Research Journal of Medical Sciences 10 (4): 275-281, 2016
ISSN: 1815-9346

Optimizing Subsurface Flow Wetland Using Pamis and Escoria Stone

[1]M.O. Dovlat Abadi, [2]A. Rahmani Sani and [3]M. Borghei
[1]Department of Environmental Engineering, Islamic Azad University, Tehran, Iran
[2]Department ofEnvironmental Science, Faculty of Health,
Sabzevar University of Medical Sciences, Sabzevar, Iran
[3]Faculty of Chemical and Petroleum Engineering, Sharif University, Tehran, Iran

Abstract: Based on this study, the effects of two filter materials of pamis and escoria and comparing them with the sand bed were considered and analyzed. Three similar beds were made with 8 days hydraulic detention time and one primary sedimentation tank with 2-h time. One bed was filled as a witnessed test with sand and sec and third beds were filled with pamis and escoria stone for the study. To water the reeds with the urban wastewater, one urban wastewater system was used with these features BOD = 250 mg L^{-1}, TSS = 200 mg L^{-1}, COD = 300 mg L^{-1} and pH = 7.2, TP = 6 mg L^{-1}, TN = 21 mg L^{-1}; the pilot was used during 1 year and it was used later also. The experiments were done by use of the standard method and analyzed the data using excel software. The results showed that the removal output of COD (79.93%), TSS (90.55%), TP (84%) and TN (86.01%) in the test beds whereas it was 87.91, 94.12, 87.21, 89.15% in escoria beds and 95.94, 97.14, 91.13 and 91.03% pamis beds, respectively. The surface roughness and a big space of porous material in the bed filter is to increase the biofilm on it. It causes an increase in the removal output for carbon and nitrogen-organ materials and the suspended solid. The pamis stone has increased the removal output considerably in the reeds. The escoria stone is lower than pamis and higher than sand in their features. It justifies the use in industrial centers.

Key words: Primary sedimentation, escoria, pamis, subsurface flow (SSF), wetland

INTRODUCTION

Subsurface Flow (SSF) wetland is considered as natural methods such as methods to refine the wastewater. They are applied in removal different kinds of urban and industrial wastewater. They are used because of its ease in production, refining method and maintenance. Concerning the energy expenses that are increasing in the world and the necessity to use it in an optimal way, the production and reviewing of applied materials are developing greatly. The reeds are, generally, categorized into two groups: natural reeds and SSF wetland (made by human being) (Bruch *et al*., 2011). SSF wetland is grown in a self-growing way beside the lagoons, rivers and lakes. They are used in removal of the contamination from contaminated waters near the area because they do not receive the wastewater in a purposeful way. SSF wetland are some pools in essential dimensions with a depth of 60-80 cm. They are planted by some soil or sand filled materials; then, different kinds of reeds such as Lowi, Bouria and Ney. These types of reeds depend on the kind of area they are planted (Tanner *et al*., 2005).

There are different types of reeds based on the free-surface flow and under-surface flow, regarding the water depth in the bed. The plants are drawn to the stalk inside the bed in the surface structure or flow. But, in under-surface flow, the wastewater moves inside the bed depth after moving into the bed and then it goes out. The reeds are categorized into two groups based on its kind of flow entered into the bed. They are reeds with a horizontal flow and reeds with vertical flow (Vymazal, 2008). Because of low refinery expenses by using the reeds, the reeds output is considered to refine many optimizing refinery projects. Jong Hiewong and Chioseek (Choi *et al*., 2006), Moris and Smith (Huett *et al*., 2005) performed the wastewater refinery with and without reeds beds. They reported a higher output for beds having reeds. Jorsenberg reported the removal output percent of TN in both beds with and without reeds about 95% by adding methanol to the wastewater. Using the SSF wetland by a heterogeneous and endurable flow was reported by McBred and Taner. Ato Austin and Allen (Stein *et al*., 2006) Mehrdadi and Rahman (Mehrdadi *et al*., 2009). They applied the endurable flow in beds with and without

Corresponding Author: Abolfazl Rahmani Sani, Department of Environmental Health Engineering, School of Public Health, Sabzevar University of Medical Sciences, Sabzevar, Iran

reeds. They also reported a high percentage of removal in beds covered by reeds when compared to the beds without reeds.

