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An environmental-friendly study on sanitary wastewater treatment for small community

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ABSTRACT

The aim of this study was to evaluate the efficiency of the combined septic tank and constructed wetland systems as series when they are easily operated in a small community such as training camp. Using the septic tank for sanitary wastewater treatment in a small community can be an effective preliminary process. The nitrate and phosphate concentrations could be effectively decreased in the effluent by using the constructed wetland. By using the series treatment process, the removal efficiencies of ammonia, nitrate, nitrite, and phosphate were reported to be 40.11%, 37.91%, 19.49%, and 39%, respectively. Also, the removal efficiencies of total coliform and fecal coliform were found 5 log and 4 log units, respectively. Using disinfection unit will be necessary before discharging of the total and fecal coliforms in the effluent to the environment. In this study, the quality of the treated wastewater was found to be according to the acceptable Iranian effluent standards for wastewater reuse in irrigation.

Keywords: Combined systems; Constructed wetland;Hygienic wastewater; Septic tank

1. Introduction

One of the main aims of wastewater treatment process is to generate the wastewater that it could have the least negative environmental effects after discharging to the environment. Sanitary wastewater treatment, which it has been produced as a result of environmental degradation, can be reused using a simple treatment process such as a septic tank (ST). This issue has become more important due to the water crisis over the last century. Although there are several methods for sanitary wastewater treatment nowadays when they have been considered as the minimum cost, the simplicity of design and operation [1,2]. There will be many problems in the small communities for wastewater treatment and discharge to the environment. These problems are considered as a high cost of construction and operation, high energy consumption, and high sludge producing. But using the natural treatment process is considered as the simple technology and high performance. Also, the renewable energy systems such as solar, and wind could be used for their operation [3,4]. Wetlands are one of the natural treatment systems that are classified into two groups: natural and constructed. Constructed wetlands can create ecological conditions similar to natural wetlands for wastewater treatment in various physical, chemical and biological conditions. Constructed wetlands could categorize depending on wastewater flow regime as Free Water Surface (FWS) and Subsurface Flow (SSF). In SSF, wastewater flows below of the surface of media matrix and media material. It is an important factor because it could avoid clogging to ensure a sufficient hydraulic conductivity. Also, SSF is subdivided as horizontal and vertical subsurface flow according to the direction of wastewater flow pass through media matrix of constructed wetlands. The constructed wetlands as a secondary treatment with high performance are able to remove contaminants such as organic matter, inorganic materials and a variety of pathogenic microorganisms. These systems can be considered as one of the most appropriate applicable technologies for developing countries.

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Because this system has advantages such as easy construction, maintenance and operation, process stability, and low sludge production [3]. Therefore, these factors have caused the focus of worldwide attention in recent years on the constructed wetlands [5,6].

The constructed wetlands systems could be combined with another treatment system to achieve higher efficiency, which called "hybrid constructed wetlands". In hybrid systems, the advantages of different systems can be combined and enhanced for wastewater treatment. Various studies have shown that using the combined systems, the removal of various pollutants such as BOD_5, COD, TSS, nutrient, and microbial have enhanced [7,8].

This study aimed to evaluate the efficiency of the combined systems of septic tank – subsurface constructed wetland (ST-SSF) as series for hygienic wastewater treatment in a training camp when the important parameters including COD, BOD_5, TSS, turbidity, ammonia, nitrate, nitrite, phosphate, total coliform, fecal coliform, and intestinal nematode parasites were evaluated.

