Environmental Health Engineering and Management Journal

Original Article

Open Access Publish Free

Efficiency of horizontal roughing filter in removing nitrate, phosphate and chemical oxygen demand from effluent of waste stabilization pond

Seyed Mostafa Khezri[1], Gharib Majidi[2], Hossein Jafari Mansoorian[3], Mohsen Ansari[2], Farideh Atabi[4], Taha Tohidi Mogaddam[5], Nahid Rashtchi[6*]

[1]Associate Professor, Department of Environmental Engineering, School of Environment and Energy, Science and Research Branch, Islamic Azad University, Tehran, Iran

[2]MSc in Environmental Health Engineering, School of Public Health, Qom University of Medical Sciences, Qom, Iran

[3]Lecturer, Environmental Health Engineering Research Center, Department of Environmental Health, Kerman University of Medical Sciences, Kerman, Iran

[4]Assistant Professor, Department of Environmental Engineering, School of Environment and Energy, Science and Research Branch, Islamic Azad University, Tehran, Iran

[5]MSc in Environmental Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran

[6]MSc in Environmental Engineering–Water and Wastewater, Islamic Azad University, Western Tehran Branch, Tehran, Iran

Abstract

Background: The effective size of the end grain of horizontal roughing filters (HRFs) is larger than 2 mm. This study aimed to examine the efficiency of HRFs in removing nitrate, phosphate, and chemical oxygen demand (COD) from effluent of a wastewater stabilization pond.

Methods: This experimental study was conducted in 2013. The pilot project was transferred to the Karaj wastewater treatment plant (stabilization pond), and the installation, equipping, and start-up of the system began using an effluent treatment plant. Sampling was done from March to August in 3 rates, 0.5, 1 and 1.5 m/h, and included simultaneous sampling from inlet and outlet filtering to determine the concentrations of nitrate, phosphate, and COD.

Results: At filtration rates of 0.5, 1, and 1.5 m/h, the average nitrate removal equaled 25%, 32%, and 34%, respectively, average phosphate removal equaled 29%, 26%, and 28%, respectively, and the average COD removal at filtration rates of 0.5, 1, and 1.5 m/h equaled 62%, 66%, and 68%, respectively. Outlet values of phosphate and nitrate were lower than the standards set by the Environmental Standards Organization (ESO) ($P < 0.05$).

Conclusion: According to the results of this study, the HRF function was approximately adequate in COD removal, but its efficiency in nitrate and phosphate removal was lower.

Keywords: Wastewater stabilization pond, Horizontal roughing filter, Nitrate, Phosphate, Chemical oxygen demand

Citation: Khezri SM, Majidi G, Jafari Mansoorian H, Ansari M, Atabi F, Tohidi Mogaddam T, et al. Efficiency of horizontal roughing filter in removing nitrate, phosphate and chemical oxygen demand from effluent of waste stabilization pond. Environmental Health Engineering and Management Journal 2015; 2(2): 87–92.

Article History:
Received: 2 April 2015
Accepted: 10 June 2015
ePublished: 23 June 2015

***Correspondence to:**
Nahid Rashtchi
Email: nahidrashtchi1392@gmail.com

Introduction

The increasing demand for water and the limitation of water sources illustrate the importance of recycling wastewater more and more. The cost of treating wastewater is lower than other methods of increasing water supplies. Considering the necessary water quality, the reuse of wastewater is divided into 2 essential parts: potable water and nonpotable water. Nonpotable water is used for irrigational, industrial, and aquatic usages and in entertainment and environmental projects (1). The effluents from biological treatment plants are not able to reach the standards necessary for reuse. To make reusing wastewater feasible, an advanced treatment must be conducted on the effluent of biological treatment plants, the dominant process of which is based on separating solid and liquid, like chemical coagulation, focalization, filtration, and disinfection (2).

Some parameters in outlet effluent considered for evaluating the performance of wastewater treatment plants are: (*a*) chemical oxygen demand, (*b*) nitrate, and (*c*) phosphate. The biodegradable organic materials (proteins, carbohydrates, and fats) are measured in terms of biological and chemical oxygen demand. In case these materials enter the environment without treatment, their biological persistence leads to a reduction of oxygen sources, the creation of anaerobic conditions, and arising odor problems (3,4). The Environmental Protection Organization (EPO) standards for discharge and reuse of wastewater are shown in Table 1 (5).

