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The impact of barrier walls (baffle) on performance of septic tanks in domestic wastewater treatment

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ABSTRACT

Proper management is one of the most important environmental issues in wastewater treatment. Selecting the method of treatment depends on several factors, such as available facilities and technologies, quality and quantity of raw wastewater, outlet effluent standards, and budget. Because of low cost, design, construction, and easy operation of biological methods of wastewater treatment, they have been considered for a long time. Septic tank is one of the biological systems based on sedimentation and anaerobic biological treatment. The main problem associated with septic tanks is low efficiency. The present study aimed to determine the effect of hydraulic regime reform on performance of septic tanks in domestic wastewater treatment. This cross-sectional study was conducted on domestic wastewater in cement factory in Estahban during 7 months. In addition to evaluating the performance of septic tanks in domestic wastewater removal, some changes were made in its structure in order to modify hydraulic regime flow for increasing efficiency. After 4 months, as the period of habituation and stability of the reactor, physicochemical parameters such as biochemical oxygen demand, chemical oxygen demand, total suspended solid, total solid, total phosphorus, and total Kjeldahl nitrogen were evaluated in both inlet and outlet. The reactor's performance in removal of the abovementioned parameters was 83%, 76%, 84%, 48%, 4.35%, and 2.40%, respectively. The control reactor's efficiency for these parameters was 38% under the best condition.

Keywords: Baffle; Wastewater treatment; Septic tank; Hydraulic regime

1. Introduction

Water is a critical and vital factor for socioeconomic development and preservation of ecosystems. Thus, some researchers believe that the future world war may occur over water. On a global scale, there is an increasing need for water. Therefore, the quality of water resources is of utmost importance. Due to increasing population, water resources allocation has strongly increased for domestic, industrial, and agricultural usages. Hence, there is an increasing pressure on the environment, particularly water resources [1]. Since the Industrial Revolution, large amounts of organic matters and nutrients have been discharged into the environment through sewage [2]. Wastewater is in fact the water used by communities, which is polluted for various applications and is not used for consumption [3].

Development of cities, increasing population, and industrialization has caused the quality of wastewater to be deteriorated [4]. Considering urban water scarcity due to ongoing drought, treatment of wastewater is an important

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issue [5]. Due to the high cost of wastewater treatment, many underdeveloped and developing countries use it in agriculture. This will have long-term harmful effects on soil, ground water, and human health [4]. In order to protect the environment and promote public health, wastewater must be treated [6].

Each community should have clear goals and criteria in order to be able to select an appropriate wastewater treatment system. Selected system or systems must in turn meet community needs with reasonable costs [7]. Generally, wastewater can be treated through physical, chemical, physicochemical, and biological methods [6]. Each of these methods has its own performance according to the type of wastewater treatment. Chemical methods are often not suitable for municipal wastewater treatment due to need for complex and costly equipment and tools, energy consumption, etc. Despite low cost, physical methods are only used as an alternative due to low efficiency in removal of almost all pollutants. Physicochemical methods are most widely used in industrial wastewater treatment [8,9]. Moreover, biological methods have been considered for a long time due to advantages, such as eco-friendliness and low cost [10]. Septic tank is a suitable, low cost system for biological treatment of domestic wastewater due to its simple construction and operation. Treatment in septic tanks is based on material sedimentation resulting from deceleration and anaerobic biological treatment in sludge accumulated at the bottom in long run. Effluent pollution that comes out of septic tanks is almost equal to wastewater pollution coming out of reservoir in the primary sedimentation. Generally, septic tanks are only able to remove of wastewater pollutants slightly therefore, it cannot be used as a standalone unit for wastewater treatment and outlet effluent needs to be treated completely [11,12].

Septic tanks are better to be built somehow that their repairing can be done easily and properly when needed [13,14]. Since the removal of waste should be done every 3 to 4 weeks the capacity and dimensions should be selected to achieve this objective because long retention wastewater is the reason for forming sludge which may result in insufficient emptying [15]. The type of pollution degree is one of the main factors which differs domestic sewage that are flowing through sewage systems [16, 17].

A variety of biological reactors:

To express the characteristics of the abovementioned hydraulic reactors in terms of mixing wastewater in reactor, an index called dispersion number is used that is shown in the following equation:

$$d = \frac{D}{UL} \quad (1)$$

where d = dispersion coefficient, m s^{-1}; L = effective length, m; U = average flow velocity, m s^{-1}.

If this coefficient tends to zero in the reactor, the reactor will be plug flow. On the other hand, if it tends to infinite, the reactor will be mixed completely.

