than that of sand-gravel during the filtration process period. It

was reported higher flow velocities that reduced the filtering ability. The pressure-flow conditions could increase the discharged sediment concentrations because the pumice is a material with abundant macropores [5, 13, 25]. When the pumice media is subjected to pressure, particles retained on surface

cavities go out at higher concentrations than the sand-gravel.

The average removal efficiencies of the filter types were calculated at 76.6% for sand-gravel and 70.1% for pumice. The sand-gravel media filter had a higher average removal efficiency compared to a pumice media filter. This can be explained by the regular porosity of sand-gravel medium and different pore size distribution of the two materials [5]. The percentage of sediment accumulated in each layer is given in Figure 7.

According to the figure, the highest accumulation value is found in the central (second) layer for

all types of filters. These values were measured as 52.06% and 70.71% for sand-gravel and pumice media respectively. The reason for this is that the central layer has a finer grain size and higher porosity [5, 26, 27]. The researches show that high porosity has a positive effect on sediment retention. The central layer is followed by the first and third layers. Additionally, accumulation in layer with finer grain-sized for pumice has generally higher than for sand-gravel media.

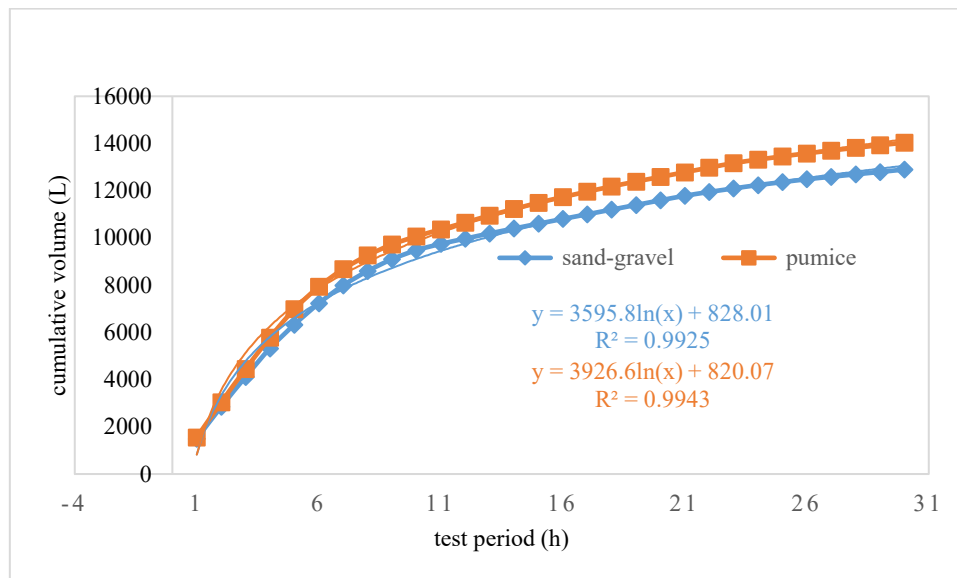


FIGURE 4

The cumulative flow volumes for sand-gravel and pumice media filters

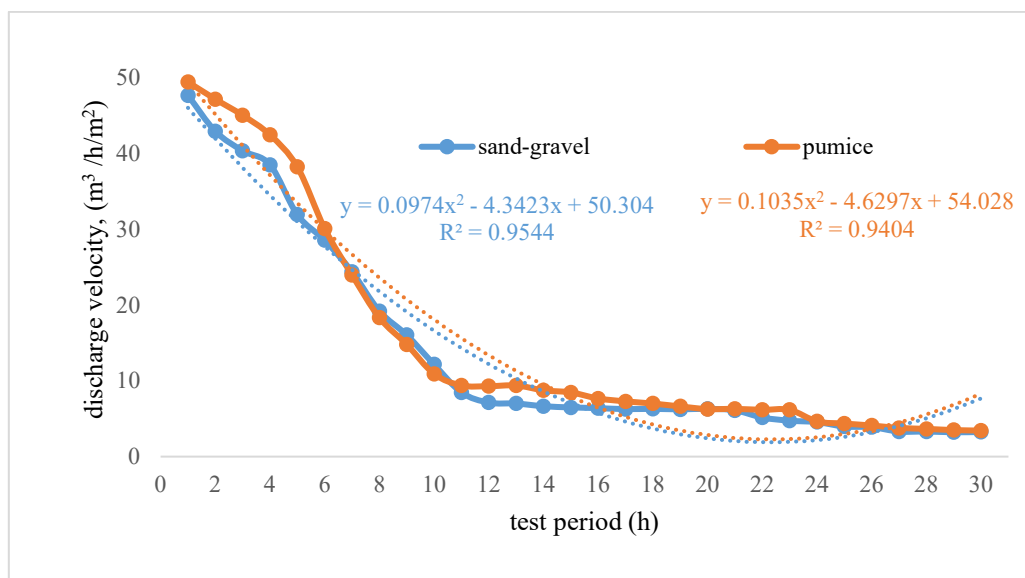


FIGURE 5

The discharge velocities for sand-gravel and pumice media filters

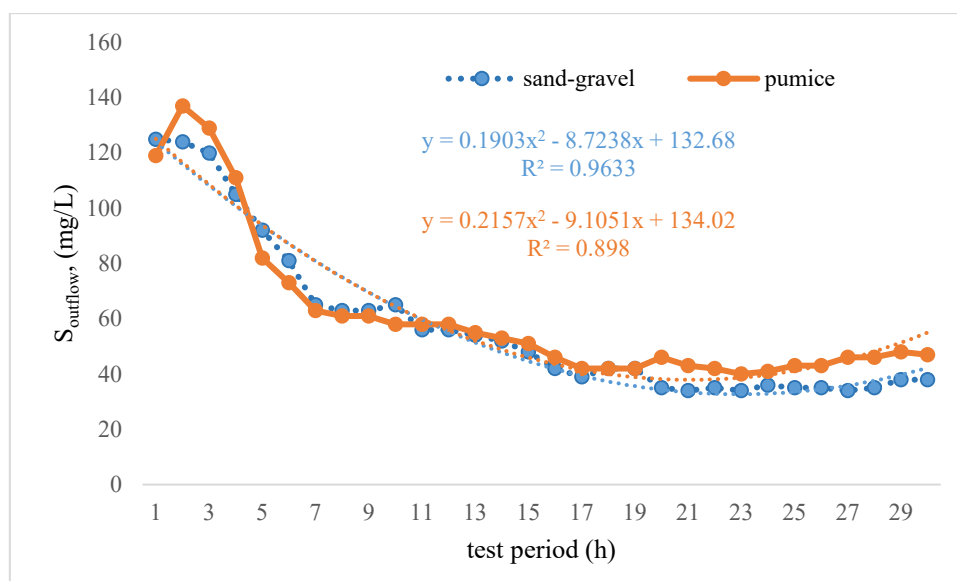


FIGURE 6

The solid concentrations in discharge water for sand-gravel and pumice media filters