From the late 1960s, determining the effects of nutritional compounds in aquatic environments (the creation of eutrophication and pollution of underground waters to nitrates) limited the concentration of nitrogen and phosphorus in inlet effluent into the environment and receptive water (6). Based on studies conducted by Wang, the eutrophication in surface waters was decreased by controlling the discharge of wastewaters containing nitrogen and phosphorus and by treating domestic and industrial wastewaters; the concentration of dissolved oxygen in the studied area surface waters was increased (7).

There are ways to increase the quality of stabilization pond effluent, sand bed filters and are example of ways. Horizontal roughing filters (HRFs) are filters with an effective end grain size of larger than 2 mm. The efficiency of roughing filters in removing solids is higher than that of a sedimentation tank (8). During the pass of flow through the bed, the suspended substances are gathered. Material size of the bed is about 4 mm to 25 mm. The roughing filters are generally formed with three layers. The size of the course at the beginning of the flow path is large and at the end is small. This kind of layering increases absorption capacity while the solids entering the bed–depth gradually separate because of the decline in the holes' diameters. Roughing filters are between 5 and 9 meters long, their width is about 2 to 5 meters, and their height is about 1.5 meters (9). Advantages of HRFs include a higher capacity for gathering silt and sediment matters, lack of length limitation, no use of mechanical mobile pieces, and simplicity of establishment and utilization (8). Due to the feasibility of much length, this kind of filter will have a resistance power up to about 500-1000 NTU against suspended solids and turbidity (for example, in time of flood-water) (10).

Table 1. EPO standards for discharge and reuse of wastewater

Parameter	Discharge into surface waters	Irrigation
TSS (mg/l)	40	100
pH	6.5-8.5	6-8.5
Turbidity (NTU)	50	50
Total coliform (MPN)	1000	1000
Fecal coliform (MPN)	400	400
COD (mg/l)	60	200
Nitrate (mg/l)	50	-
Phosphate in terms of phosphorus	6	-

Abbreviations: EPO, Environmental Protection Organization; TSS, total suspended solids.

The aim of this study was to examine the efficiency of HRFs in nitrate, phosphate, and chemical oxygen demand (COD) removal from the effluent of waste stabilization ponds.

Methods

This experimental study was performed in 2013 and used a HRF. The pilot was designed and developed based on Wegelin criteria approved by the World Health Organization (WHO) (11). After its construction, the pilot was transferred to the Karaj wastewater treatment plant, and installation, equipping, and start-up of the system began using treated outlet effluent. The wastewater treatment plant of Karaj works on a stabilization pond. The sampling period lasted from March to August.

The development and installation of pilot

This pilot was constructed of a sheet of nongalvanized iron 3 mm thick and 2 sheets with dimensions of 1.5 × 2 meters. After rolling, the sheets became incomplete cylinder shaped and were welded along their length. Both ends were covered by two circular sheets, and then welding and leakage detection were performed. The quad netted wall made of galvanized sheet was used to separate the bed layers. Holes 4 mm in diameter and 4 square cm in density were created in these 4 pieces using a turnery drill. The walls were welded to the body at a distance of 1.6 m and 1.3 m from the beginning of the filter. The distances between drainage pipes in the first, second, and third holes were 20 cm, 30 cm, and 40 cm, respectively. On these drain pipes, netted faults with holes 5 mm in diameter and a density of 7 holes per square cm were installed. In the third drainage, each hole of one piezometer was installed to determine the hydrological gradient of flow. The filter's exit was guided by a 1-inch diameter trunk-like pipe into the drainage of the pump room bottom. The filter bed was washed hydrologically. The exit faucet of the filter was closed, and the filter holes completely filled with effluent. Then, the arranged drainage pipe faults on the filter floor opened at the same time. As a result of this action, hydraulic cutting force will dislodge sediments from the surface of media and out of the floor drains. The washing strategy of the filter bed was based on change of pressure head lost. At the beginning of the filter start-up, the effluent level in the entrance area was 10 cm from the bed level. As sediment was gradually gathered in the bed, the height of effluent in the inlet area increased to the same level as the filter bed. At this time, the bed washing process was done.