The increase in depth of SSF wetland was performed by under surface SSF wetland with a height of 1 m in 2005-06 by Arias *et al.* (2005) and Headley *et al.* (2005). Brix and Carlux found removal output of 95% for BODs. Thomas and Harrity by using three beds of under surface beds with a depth of 0.1, 0.5 and 0.8, respectively and concluded that the wastewater contamination occurs in a length view form of the bed that tends to a fixed amount in a deep point.

By combining the fixing lake and lagoons with SSF wetland return back to 1990s that was done to improve their output. It was reported that the removal of TSS, BODs, parasite lava and coliform has increased considerably in the final outlets. Saydam, Rahman and Mehrdady have made studies in this area.

The results of the present study and the related literature showed that although, important researches have been done about the type of entered flow, the bed depth and the plant types sand has been used as bed filler and it is not mentioned by any other names. Hence, sand has little soft and rough surfaces, also its limited porosity. It was used in this research with sand bed, Z types of mineral stone and escoria stone to analyze the porosity percent of the fillers and the effect of their rough in removal output percent. The amount of rough for the surface and the amount of porosity for respective sand, mineral stone and Escoria stone that ranges from little, average to high (Karim *et al.*, 2004).

MATERIALS AND METHODS

This project was performed in the Center of Applied Researches of Hygiene, Faculty in Medical Science University of Sabzevar, Iran.

Making the beds: In this study, 3 beds were made of glass with a thickness of 6 mm in length with dimension of 1 meter, breadth of 50 cm and depth of 60 cm. The glass was made of security glass. The time selected for hydraulic maintenance of all the beds was 8 days. The material of glass was selected because of observing the biofilm made, or formed in the beds and roots among the material (Fig. 1), one cylinder storage tank with 220 L volume was installed as primary sedimentation tank. The urban wastewater was used with features BOD = 250 mg L^{-1}, COD = 300 mg L^{-1}, TSS = 200, pH = 7.2, TP = 6 mg L^{-1} and TN = 21 mg L^{-1} . The wastewater was entered into a 3-bed tool after passing through a 3-pipe tool and exiting of the primary sedimentation material.

Fig. 1: Glass pilot plant of subsurface flow wetland

Table 1: Parameters of effective size, homogeneity, roughness and porosity

The cumulative percent passing the sieve	Percent remaining on the sieving	Weight remaining on the sieving (Gr)	Hole size	Sieving based on Astm
99.25	69.00	6.9	9.20	7.3
13.92	78.00	870.0	6.10	5.0
1.27	10.50	105.0	2.36	8.0
0	0.65	6.5	2.00	10.0

The filling material of the bed: Sand, pamis stone and escoria stone were used in this study. The escoria stones were first mashed to combine materials. Then, 1 kg of each material was moved into soil mechanic laboratory to determine the parameters of effective size, homogeneity, roughness and porosity. Then, the features were presented in Table 1.

Based on the grain-grouping chart, about 87% of the grain sizes were between 6.1-9.2 mm. The porosity capacity of the material was 35% and saturated hydraulic lead was Ks = 500 $m^2/m^2/d$ meter in a day (Fig. 2).

Planting: The applied or practical plant was related to a common reed is known as Cat Tail of cat form in the region. The plant was selected from the refinery of wastewater refinery house in Sabzevar in Spring as some sprouts with a length of 10-15 cm. It had strong and volumetric roots. It was planted inside the beds with ordered length and breadth distance. About 5 cm of the sand (light sand) was spread on the beds to improve and strengthen the roots and were cut and styled inside the bed (Fig. 3).

The pilot performance: Regarding the type of weather in the region in February, 2012 starts getting warmer. Hence, the reeds roots were sent from the existing reeds into the storage house of refinery of Sabzevar wastewater in February, 2012. It was done to do research in Spring on the plant moving mechanism into the pilot. The sprouts

Fig. 2: The filling material of the bed: a) sand; b) escoria stone and c) pamis stone

Fig. 3: Planting in pilot plant

were moved to the pilot place in March, 2014 because of the desirable warm weather. The diluted wastewater was used for watering them (60% urban wastewater and 40% water). The sprouts were watered with the diluted wastewater for 3 weeks. The urban wastewater was used to ensure desirable growth of the plants. The start of the experiments was in April, 2014 (Fig. 4).