Environmental conditions, especially nutrient concentration, change in plug flow reactors. In other words, in the primary part of the reactor in which wastewater is mixed with sludge, the concentration of organic substances is more than saturation coefficient and according to Monod equation, the rate of organic matter decomposition. Therefore, the more oxygen is needed at the bottom of the reactor due to low concentration of organic material, the lower the activity of microorganisms and self-immolation conditions will be. Indeed, dissolved oxygen must be at its minimum level. In completely mixed reactors, however, environmental condition is the same in all parts of the reactor because inlet wastewater is mixed with sludge. Based on Monod equation, when concentration is reduced to ks or less, the velocity of biochemical reactions is greatly reduced. These changes lead to higher efficiency in plug flow systems regarding reduction of organic materials, which is better than completely mixing systems [18].

According to what was mentioned above for modifying flow hydraulic regime in septic tanks, some measures must be taken to direct flow towards creek-like reactor so as to improve its efficiency in wastewater treatment. Moreover, the number of septic tank parts or number of ponds in series must be calculated in order to determine the maximum performance.

2. Materials and methods

Investigations have indicated that hydraulic regime can be changed by installing baffles in reactors. To obtain the optimal number of baffles, a pilot is needed to be designed. Then, dispersion number changes are evaluated based on baffles.

Based on the following equation, when a reactor is divided into two or more reactors, a creek-like reactor can be created, which increases efficiency. However, the number of parts needs to be evaluated and calculated. If the number of reactors exceeds a determined level, efficiency does not increase and performance is decreased.

$$C_e = C_i^* \frac{1}{1 + K_t} \quad (2)$$

where C_e = inlet concentration of pollutants; C_i = outlet concentration of pollutants; K = coefficient of kinetics; t = hydraulic retention time

At first, a glass pilot with a certain size was designed, made, and loaded completely by water. Then, inlet flow was determined based on the retention time of 24 h. To investigate dispersion number, Rhodamine was injected into the inlet as a traceable pollutant and after half an hour, sampling was conducted from the outlet in order to evaluate the color. This process was continued with half an hour intervals until the color concentration in the outlet was equal to zero. After that, 2, 4, 6, 7, and 8 baffles were installed inside the reactor and the dispersion number was evaluated separately based on the above-mentioned method. It should be noted that dispersion number was calculated separately for each mode. Schematic image of the baffle used in this study has been depicted in Fig. 1.

The results indicated that by installing seven barrier walls and dividing the volume of the reactor into eight equal parts, the lowest dispersion number could be obtained. However, increasing this number to 8 caused no significant changes in dispersion number. Also, according to Table 1,

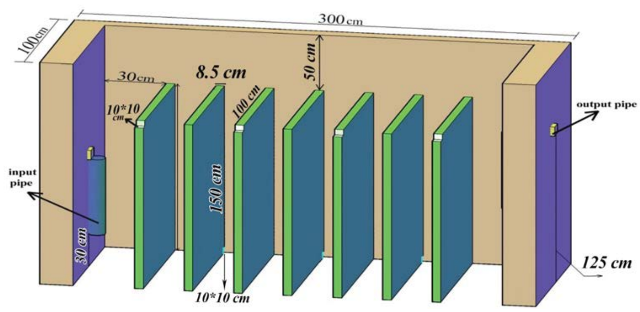

Fig. 1. The schematic image of the baffle used in the study.=

Table 1
Dispersion numbers of the reactors

Number of walls	Dispersion number
0 (Control reactor)	0.500
2	0.120
4	0.090
6	0.084
7	0.067
8	0.066

when the number of containers was more than 7, no changes occurred in output efficiency.

2.1. Design and construction of industrial-scale pilot

After these preliminary studies, building and deployment of a pilot in full scale with the following characteristics was conducted at the site of Estahban cement factory. Image of the baffle used in this study has been shown in Fig. 2.

The characteristics of the pailot used in this study is given in Table 2 as follows:

Two pilots were made with 300 cm width, 100 cm length and 200 cm depth.

One of them was chosen as control reactor and the other one was divided into eight equal sections by seven baffles with 100 cm length, 8.5 cm width and 150 cm length. Each baffles was connected to the next one by square shape slot hole. The distance between each baffle is 30 cm.

Fig. 2. The baffle used in the study.