Sampling and conducting experiments

The sampling period for nitrate and phosphate at filtration rates of 0.5, 1 and 1.5 m/h was 30 days, with samples taken every other day. The sampling period for COD at a filtration rate of 0.5 m/h was 60 days, with samples taken every other day. The sampling period for COD at filtration rates of 1 and 1.5 m/h was 26 days, on a daily basis with sampling performed every day. A total of 15 samples for nitrate and phosphate were taken at filtration rates of 0.5, 1, and 1.5 m/h . A total of 30 samples for COD were taken at the filtration rate of 0.5 m/hand at filtration rates of 1 and 1.5 m/h 26 samples were taken. All experiments were measured in accordance with *"Sandard Methods for the Examination of Water and Wastewater"* (12).

Results

In Table 2, the average amount, standard deviation, and slope of nitrate changes for inlet, outlet, and removal efficiency are presented according to filtration rates. In Table 3, the average amount, standard deviation, and range of phosphate changes for inlet, outlet, and removal efficiency are presented according to filtration rates. In Table 4, the average amount, standard deviation, and range of changes for COD for inlet, outlet, and removal efficiency are presented according to filtration rates. Figures 1 and 2 show the changes in efficiency of nitrate and phosphate removal, respectively, at 3 filtration rates. Figures 3 and 4 present the changes in efficiency of chemical oxygen demand removal at 3 filtration rates.

Discussion

The average nitrogen removal efficiency values at the studied filtration rates equaled 25%, 32%, and 34%, respectively. For phosphate, these figures were 29%, 26%, and 28%, respectively, and for COD at the studied filtration rates were 62%, 66%, and 68%, respectively. The average removal efficiency of nitrate, phosphate, and COD

Table 2. Average quantities of nitrate changes according to filtration rate

Zone	Quantities				
	Filtration rate (m/h)	Average (mg/l)	Standard deviation	Minimum (mg/l)	Maximum (mg/l)
Inlet					
	0.5	19.2467	4.10259	12.50	26.50
	1	44.2077	28.10156	8.80	100.80
	1.5	22.9643	9.02105	7.40	39.10
	Total[a]	28.2119	19.56063	7.40	100.80
Outlet					
	0.5	14.2200	2.93068	9.60	19.90
	1	30.4769	20.12632	4.80	74.60
	1.5	14.9643	5.62284	5.60	23.90
	Total[a]	19.5000	13.67273	4.80	74.60
Removal Efficiency (%)					
	0.5	25.400	9.2875	8.0	39.0
	1	32.000	8.6313	19.0	46.0
	1.5	34.000	5.6432	25.0	42.0
	Total[a]	30.310	8.7024	8.0	46.0

[a]Average of the 3 filtration rate.

Table 3. Average quantities of phosphate changes according to filtration rate

Zone	Quantities				
	Filtration rate (m/h)	Average (mg/l)	Standard deviation	Minimum (mg/l)	Maximum (mg/l)
Inlet					
	0.5	9.1867	3.84111	2.30	15.20
	1	11.4615	2.55556	6.50	14.60
	1.5	10.4857	2.42006	6.80	14.30
	Total	10.3238	3.11431	2.30	15.20
Outlet					
	0.5	6.3600	3.01492	2.00	12.80
	1	8.4769	1.97575	4.40	11.70
	1.5	7.5000	1.76940	4.40	11.30
	Total	7.3952	2.45068	2.00	12.80
Removal Efficiency (%)					
	0.5	29.733	12.0266	11.0	46.0
	1	26.000	6.2183	15.0	33.0
	1.5	28.214	7.6779	17.0	39.0
	Total	28.071	9.0430	11.0	46.0