Fig. 4: Subsurface following wetland with sand, pamis and escoria

Table 2: The wastewater parameters, the summary, the equipment and the reference

References	Equipment	Scale	Summary	Parameters
APHA 1998	Laboratory thermometer	oC	Temp	Temperatures
APHA 1998	Dry oven	Mgl-1	TSS	Total suspended solids
APHA 1998	Incubator	Mgl-1	CBOD	Materials to carbon
EPA 353.2	...	Mgl-1	TN	Total nitrogen
EPA 365.1	...	Mgl-1	TP	Total phosphor
APHA 1998	PH	...	pH	pH

The operational conditions: The study was performed in an environmental condition by using desert pilot of the pre-refining units by combining SSF wetland which are undersurface during one year. The studies conducted includes TP, TN, COD, BOD, TSS, temperature and alkaline tests were performed. The wastewater samples were extracted twice a week. Each time they were prepared as a 4-h preparation method. The results were extracted, based on moving average method. The sample place was moved from the entrance exit part of sedimentation, the exit preparation undersurface reeds into laboratory which was located in the Faculty of Hygiene in the university. The wastewater samples were experimented by the existing method in the book "method standard".

Analysis of samples: The wastewater parameters, the summary, the equipment and the references were mentioned in Table 2.

RESULTS AND DISCUSSION

COD removal in the beds: COD removal in beds Table 3 shows the entered and exited amounts of the tested bed and research bed. The removal average of COD in escoria bed was 87.91% (Table 3). This amount was 95.94% in pamis bed and 79.93% in sand bed. The reason for this increase could be the amount of oxygen existing and the

Table 3: COD removal in the beds

Efficiency mean	Output COD mg L^{-1} mean	Input COD mg L^{-1} mean	Title
14	258.00	300	Primary sedimentation
	51.79	258	Sand bed
	31.20	258	Escoria bed
	10.48	258	Pamis bed

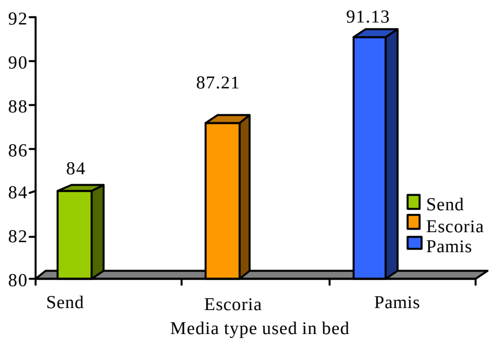

Fig. 5: Compare the removel of COD in the bed

Table 4: TSS removal in the beds

Efficiency mean	Output COD mg L^{-1} mean	Input COD mg L^{-1} mean	Title
33	134.00	200	Primary sedimentation
	12.66	134	Sand bed
	77.87	134	Escoria bed
	3.83	134	Pamis bed

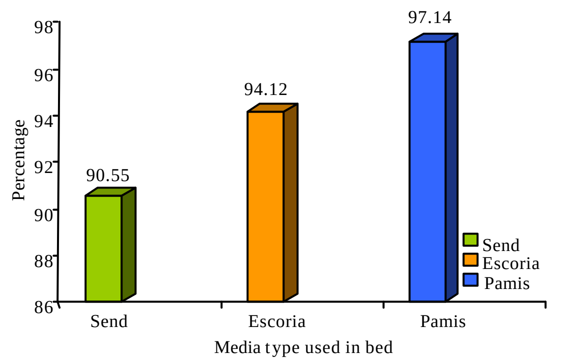

Fig. 6: Compare the removel of TSS in the bed

more growth of biological film in the pamis bed. Analyzing the organic materials occurred in two forms of aerobic and non-aerobic by sedimentation and filtration of organic material particles inside the bed (Vymazal, 2008). Since, most of the output related to the reeds bed aerobic refining, the output increase in pamis bed should be further studied. The oxygen transit methods in the undersurface reeds are done in two ways. Firstly by transiting the oxygen from air proximity and then penetrating from soil layer as per the movement flow performed by process being done in a physical way. This process is done because of the pressure discrepancy between the water inside and the plan texture and the atmosphere air. It plays an important role in the bed aerobics mechanism. The movement flow way occurs because of the water speed discrepancy. The second way is by oxygen penetration.