2. Materials and methods

2.1. Experimental setup

This is an experimental study which is conducted in the nine-month period from November 2014 to July 2015. The sanitary wastewater of small community (training camp) was selected as influent to treatment process in Qazvin province. Based on the design fundamental, a prefabricated ST unit and SSF system by horizontal flow were constructed and operated in series. They were used to determine wastewater quality parameters including COD, BOD_5, TSS, turbidity, ammonia, nitrate, nitrite, phosphate, total coliform, fecal coliforms, and intestinal nematode parasites. Based on the maximum produced wastewater (160 L/d), the specification of retention time and total volume in ST were reported to be 2 d and 38 m^3, respectively. The dimensions of constructed wetland were 1 × 4 × 20 m (D × W × L) where the plants such as Vetiver grass and Qazvin native straw were used for wastewater treatment in this study. The control system (without plant) was built with the same physical and hydraulic conditions as the SSF system. The total surface areas for subsurface constructed wetland and control systems (without plants) were 160 m^2 (80 m^2 for each system). The calculated hydraulic residence time for subsurface constructed wetland was calculated at a range of between 1.5 and 3 days according to minimum and maximum inflow discharge rate. The pictures of the treatment process of the septic tank (ST) and subsurface constructed wetland (SSF) are shown in Figs. 1a, b.

2.2. Sampling and data analysis

Samples were collected from the input to septic tank as raw wastewater, the input to subsurface constructed wetland and control system, and the output of subsurface constructed wetland and control system, twice per month. The samples were transferred to the laboratory of Qazvin University of Medical Sciences in less than 48 h at 4°C. Intestinal nematode parasite count was done based on Bailenger method [9] and was observed using a microscope. Other desired parameters were measured according to the Standard method for water and wastewater analyses [10]. Experimental errors were reduced with repeating of the tests. Analyses of samples were performed using theSPSS16 software. The examined parameters were compared with the Iranian standard for wastewater reuse in irrigation [11] and EPA guidelines [12].

3. Results and discussion

The physicochemical and biological characteristics of raw wastewater, input and output of control system and SSF system, as well as Iranian and EPA guidelines, are provided in Table 1.


(a)


(b)

Fig. 1. The pictures of treatment process: (a) Septic tank (ST), and (b) Subsurface constructed wetland (SSF).

Table 1
Average concentration (±SD) of physicochemical and biological characteristics of influent and effluent of wastewater

Parameter	Unit	Raw wastewater (influent)	ST effluent	Control case effluent	SSFCW effluent	Iranian standards for irrigation	EPA for irrigation
pH	–	6.9–8.2	7.4–8.3	7–8	7.2–8.2	6–8.5	6.5–8.4
COD	mg/L	605.4 ± 83.7	365.1 ± 12.8	195 ± 15.6	97.88 ± 11.6	200	120
BOD_5	mg/L	440.27 ± 110.7	230.94 ± 50.1	101 ± 9.6	41.3 ± 10.9	100	30
TSS	mg/L	131.7 ± 10.3	61 ± 6.25	34 ± 1.8	24.5 ± 1.3	100	5
Turbidity	mg/L	588.78 ± 94.64	169.3 ± 42.7	52 ± 4.6	440.05 ± 7.5	50	2
Total coliform	MPN/100 mL	7.8E8 ± 6.02E8	5.2E7 ± 2.78E6	6.68E6 ± 2E7	1.3E3 ± 6E2	1000	200
Fecal coliform	MPN/100 mL	5.1E6 ± 4.2E6	4.5 E5 ± 2.7 E5	5E4 ± 2.32E3	4.1E2 ± 1.5E2	400	–
Ammonia-N	mg N/L	54.39 ± 0.47	54.17 ± 0.5	54.16 ± 0.33	32.6 ± 2.5	–	–
nitrite-N	mg N/L	0.12 ± 0.003	0.11 ± 0.003	0.11 ± 0.0006	0.097 ± 0.01	–	–
Nitrate-N	mg N/L	10.85 ± 0.06	10.21 ± 0.13	8.3788 ± 1.3	6.7 ± 0.14	10	–
Phosphate-P	mg/L	5.88 ± 1.03	5.62 ± 1.05	5.38 ± 0.89	4.04 ± 0.9		10
Nematode	Number/100 mL	2.11 ± 1.18	0.27 ± 0.5	1 ± 1.1	0	≥1	1

Table 2
Comparison of the removal efficiencies in ST and combing system of ST-SSF processes

Removal efficiency	COD (%)	BOD_5 (%)	TSS (%)	Turbidity (%)	Total coliform (%)	Fecal coliform (%)	Nematode (%)
ST	38.4	46.5	32.6	71.4	93.32	89.66	86.84
ST-SSF	83.66	90.94	81.53	92.46	5 log	4 log	100

The comparing of the different removal efficiencies for the parameters of COD, BOD_5, TSS, turbidity, nematode, total coliform and fecal coliform in only ST system and then the combing system of ST-SSF is shown in Table 2.