Table 4. Average quantities of COD changes according to filtration rate

Zone	Quantities				
	Filtration rate (m/h)	Average (mg/l)	Standard deviation	Minimum (mg/l)	Maximum (mg/l)
Inlet					
	0.5	63.6333	41.25069	23.00	208.00
	1	64.7308	33.49096	11.00	125.00
	1.5	86.2593	22.11785	48.00	140.00
	Total	71.3373	34.75253	11.00	208.00
Outlet					
	0.5	21.0333	11.80439	3.00	45.00
	1	19.7692	8.58980	4.00	32.00
	1.5	27.0000	7.24834	12.00	40.00
	Total	22.5783	9.91195	3.00	45.00
Removal Efficiency (%)					
	0.5	62.200	22.1553	22.0	88.0
	1	66.577	10.8043	43.0	80.0
	1.5	68.407	5.9048	57.0	84.0
	Total	65.590	15.0787	22.0	88.0

Abbreviations: COD, chemical oxygen demand.

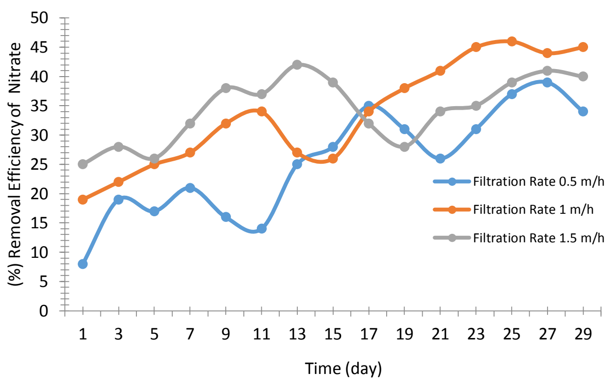

Figure 1. Changes of nitrogen removal efficiency at three filtration rates.

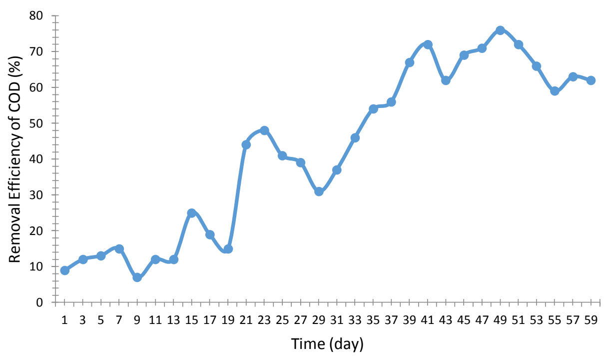

Figure 3. Changes of COD removal efficiency at filtration rate of 0.5 m/h.

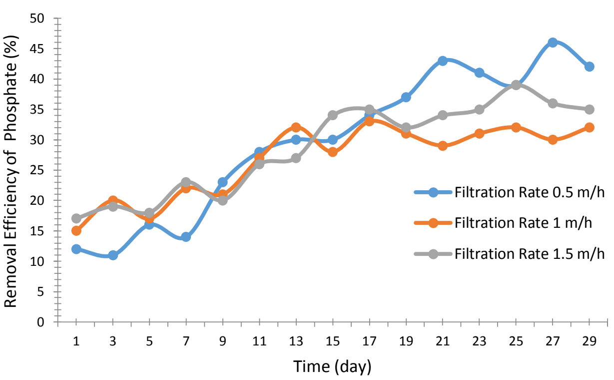

Figure 2. Changes of phosphate removal efficiency at three filtration rates.

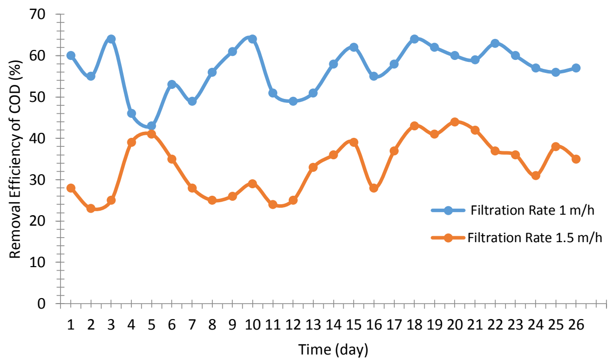

Figure 4. Changes of COD removal efficiency at filtration rates of 1 and 1.5 m/h.

at the studied filtration rates equaled 34%, 28.07%, and 65.59%, respectively.