The oxygen can be obtained because of photosynthesis inside the reeds empty stalks. The transition, or movement, by the cells carrying gas into the roots and the plant underground stalks and their spread into the stalks are reported (Sani *et al*., 2013). This oxygen in the area around the roots make their environment aerobicized. This oxygen is consumed by the micro-organisms around and on the root. The oxygen transition occurs about 5-45 g/m^{-1} in a day. It occurs based on the plant concentration. The reason to increase the removal output in pamis bed when compared with two other beds could be categorized: the amount of element sedimentation in pamis stone is less than sand because of the atmosphere around the materials. It helps to make an aerobic atmosphere in the bed, the penetrating of reeds roots in the layer of pamis stone is much more than sand. Then, it helps to transport the oxygen and it makes more accumulation of micro-organisms on the roots because of the roughness of the surface, the accumulation of the biologic layer on the pamis stone is for the pamis stone, rather than sand. Then, because of these reasons, the removal output of COD in pamis bed is more desirable than sand (Fig. 5).

TSS removal in the beds: Table 4 shows that the data inputs and outputs, including the external output of the beds. Because the average removal output in the normal table for pamis bed was 97.14, 94.12% for escoria stone and 90.55% for the sand bed (Vymazal and Kropfelova, 2009).

TSS removal in the beds: removal suspended solid in the reeds is performed by the flocculation, sedimentation, filtration, prevention by the media and the plants roots. The form, size and special weight of the particles are important in the sedimentation process (Fig. 6). The sedimentation process occurs in two ways: the separated particles and the flocated particles. As the whole condition of the beds, except the filler material is the same, then increase in the removal output of the solid in pamis bed and escoria bed should be as per its difference with the normal sand. Because of the heterogeneous form of pamis and the sharp edges, their sedimentation in each other is less than the straight and homogenous sand. Then the penetration of roots in the space between pamis stones is much more than others. It makes a common filler of stone and root against the passing of solid and it influences the amount of removal. The porous space makes a biogenic and gelatin layer.

Table 5: TN removal in beds

Efficiency mean	Output COD mg L^{-1} mean	Input COD mg L^{-1} mean	Title
-----	21.40	21.4	Primary sedimentation
	2.99	21.4	Sand bed
	2.32	21.4	Escoria bed
	1.91	21.4	Pamis bed

Table 6: TP removal in beds

Efficiency mean	Output COD mg L^{-1} mean	Input COD mg L^{-1} mean	Title
-----	6.00	6	Primary sedimentation
	0.96	6	Sand bed
	0.76	6	Escoria bed
	0.53	6	Pamis bed