The different removal efficiencies of ammonia, nitrate, nitrite, and phosphate in ST, SSF, and combing system of ST-SSF are compared in Fig. 2.

According to the results presented in Table 2, the efficiencies of physicochemical parameters such as COD, BOD_5, TSS, and turbidity were obtained 38.40%, 46.50%, 53.6%, and 71.4%, respectively. However the different pollutants could be reduced in septic, but the effluent is not able to the acceptable standards for wastewater reuse in irrigation. So it is often used as a temporary option for wastewater disposal. Total coliforms, fecal coliforms, and intestinal nematode parasites are the common biological indicator in wastewater treatment. The removal efficiencies of total coliforms and fecal coliforms were reported 91.57% and 88.93%, respectively using ST system. The ST system was not able to reduce more than 1 log unit microbial parameters, including total coliforms and fecal coliforms. Also, the removal efficiency of nematode by ST system was achieved 86.84%. The effluent from the septic tank is not sufficient to discharge to the environment because the total removal of pathogenic bacteria, cysts and parasites are obtained incomplete. So,the septic tank system is usually used as pre-treatment [13]. Although a high percentage of nematode removal was obtained based on having a sufficient retention time and settlement, ST system was not able to remove them completely. WHO has been emphasized on the risk of intestinal infections caused by parasites when it is much considered both for workers and for wastewater reuse in irrigation [14].

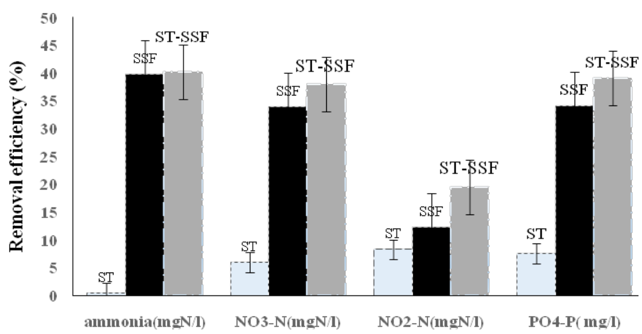

Fig. 2. Comparison of the different removal efficiencies for ammonia, nitrate, nitrite, and phosphate in septic tank (ST), subsurface constructed wetland (SSF), and combing system of septic tank- subsurface constructed wetland (ST-SSF).

The removal efficiencies of ammonia, nitrate, nitrite, and phosphate using ST system were found to be 0.39%, 5.93%, 8.26%, and 7.5%, respectively (Fig. 2). The reduction of COD, BOD_5, and also nitrogen and phosphate compounds especially ammonia, using ST system were found very low. It is seen that the residual concentration of TSS in the effluent was found to be the permissible Iranian standards for irrigation. It can be due to the low concentration of TSS in influent. For the other study parameters, this system was not able to reduce them to acceptable Iranian standards for wastewater reuse in irrigation and EPA guidelines.

According to the results presented in Table 2, the removal efficiencies of COD and BOD_5 were found to be 83.86% and 90.94%, respectively when the combing systems of the septic tank and subsurface constructed wetland (ST-SSF) were used. The role of wetland plants for absorbing pollutants from wastewater is very limited. The wetland plants aerate the root zone and also facilitate the movement of water to avoid clogging the system. Transporting of oxygen to the roots occurs by air-filled channels of roots and rhizomes in wetlands. The roots and rhizomes use the majority of this oxygen for respiration, but some oxygen is lost to the rhizosphere [4,15]. However, many researchers have indicated that the anoxic-anaerobic decompositions play an important role in subsurface constructed wetland [5,16]. The subsurface constructed wetland act like fixed film bioreactors. So the removal of organics is mostly very high in SSF [5].