Using the Scheffe test, the removal efficiency of nitrate and phosphate at different filtration rates were compared. The percentage of nitrate removal was higher at the filtration rate of 1.5 m/h than at 0.5 m/h ($P > 0.05$). Because the data for percentage of COD removed was abnormal, the Mann-Whitney test was used to compare the rates with each other. The COD removal rates at the three tested filtration rates had no significant differences ($P > 0.05$).

In a study conducted by Ehteshami et al, the average COD removal in constant performance statuses of the HRF at similar filtration rates equaled 60%, 51%, and 38%, respectively (13). The present study, however, showed no significant difference in COD removal efficiency. The results of the current study had no conformity with those of Ehteshami's study.

Sarvmeili examined the performance of the HRF with the filtration rate 2.5 m/h in improving effluent quality for urban purposes and obtained values of 63%, 22%, and 37% for removal turbidity, suspended solids, and COD, respectively (14). The average removal efficiency of COD in the present study was 65.5%, which was higher than that of Seromeli's study.

The changes in removal efficiency of nitrate, phosphate, and COD are shown in Figures 1 to 4. The highest nitrogen removal efficiency (46%) relates to filtration rate 1 m/h and occurred 42 days after the pilot study began. The least efficiency was 8% on the first day of filter work. The highest removal efficiency of phosphate (46%) related to the filtration rate of 0.5 and occurred 27 days after the pilot study began. The least efficiency was 11% on the fourth day of pilot study. The removal efficiency of phosphate at each rate increased and had no discernible fluctuation. The highest removal efficiency of COD (76%) related to the filtration rate of 0.5 m/h and occurred 49 days after the pilot work began. The least efficiency was 7% at the beginning of the pilot study. Within the first 6 days, COD removal efficiency equaled 15% at the filtration rate of 0.5 m/h. This increase over time can be related to the formation of a microbial film in the roughing filter bed, which led to a reduction in pore diameter, an increase in the substrate contact surface, and dominance of chemical and biological processes in removing elements and microbial load (15).

Based on the results of this study, the HRF in COD has an optimal performance, but its efficiency is low in removing nitrate and phosphate. The *t* test was used to compare the outlet values of COD and phosphate with the EPO standards. A significant difference was observed between outlet COD of HRF and the standard of the EPO for discharge into surface water and irrigation ($P < 0.05$). There was also a significant difference between the outlet phosphate from HRF and the EPO standards for discharge surface waters ($P < 0.05$). Due to the abnormality of the outlet nitrate data, the Wilcoxon test was used to compare outlet values with EPO standards. There was significant difference between outlet nitrate from HRF and the EPO standard for discharge into surface waters ($P < 0.05$). Outlet values of COD, phosphate and nitrate were lower than EPO standards ($P < 0.05$).

Conclusion

The study results showed that the efficiency of the HRF in removing nitrate, phosphate and COD from the effluent of a wastewater stabilization pond was affected by filtration rates. An increase in filtration rate enhanced the efficiency of the HRF. This result was in agreement with the above-mentioned studies. At the various filtration rates, nitrate and phosphate removal was more dependent than COD removal. This result was in agreement with studies by Khazayi (15), Ehteshami et al (13), and Wegelin et al (12). A biological oxygen demand (BOD) removal of 85% to 90% is not unusual for stabilization ponds, and the removal of viruses, bacteria, protozoa, and helminthes is also reported to be very high (16). Therefore, using the HRF after stabilization pond effluents can be an alternative to depth filtration as a pretreatment for membrane filtration. The filter media of the study pilot was 10-15 mm gravel for roughing filtration. This size was assessed in Mazumder et al study (16). Low removal rates of nitrate and phosphate may be caused by the filter media size. Stabilization pond effluent has an extremely high algal content, so caution should be exercised during use of the HRF. Horizontal roughing filtration plays a significant role in the treatment line, because a high COD removal and average nitrate and phosphate removal efficiency was achieved simultaneously and in one-step without requiring any sophisticated control of pH, redox potential, etc. According to the results, the best situation for better operation of the HRF is a filtration rate of 1 m/h for 5 days.