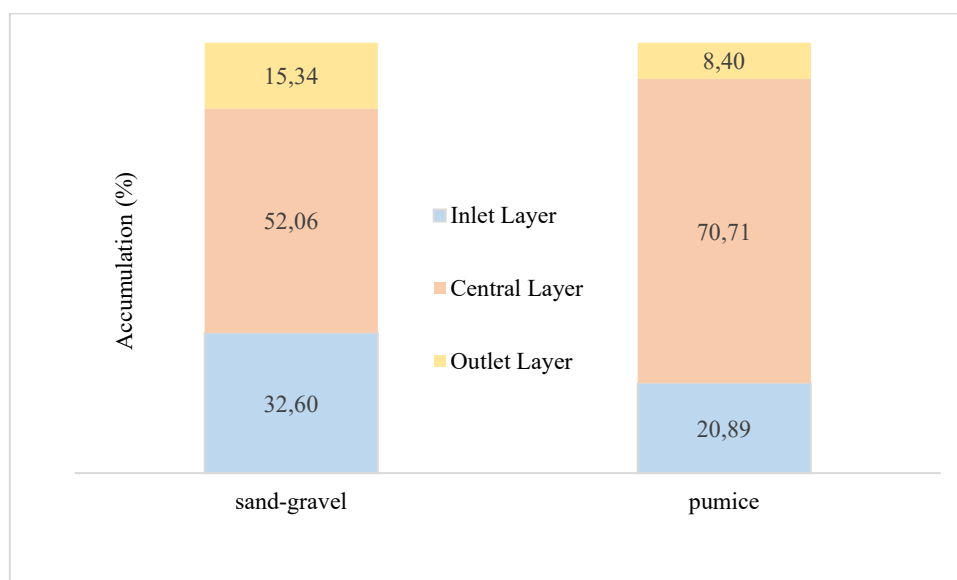


FIGURE 7

Sediment accumulation in the filter layers for sand-gravel and pumice media filters

CONCLUSIONS

At the same experimental conditions, the highest total discharge volume, the lowest average discharge velocities, the highest solid concentration of filtered water, and the highest accumulation percentage of solids at the layers were observed in pumice media filters. The pumice media filters, due to their higher solid deposition capacity, can be used as a pre-filtering unit before the sand-gravel filters. The use of sand-gravel, and pumice together may increase the water quality delivery and durability of the pressured irrigation system. Both pumice and sand-gravel media filters are suitable for lower pressure micro-irrigation types such as surface and subsurface drip irrigation systems and low-pressure dripper

stakes, etc. on the small field applications and greenhouses.