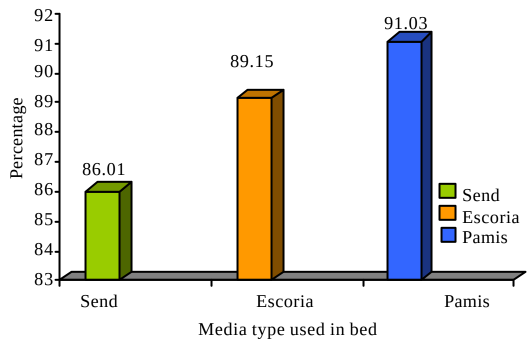

Fig. 7: Compare the removel of TN in the bed

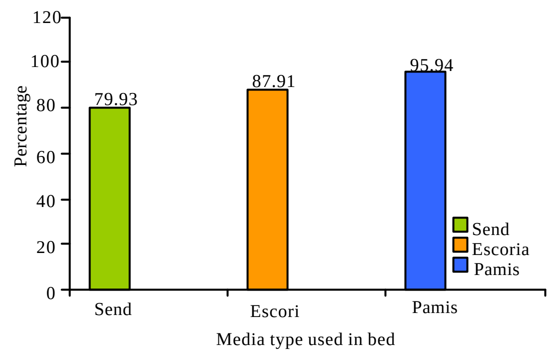

Fig. 8: Compare the removel of TP in the bed

This layer has a positive influence on removal of the organic materials that are affective in absorbing the suspended BOD. If the reasons for better removal output for pamis stone could be categorized: pamis stone has a higher biofilm growth, because of its higher porosity when compared to sand. Hence, it helps to sedimentation in a flocculation method. The sedimenting percentage is much higher than sand; it is effective on the removal output; the better penetration of the plant roots in the spaces between environments to absorb the micro-organism. This makes common stone filler and common root filler that can be effective on the removal output because of the higher percentage of oxygen transmission in the root space of pamis, the amount of removal the suspended BOD which is stuck at the root and media is much more than the sand bed. Escoria is located in the middle somewhere between pamis and sand because of its physical form, surface roughness and the existent porosity. Then, its removal output is between media.

TN removal in the beds: Table 5 shows the internal and external amounts from the beds and the amount of removal output in the beds were TN in pamis beds 91.03% in escoria bed 89.15% and in sand bed 86.01% (Fig. 7). The most important mechanism of nitrogen removal is based on two biological methods, i.e., biologic nitrification and denitrification. Firstly, ammonic is changed into nitrite by nitro zomonas bacteria and nitro bacteria. Secondly, nitrite is changed into nitrate and then it is changed into Azote in an unaerobic conditions and Anoxic by nitrifire bacteria. Nitrogen is essential for plants in a mineral form. If the amount of nitrogen is not enough, it would be a limiting factor (Mitsch and Gosselink, 2000). The Ammoniac is solved in water. It makes ammoniom iona. The removal method for ammonium iona is absorbing by the plants or the sieve. It can be as an electrostatic on the surface of the negative iona of the soil particle. The process of stabilizing Nitrogen is done by the micro-organisms. The change of azote in the wastewater is done by oxidation changing it into nitrate azote; then, stimulating the ammoniac azote. The reeds roots are one of the important factors to absorb the nutrition materials; increasing it makes a higher efficiency of absorbing the azote, the plant absorbs the material as an iona. Then, there is more nitration in the reeds beds. This process is important because Nitrogen is absorbed in the Nitrate form (Nelson *et al*., 1999), i.e., both oxygen penetration and roots growth is important. Mehrian and Mehrian (2015) investigate structural health monitoring using optimizing algorithms based on flexibility matrix approach and combination of natural frequencies and mode shapes. Then, the growth of the biological film on the roots and the bed media can directly be related to the type of bed fillers. Then, the highest amount of removal output for removal Azote was observed in pamis bed and in escoria bed and finally sand bed.

TP removal in the beds: Concerning the removal phosphor in the beds, Table 6 shows the internal and external amounts for the beds together with the output for each bed , i.e., 91.13% for pamis bed, 87.21% for escoria bed and 84% for sand bed (Fig. 8). The mechanisms of removal phosphor combination are used in urban wastewater by SSF wetland in a physical, chemical and biologic way. The dominant form of phosphor is like orthophosphate which is used by sieves and macro fits (DeBusk, 1999).

The surface absorption of phosphor combination of filler materials and the plants root and bed the chemical sedimentation of phosphor with other elements, like aluminum, Iron, calcium and clay material made complex combinations by biological reactions and the sedimentation and their sedimentation on the sediments surface. Finally, it could lead to direct absorption by the plants. Hence, quality and type of the filler material in the bed is very effective on removal phosphor. Thus, there are some important surface absorption processes and chemical sedimentation, which are directly effective on removal phosphor. The filler small-sized particle, texture makes it possible to absorb more phosphor. The existence of iron, aluminum, calcium combinations in the soil beds increases the potential to omit the phosphor combinations (Vymazal, 2007). The results showed that the plant and filler materials are important in absorbing phosphor. In the pamis bed, the plant growth and the roots are more complete than two other beds. Its special surface form is compared to other bed fillers. Then, the output increase is absolutely logical in the bed.