The subsurface constructed wetland system was found to be able to reduce TSS and turbidity from 61±6.25 mg/L and 169.3± 42.7 mg/L to 24.5±1.3 mg/L and 44.0±7.5 mg/L, respectively. They were found to be in the permissible Iranian standards for irrigation. The system is able to remove TSS and turbidity effectively by using filtration and settlement units. Most of TSS and turbidity are settled in the early phase of the zone [5,17]. One of the advantages of substrates in wetlands is providing beneficial media for microbial growth which assists removal of colloidal substances, such as SS and a part of the COD and BOD_5, by aerobic or anaerobic activity. So the removal efficiencies of these parameters were found high in the subsurface constructed wetland process. Ge et al. [18] pointed out that the most of the suspended pollutants such as suspended COD, BOD_5, TN,TP, and SS can be removed effectively when the subsurface constructed wetland was performed. As shown in Table 1, TSS and turbidity are the most important parameters when they were efficiency reduced from 131.3±10.3 mg/L and 588.78±94.6 mg/L to 34±1.8 mg/L and 52.6±4 mg/L in the control system, respectively. The average residual concentration of TSS and turbidity from constructed wetland were reported 24.5±1.3 mg/L and 44.05±7.5 mg/L, respectively. By comparison of the average residual concentration of TSS and turbidity in the effluent of SSF system and the control system, it can be concluded that the bed of plants play an important role in the reduction of TSS and turbidity in wetlands.

From results shown in Fig. 2, using the subsurface constructed wetland system, the removal rate of ammonia, nitrate, nitrite, and phosphate were reported 39.8%, 34%, 12.33% and 34.05%, respectively. The main mechanisms of nitrogen removal are nitrification and denitrification process. The subsurface constructed wetland are suitable for removal of nitrate (denitrification), but it is not appropriate for removal of ammonia (nitrification) because of the insufficient oxygenation of the rhizosphere and therefore incomplete nitrification doing [19]. Tao et al. [20] noted that if the dissolved oxygen concentration is lower than 0.5 mg/L, a certain nitrification is not observed. Therefore, due to anaerobic conditions, microbial removing by nitrification is very limited and will not be completed. Other mechanisms such as adsorption, volatilization, and plant uptake accounted to be less important in the removal of nitrogen in SSF systems [5,19].

The major removal mechanism of phosphorus in the subsurface constructed wetland is considered adsorption and precipitation by substrate constitute [21]. Previous research has indicated that phosphorus easily reacts with iron, aluminum and calcium ions released by the substrates [22]. It was found that microbial action plays a much less important role in phosphorus removal in the constructed wetland [18].

By concerning to the results, SSF system was separately able to reduce the pathogens microorganisms significantly. The removal rate of total coliforms, fecal coliforms and nematode parasites by SSF system were found to be 99.99% (4 log), % 99.8 (2 log) and 100%, respectively. The main removal mechanisms include filtration, sedimentation, hunting by the larger organisms, natural decomposition, antimicrobial activity, unsuitable temperature and others [13]. The levels of biological parameters in the final effluent were not found in the acceptable limits regarding the Iranian guidelines and EPA for wastewater reuse in irrigation. For achieving output standards, using the disinfection unit will be necessary.

As shown in Table 2, the removal rates of COD, BOD_5, TSS, and turbidity indicated higher in the combined system of ST-SSF than the singly used SSF and ST systems. These removal efficiencies were found 83.68%, 90.49%, 81.53% and 92.46%, respectively in the combined system of ST-SSF. The quality of the treated wastewater was found to be according to the acceptable Iranian effluent standards for wastewater reuse in irrigation. Using the combined system of ST- SSF, the removal efficiencies of ammonia, nitrate, nitrite, and phosphate were found 40.11%, 37.91%, 19.49% and 39%, respectively. It showed a better performance than singly used SSF and ST systems.

The variation of total coliform and fecal coliform counts by ST, SSF, and combined ST- SSF systems are indicated in Figs. 3 and 4, respectively.

Previous studies showed that the combined systems such as hybrid systems wetland – aerated lagoons, horizontal-vertical flow, and ST-SSF process have demonstrated effective removal of various wastewater pollutants including BOD_5, COD, TSS, and nitrogen [17,23].