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REFERENCES

- [1] Hynes, N. R. J., Kumar, J.S., Kamyab, H., Sujana, J. A. J., Al-Khashman, O. A., Kuslu, Y., Ene, A. and Suresh Kumar, B. (2020) Modern enabling techniques and adsorbents based dye removal with sustainability concerns in textile industrial sector -A comprehensive review. *J. Cleaner Product.* 272, 122636.
- [2] Abbaszadeh, S., Alwi, S.R.W., Webb, C., Ghasemi, N. and Muhamad, I.I. (2016) Treatment of lead-contaminated water using activated carbon adsorbent from locally available papaya peel biowaste. *J. Cleaner Prod.* 118, 210-222.
- [3] Mor, S., Chhoden, K. and Ravindra, K. (2016) Application of agro-waste rice husk ash for the removal of phosphate from the wastewater. *J. Cleaner Prod.* 129, 673-680.
- [4] Chen, P.A., Cheng, H.C. and Wang, H.P. (2018) Activated carbon recycled from bitter-tea and palm shell wastes for capacitive desalination of salt water. *J. Cleaner Prod.* 174, 927-932.
- [5] Kuslu, Y. and Sahin, U. (2013) A comparison study on the removal of suspended solids from irrigation water with pumice and sand-gravel media filters in the laboratory scale. *Desalin. Water Treat.* 51, 2047–2054.
- [6] Ozmetin, E., Calgan, E., Suzen, Y., Korkmaz, M. and Ozmetin, C. (2017) Optimisation of textile industry wastewater treatment using Bigadic zeolite (clinoptilolite) by response surface methodology. *J. Environ. Prot. Ecol.* 18(3), 1127-1136.
- [7] Anaç, S. and Tamzok, N. (2008) Structural transformation in the Turkish mining industry. *Proceedings Book of 21st World Mining Congress, Krakow-Poland, 7-11 Sept, Sobczyk and Kicki (eds), 367–376.*
- [8] Capra, A. and Scicolone, B. (2007) Recycling of poor quality urban wastewater by drip irrigation systems. *J. Cleaner Prod.* 15, 1529–1534.
- [9] Çiftçi, D.I. and Meriç, S. (2015) A review on pumice for water and wastewater treatment. *Desalin. Water Treat.* 57, 18131-18143.
- [10] Fiallos, F.R.M., Robalino, W.S.M. and Beltran, B.E.P. (2017) Biofiltration on peat bed, for the treatment of wastewater from the washing of jeans. *Revista Publicando* 4(10), 1- 12.
- [11] Samarghandi, M.R., Zarrabi, M., Amrane, A., Soori, M.M. and Sepehr, M.N. (2013) Removal of acid black dye by pumice stone as a low cost adsorbent: kinetic, thermodynamic and equilibrium studies. *Environ. Eng. Manag. J.* 12(11), 2137-2147.
- [12] Farizoglu, B., Nuhoglu, A., Yildiz, E. and Keskinler, B. (2003) The performance of pumice as a filter bed material under rapid filtration conditions. *Filtr. Sep.* 40(3), 41–47.
- [13] Ghebremichael, K.A. (2004) Moringa Seed and Pumice as Alternative Natural Materials for Drinking Water Treatment. PhD dissertation, Royal Institute Technology (KTH), Stockholm, Sweden. ISBN 91-7283-906-6.
- [14] Veliev, E.V., Ozturk, T., Veli, S. and Fatullayev, A.G. (2006) Application of diffusion model for adsorption of azo reactive dye on pumice. *Pol. J. Environ. Stud.* 15(2): 347-353.
- [15] Xu, W. (2020) Research on the driving mechanisms and control factors of ecological innovation in high-tech enterprises. *Fresen. Environ. Bull.* 29(09a), 8237-8243.
- [16] Dorak, Z., Koker, L., Saglam, O., Akcaalan, R. and Albay, M. (2017) Determination of zooplankton community structure, biomass and trophic state of a shallow turbid lake. *Fresen. Environ. Bull.* 26 (1a), 834-845
- [17] Kaplan, M., Baser, M., Kale, H., Irik, H.A., Ulger, I. and Unlukara, A. (2017) Change in yield and chemical composition of tall fescue (*Festuca arundinacea* Shreb.) plants under salt stress. *Turkish Journal of Field Crops.* 22 (2), 204-210.
- [18] Arifoglu, Y. D. and Karabas, H. (2019) Investigation of the use of Hendek (Sakarya, Turkey) wastewater treatment plant effluents for irrigation purposes with different pilot plants. *Fresen. Environ. Bull.* 28(8), 6035-6040.
- [19] Tekin, S. (2019) Investigation of reciprocal influence of wastewater infiltration on N, P, K, organic matter and salt content of various soil types. *Fresen. Environ. Bull.* 28(8), 5747-5753.
- [20] Nakayama, F.S., Boman, B.J. and Pitts, D.J. (2007) Maintenance. In: Lamm, F. R., Ayars, J. E. Nakayama, F. S., *Microirrigation for Crop Production. Design, Operation, and Management.* Elsevier, Amsterdam. 389–430.
- [21] Mutlu, T. and Verep, B. (2018) Water quality of streams flowing into South Eastern Black Sea coasts in terms of physico-chemical properties. *Fresen. Environ. Bull.* 27(5a), 3752-3758.
- [22] Tu, M. C. and Traver, R.G. (2018) Clogging impacts on distribution pipe delivery of street runoff to an infiltration bed. *Water* 10(8), 1045.
- [23] Bulancak, S., Demir, V., Yürdem, H. and Uz, E. (2006) Determination of the efficiencies of different types of filters and filter combinations used in drip irrigation systems in open channel. *Ege University, Ege Univ. J.Fac. Agric.* 43(1), 85–96.
- [24] ASAE (2005) Media Filters for Irrigation-Testing and Performance Reporting. ASAE Standards. St. Joseph, MI. 1-14.

- [25] Gill, L., Doran, C., Misstear, D. and Sheahan, B. (2009) The use of recycled glass as a filter media for on-site wastewater treatment. *Desalin. Water Treat.* 4, 198–205.
- [26] Singhal, N., Elefsiniotis, T., Weeraratne, N. and Johnson, A. (2008) Sediment retention by alternative filtration media configurations in storm water treatment. *Water Air Soil Pollut.* 187, 173–180.
- [27] Ozcoban, M.S. (2019) Variation of permeability of clay soils with different conditions permeated with leachate. *Fresen. Environ. Bull.* 28(2), 885-890.

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