CONCLUSION

The SSF wetland is very widespread in urban and industrial wastewater uses because of low expenses of its production, exploitation, keeping in comparison with other mechanical methods and its easy to use application method. However, the application of these systems is not technically justified in industrial wastewater refineries, because of high usage of land. The results show that this industrial application can be justified, when optimizing these systems. The pamis stone is one of the tools that increases the removal output in reeds because of its high porosity and its special surface form when compared to the sand. It is washable because of its high lifetime circle and it can be reused. Hence, one of the methods to decrease the land in the reeds is to use special media that increases the omotting percent. This is observed in pamis stone in a real way.

ACKNOWLEDGEMENT

Many thanks to the head of the Islamic Azad University of Tehran Research

REFERENCES

Brix, H. and C.A. Arias, 2005. The use of vertical flow constructed wetlands for on-site treatment of domestic wastewater: New Danish guidelines. Ecol. Eng., 25: 491-500.

Bruch, I., J. Fritsche, D. Banninger, U. Alewell and M. Sendelov *et al*., 2011. Improving the treatment efficiency of constructed wetlands with zeolite-containing filter sands. Bioresour. Technol., 102: 937-941.

Choi, J.H., S.S. Park and P.R. Jaffe, 2006. The effect of emergent macrophytes on the dynamics of sulfur species and trace metals in wetland sediments. Environ. Pollut., 140: 286-293.

DeBusk, W.F., 1999. Wastewater treatment wetlands: Applications and treatment efficiency. Masters Thesis, University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, Gainesville, Florida.

Headley, T.R., E. Herity and L. Davison, 2005. Treatment at different depths and vertical mixing within a 1-m deep horizontal subsurface-flow wetland. Ecol. Eng., 25: 567-582.

Huett, D.O., S.G. Morris, G. Smith and N. Hunt, 2005. Nitrogen and phosphorus removal from plant nursery runoff in vegetated and unvegetated subsurface flow wetlands. Water Res., 39: 3259-3272.

Karim, M.R., F.D. Manshadi, M.M. Karpiscak and C.P. Gerba, 2004. The persistence and removal of enteric pathogens in constructed wetlands. Water Res., 38: 1831-1837.

Mehrdadi, N., A. Rahmani, A.A. Azimi and A. Torabian, 2009. Study of operation subsurface flow wetland in batch flow system for municipal wastewater treatment. Asian J. Chem., 21: 5245-5250.

Mehrian, S.M. and S.Z. Mehrian, 2015. Modification of Space Truss Vibration using Piezoelectric Actuator. In: Applied Mechanics and Materials. Adrian, O. (Ed.). Trans Tech Publications, Switzerland, Europe, pp: 246-252.

Mitsch, W.J. and J.G. Gosselink, 2000. The value of wetlands: Importance of scale and landscape setting. Ecol. Econ., 35: 25-33.

Nelson, M., M. Finn, C. Wilson, B. Zabel and M.V. Thillo *et al*., 1999. Bioregenerative recycling of wastewater in Biosphere 2 using a constructed wetland: 2-year results. Ecol. Eng., 13: 189-197.

Sani, A.R., N. Mehrdadi, A. Azimi and M. Delara, 2013. Pollutant removal from municipal sewage by optimized anaerobic pond and subsurface flow wetland. Asian J. Chem., 25: 1177-1181.

Stein, O.R., J.A. Biederman, P.B. Hook and W.C. Allen, 2006. Plant species and temperature effects on the k-C first-order model for COD removal in batch-loaded SSF wetlands. Ecol. Eng., 26: 100-112.

Tanner, C.C., M.L. Nguyen and J.P.S. Sukias, 2005. Nutrient removal by a constructed wetland treating subsurface drainage from grazed dairy pasture. Agric. Ecosyst. Environ., 105: 145-162.

Vymazal, J. and L. Kropfelova, 2009. Removal of organics in constructed wetlands with horizontal sub-surface flow: A review of the field experience. Sci. Total Environ., 407: 3911-3922.

Vymazal, J., 2007. Removal of nutrients in various types of constructed wetlands. Sci Total Environ., 380: 48-65.

Vymazal, J.K.L., 2008. Wastewater Treatment in Constructed Wetlands with Horizontal Sub-Surface Flow. Springer, Dordrecht, Netherlands,.