Abdel-Shafy and El-Khateeb [24] studied the integration of ST and SSF for sanitary wastewater treatment. The total area of the constructed wetland was 200 m^2. The removal percentages for COD, BOD_5, TSS, and fecal coliform using the septic tank were reported 41%, 46%, 59%, and 89.89%, respectively. The removal rates for these parameters using only the subsurface constructed wetland were reported 79%, 78%, 80%, and 99.99% (4 log), respectively. Also,the removal rates for these parameters using the hybrid system (ST-SCF) were reported 87%, 89%, 92%, and 99.999% (5 log), respectively. The overall performance of our study was found to be lower than which achieved by Abdel-Shafy and El-Khateeb. It can be due to the larger total surface area, relatively stable environmental condition, and inflow fluctuations. Sharafi et al. achieved the high performance of the constructed wetland system for removing of the pathogenic bacteria, parasites, and cysts [25]. Allen et al. pointed out that temperature and surface load rate (SLR) play a key role in the performance of the constructed wetland system [26].The result is in agreement with the results obtained. The average residual concentration of nitrate and phosphate were achieved to be

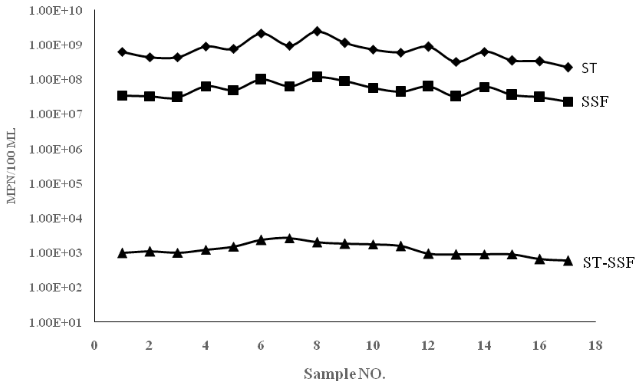

Fig. 3. The variation of total coliform counts by ST, SSF, and ST-SSF systems.

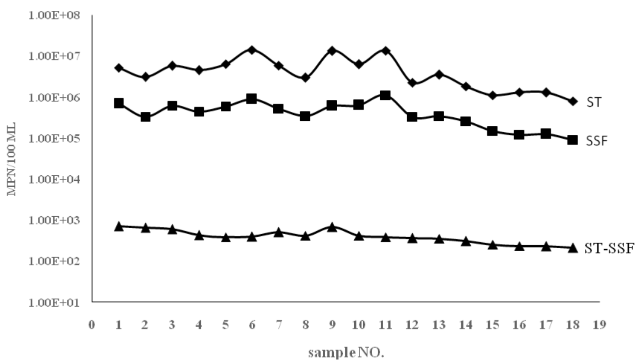

Fig. 4. The variation of fecal coliform counts by ST, SSF, and ST-SSF systems.

within the permissible limits of the irrigation according to the EPA and Iranian standards. The removal rates of total coliform, fecal coliform and intestinal nematode parasite by combined ST-SSF system were reported 99.999% (5 log), 99.9% (4 log) and 100%, respectively.

4. Conclusions

Using septic tank only for sanitary wastewater treatment in a small community can be an effective preliminary process. The nitrate and phosphate concentrations could be effectively decreased in the effluent when the constructed wetland was used. By using the series treatment process such as septic tank and constructed wetland systems, the pollutant removal efficiencies were increased. The removal efficiencies of COD, BOD_5, TSS, and turbidity were reported to be 83.86%, 90.94%, 81.53% and 92.46%, respectively where the series treatment process was used for sanitary wastewater treatment. Also, the most removal efficiencies for total coliform, fecal coliform and nematode were found 5 log unit, 4 log unit, and 100%, respectively when the combined ST-SSF systems were used. It appeared the removal efficiencies of ammonia, nitrate, nitrite, and phosphate were found to be 40.11%, 37.91%, 19.49% and 39%, respectively. Using disinfection unit will be necessary before discharging of the total and fecal coliforms in the effluent to the environment. In this study, the quality of the treated wastewater was found to the acceptable Iranian effluent standards for wastewater reuse in irrigation.

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