Ethical issues

The authors certify that all data collected during the study is presented in this manuscript, and no data from the study has been or will be published separately.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Seyed Mostafa Khezri, Farideh Atabi, Taha Tohidi Mogaddam, and Nahid Rashtchi designed the study. Gharib Majidi, Mohsen Ansari, and Hossein Jafari Mansoorian performed the literature search and wrote the manuscript. All authors participated in data acquisition, analysis, and interpretation. All authors critically reviewed, refined, and approved the manuscript.

References

1. Torabian A, Motalebi M. Management plan of treated effluent reuse - case study: Ekbatan town. Journal of Environmental Studies 2004; 29(32): 57-62. [In Persian].
2. Mohamadi A, Naseri S, Mahvi AH, Roshani B, Firozmanesh M, Salehi R. The study of performance of multimedia filters to removal the bacteria in the municipal wastewater to reuse and chlorine reduction for disinfection. Journal of Kordestan University of Medical Sciences 2005; 8(4): 8-15. [In Persian].
3. Tchobanoglous G, Louis F, Burton H, Stensel D. Wastewater Engineering: Treatment and Reuse. 4th

ed. New York: McGraw-Hill; 2004.
4. Salvato JA, Nemerow NL, Agardy FJ. Environmental Engineering. 5th ed. New Jersey: Wiley & Sons; 2003.
5. Ghaneian M, Mesdaghinia A, Ehrampoush M. Principeles of Wastewater Reuse; Applications, Standards and Side Effectes. Tehran: Teb Gostar; 2001. [In persian]
6. Gerardi MH. Nitrification and Denitrification in the Activated Sludge Process. New Jersey: John Wiley & Sons; 2003.
7. Wang H, Wang H. Mitigation of lake eutrophication: Loosen nitrogen control and focus on phosphorus abatement. Progress in Natural Science 2009; 19(10): 1445-51.
8. Khazaei M, Nabizadeh R, Nadafi K, Nourieh N, Omidi Oskouei A. Elimination of suspended solids from aerated lagoon effluent by horizontal roughing filter. Journal of Qom University of Medical Sciences 2010; 4(1): 42-7. [In Persian]
9. Nabizadeh Noudehi R, Nadafi K, Vaezi F, Khazaei M, Safdari M. Efficiency of horizontal roughing filter (HRF) in coliform removal from aerated lagoon effluent. Water and Wastewater. 2008; 19(2): 2-9. [In Persian]
10. Fazeli M. Determination of design basic and development of DHRF. [Ph.D thesis] Tehran: Tehran University; 2003. [In Persian]
11. Wegelin M, Boller M, Schertenleib R. Particle removal by horizontal-flow roughing filtration. J Water Suppl Res Tech Aqua 1987; 36 (2): 80-90.
12. American Water Work Association. Standard Methods for the Examination of Water and Wastewater. 20th ed. American Water Work Association; 2005.
13. Ehteshami M, Takdastan A, Alavi N, Jafarzadeh Haghighifard N, Ahmadi Moghdam M, Khazayi M, et al. Efficacy of HRF in COD removal from secondary effluent of Yasuj municipal wastewater. Armaghane-danesh 2011; 16(4): 391-9. [In Persian]
14. Sarvmeili M. Upgrading of Wastewater Effluent Quality for Municipal Non-potable Applications by Horizontal Roughing Filter. Tehran; 2006. [In Persian]
15. Khazayi M. The study of performance of horizontal roughing filter (HRF) and hydrogen peroxide complex - a series of silver ions to reduce the bacterial load in the effluent, city of Qom [Thesis]. Tehran: Tehran University of Medical Sciences and Health Services; 2007. [In Persian]
16. Mazumder A, Kumar Roy P, Nath Barman R, Majumder M, Mukhopadhay B. Verification of filter efficiency of horizontal roughing filter by Weglin's design criteria and artificial neural network. Water Eng Sci 2008; 1(2): 117-33.