Table 2
Septic tank characteristics in this study (all units are in cm)

Communication channels between containers		Gas outlet pipe in the ceiling			Baffle				Pipes' height from the septic floor						
Width	Length	Height	Diagonal	The distance between each baffle	Height	Width	Length	Number	Output	Input	Open surface	Efficient depth	Width	Length	Pilot
0	0	250	20	0	0	0	0	0	125	150	50	150	100	300	Control
10	10	250	20	30	150	8.5	100	7	125	150	50	150	100	300	With baffle

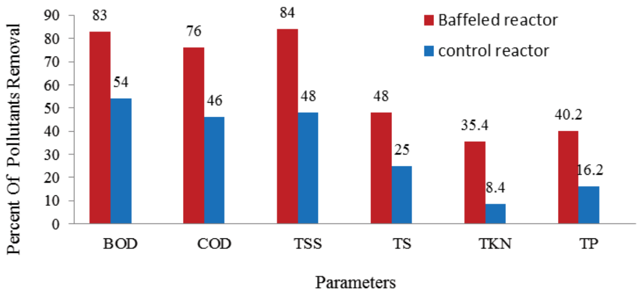

Fig. 3. Comparison the efficiency of the control reactor to the reactor having a baffle with the dispersion number 0.67.

The input and output pipes in both pilots were located in 150 and 125 cm from the floor of the pilots respectively. The pipes were located about 50 cm of primary depth of pilots and was determined as free surface from wastewater overflowing in probable turbulence.

As CH_4 is one of the produced products in anaerobe treatments, a pipe with 200 cm length and 20 cm diameter were placed for the generated gas in both pilots.

In order to stabilize the system, the available microorganisms needed to be adapted to low concentrations of wastewater in the system because the system might be shocked due to high organic load and respond to this sudden shock abnormally. Accordingly, after building the pilots based on the above principles, 8 kg of cow dung and 50 L of septic sludge of current factory floor were added to both septic tanks in order to seed and expedite the process of the reactors stabilization. Then, both reactors were launched. Wastewater treatment facilities alone cannot solve environmental concerns. To achieve optimal standards, plan performance must be reviewed and evaluated continuously [19]. Biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), suspended solids, amount and type of solids, and pH are the parameters considered for evaluating the performance of wastewater treatment plants. To this end, 4 months after launching the reactors, samples were obtained from the system's inlet and outlet for evaluating the impact of the accomplished reforms on the efficiency of the system according to the timetable. Then, physicochemical parameters (BOD_5, COD, total suspended solid (TSS), total solid (TS), total Kjeldahl nitrogen (TKN), total phosphorus (TP), electrical conductivity (EC), pH, and turbidity) were examined based on Standard Methods, 20th ed., [20].

Samples were provided in 4 stages. At each stage, six individual samples were taken on different days of the pilot's work. In the 4th stage, sampling was repeated for ten more samples, which revealed no significant changes in the results. Accordingly, sampling process was stopped and data analysis was begun.

3. Results

The mean ± SD values of each inlet and outlet parameter have been presented in Table 3.

According to Table 3, the mean value of the parameters was significantly lower in the outlet of the septic having a baffle with dispersion number 0.67 compared to the control septic. Comparison the efficiency of the control reactor to the reactor having a baffle with the dispersion number 0.67 is presented in Fig. 3.

4. Discussion and conclusion

Cui et al. [21] designed 3 new baffle flow Constructed Wetlands (CWs), namely baffle horizontal flow CW (Z1), baffle vertical flow CW (Z2), and baffle hybrid flow CW (Z3), along with one traditional horizontal subsurface flow CW (Z4) to test the removal efficiency of nitrogen (N) and phosphorus (P) from septic tank effluent under varying hydraulic retention times (HRTs). Their study results showed that two days was the optimal HRT for maximal removal of N and P from the effluent of septic tank among the four CWs. At this HRT, Z1, Z2, Z3, and Z4 CWs respectively removed 49.93%, 58.50%, 46.01%, and 44.44% of total nitrogen as well as 87.82%, 93.23%, 95.97%, and 91.30% of TP. Their study further revealed that the best design for overall removal of N and P from the septic tank effluent was Z3 CW due to its hybrid flow directions with better oxygen supply inside the CW system [21].

Kujawa-Roeleveld et al. [22] investigated the applicability of UASB septic tank for treatment of concentrated black water under two different temperatures; that is, 15°C and 25°C. Based on the results, the removal rate of total COD was respectively 61% and 74%, while that of suspended COD was respectively 88% and 94% at the two above-mentioned temperatures. The results revealed precipitation

Table 3
Comparison the reactor's performances in the removal of pollutants from wastewater of a cement factory

Parameters	Input ± SD	Output ± SD of the reactor having a baffle with dispersion number 0.67	Output ± SD of the control reactor
BOD_5 (mg L^{-1})	269.09 ± 12	48 ± 6.68	174.25 ± 11.25
COD (mg L^{-1})	411.4 ± 21	106.25 ± 4.92	279.75 ± 41
TSS (mg L^{-1})	329.22 ± 18	50.25 ± 1.89	168.75 ± 61
TS (mg L^{-1})	2,869 ± 25.8	1,512.25 ± 0.65	2,123.75 ± 7.5
TKN (mg L^{-1})	20.4 ± 3.4	12.2 ± 2.3	18.67 ± 0.4
TP (mg L^{-1})	17.34 ± 3.2	11.2 ± 1.8	14.4 ± 0.52
EC	1,678 ± 55.8	2,480 ± 25.3	1,900 ± 72.12
T (°C)	19	19	20

of phosphate, as well. Moreover, reduction of *E. coli* was due to effective sludge/water separation, long HRT, and higher operational temperature.

It is probable that sewage contains a large number of heavy metals and other industrial organic toxins which can be a real environmental threat for the chemical quality of soil, agricultural and also sanitary products [23, 24]. The aggregation of heavy metals in soil can cause decreasing the quality of food products and health [25]. The persistence of heavy metals in soil and their bioaccumulative property in living organisms can produce noticeable environmental and health problems [26]. Since the treated sludges are utilized in agriculture as a fertilizer, they should have a little risk of contamination with heavy metals based on standards [22]. Anil and Neera [27] investigated the effect of a modified septic tank system on treatment of domestic wastewater. In that study, the septic tank system was analyzed to study the effect of vertical baffles coupled with an anaerobic reactor. The study reactor had copper modified zeolite as an adsorbent that filtered the attached growth process. The results demonstrated that vertical baffled septic tank coupled with zeolite filter was a suitable treatment system. The results also showed that the above-mentioned baffle with disinfection removed 99.99% of total coliforms, 99.57% of TSS, 46.83% of ammonia nitrogen, 31.08% of nitrate nitrogen, 48.39% of TKN, 94.4% of BOD_5, and 71.74% of phosphates. An economical and efficient decentralized method for treating domestic waste water was emphasized in that research [27].

Lin et al. [28] attempted to improve the tank effluent by using microbial electrochemical septic tanks (MESTs), an alternative tank configuration to conventional septic tanks (CSTs). This was assessed in laboratory scale of 1 L simulated MESTs for 171 d at an average HRT of 8.3 d [19–25]. The results indicated that MESTs improved the removal efficiency of total P from 12.2% to 77.2%–98.7% at 25°C and from 7.45% to 20.7%–93.9% at 15°C. Sulfide was also completely removed from most MESTs effluents. However, CSTs generated 0.17 and 0.06 mm sulfide at the two above-mentioned temperatures, respectively. Comparison of MESTs to other alternative systems, such as engineered ecosystems and membrane bioreactor showed its substantial effectiveness in P removal as well as its readiness to be incorporated in the current septic systems. In conclusion, the P load that enters the subsequent percolation field would decrease and the overall role of septic systems in sanitation and environmental protection might increase by adoption of MESTs [28].

A low cost, modified septic tank was set up in a village in Egypt by Sabry [29]. The removal results in this study was very satisfying.

All chemical measurement methods may be subject to error. Therefore, the measured concentration in a sample may be different from the actual amount. Statistics is the science dealing with uncertainties of measurement and their estimation. Computer software is helpful in statistical analyses.

Statistical hypothesis and formulating the null hypothesis and its alternative hypothesis:

The results of the present study indicated that by providing a suitable room for bacteria's growth and moving hydraulic regime to the direction in which wastewater has more contact with microorganisms, we could make the maximum use of the tank's septic room and change it to a highly efficient reactor. In this study, the reactor with a baffle and dispersion number 0.67 had a better performance in removing the pollutants.

Generally, mechanisms that increase reactors' efficiency are as follows:

- Each reactor's container acts as a settling and balancing tank that has a significant impact on removal of suspended solids.
- There are seven baffles that cause suspended particles to strike the container during passage and settle gently.
- Presence of sludge bed in containers causes wastewater to catch organics while passing through this sludge because this bed contains anaerobic microorganisms. Then, a large percentage of sludge turns into methane gas and a small amount are converted to mass.
- This kind of flow hydraulic regime, especially in up flow, causes the suspended material to be eliminated from the sludge bed while passing. This act is repeated for four times in the reactor.

All abovementioned processes increase the efficiency of these reactors compared to the control septic. Therefore, they can be used as an independent refinement unit for individual residential suits, apartments, and also domestic wastewater of similar industries.

Previous researches have reported that septic tank systems with sticky and suspended growth could have appropriate efficiency in refinement of wastewater. However, these researches have not indicated the method of calculating the number of baffles and modifying the method of hydraulic regime.

This study investigated the efficiency of septic tanks in wastewater treatment through hydraulic regime modification by installing some baffles obtained based on laboratorial studies and using coagulants. The main result of this study was calculating the number of baffles needed for maximum efficiency, which can be used as an independent wastewater treatment unit.

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