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DEVELOPMENT OF TRICKLING FILTER FOR WASTEWATER TREATMENT

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Abstract

Trickling filter is a widely used medium to remove organic matter in wastewater treatment process. According to the United Nations World Water Development Report 2017 only 17% of wastewater is treated here in Bangladesh before its disposal to environment. A trickling filter is developed for wastewater treatment in this research. In an ordinary sewage treatment system firstly, sewage is collected in a septic tank. The sludge settles down at the bottom of the tank in the septic tank after a specific retention time. Then, the wastewater enters the soak pit. But very often the wastewater flow exceeds the capacity of the soakage well which gets exposed in the environment. The effluent from septic tank contains high level of biodegradable organics (BOD_5) and fecal coliform compared to accepted limits for disposing into environment according to ECR'97. For reducing the degree of contamination of natural waterbodies a trickling filter was developed to use in conjunction with septic tank system. For monitoring the treatment efficiency of the filter, three wastewater samples had been collected from different wastewater sources and filtered out through the filter. BOD_5, COD, TC, FC, TS, TDS, TSS, Fe, NO_3^- , PO_4^{3-} were measured in the laboratory for comparing the water quality of the wastewater before and after the filtration process through the developed filter. The efficiency of the filter for BOD_5 and COD removal were found to be 72% and 75%, respectively. The microorganisms (TC & FC) were also found to be removed significantly within the gravel bed layers. The average removal capacity of the filter for reducing total coliform and fecal coliform were found to be 54% and 72%, respectively. Solid particles were removed while passing through the shower head and some stuck in the void of filter media. About 75% of total suspended solids had been removed with this filter. The amount of iron, nitrate and phosphate in the soak pit water were found to be low. Even then 65% Fe, 25% NO_3^- and 22% PO_4^{3-} had been reduced with this filter. So, the developed filter could be a promising option for its use in conjunction with septic tank system to safeguard the environment.

Introduction

Safe water is the first and foremost need of our daily life. As the human population is increasing worldwide, water scarcity will be the most vulnerable problem of 21st century (D., 1996).According to The World Bank, approximately 56% of global population is living in urban environment (The World Bank, 2012). By the year 2015, there are 23 megacities with a population of over 10 million each, among them there are 18 countries which are existing in the list of developing nations (Jayashree Dhote, 2012). But

the water pollution is triggering this problem in an alarming rate (UNDESA, 2012). The most common sources of water pollution are wastewater and sewage, industrial waste, burning fossil fuels, sewer line leakage, use of fertilizers and pesticides etc (Shuokr Qarani Aziz, 2017). The wastewater and sewage are treated with chemicals and then released to water bodies (Chen, Ekama, Loosdrecht, & Brdjanovic, July 2020). Sewage contains pathogens that can cause fatal diseases. The sewage (Bahram Rezai, 2021) water also contains phosphorus and nitrogen released from human waste, food, certain soaps and detergents. So, the proper treatment of sewage before disposal to the environment is required.
Sewage treatment is the process of removing contaminants from wastewater and household sewage water (Ahmed S. Al-Chalabi, 2020). The preliminary step for a sewage treatment is storing the sewage in a basin and get the solids settles down to the bottom of the basin (Anusha K A, 2020). And the rest oil, greases and lighter solid particles may be discharged or subjected to secondary treatment (Shuokr Qarani Aziz, 2017). The wastewater is kept in a soakage well. As the population in the urban cities are increasing day by day and the sewerage system is not upgrading with this growth of population, so it is very obvious that the wastewater outflows the soakage well and directly release in the environment by a pipe. This untreated waste released in the environment unbalance the ecological system due to high amount of pathogen and microorganisms. That’s the reason for what treating this sewage water has become necessary. In recent studies it is evident that for treating sewage biological methods are being used widely (Bahram Rezai, 2021).There are some standard limits of water parameters for disposal of sewage water into environment (Mahmoud, Tawfik, & El-Gohary, March 2010). So, without using any chemical and by placing a tricking filter before the disposal of sewage to the environment may reduce the number of pathogens and other harmful parameters to an acceptable limit (Iffat Naz, 2014)and make the water safe for environmental ecosystem (Wenshan Guo, 2010). But for this high amount of sewage wastewater using chemical is not economically viable. It will also destroy the ecological system by hampering aquatic life (Sonali R. Dhokpande, 2014). So trickling filter is found safe and economical in this perspective.

This study aims to suggest a trickling filter for treatment of effluent from septic tank before dumping it into waterbodies. Trickling filter uses filtration, adsorption, and assimilation for removal of contaminants from wastewater. It provides aerobic treatment of wastewater. Wastewater is generally pumped from a recirculation tank or compartment, dispersed over a media bed, and allowed to drain back into the recirculation tank. Trickling filter has been used for over 100 years which is one of the oldest biological wastewater technologies. Many researchers introduced many types of trickling filter for wastewater treatment. Khantong Soontarapa and Nuntachai Srinapawong two researchers from Chulalongkorn University have researched on combined membrane-trickling filter system. The proposed system is a modified trickling filter with a chitosan membrane coated matrix bed at the bottom, followed up by a conventional matrix bed. The system is called a combined membrane–trickling filter system and it is one of the first biochemical operations developed for the treatment of domestic and industrial wastewaters (Khantong Soontarapa, 2019).There are various types of biological treatment to remove biological oxidizing agents.

OBJECTIVES

• Development of a Trickling Filter for wastewater treatment
• Monitoring the treatment efficiency of the filter for wastewater treatment collected from a soak pit.

Methodology

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SAMPLE COLLECTION

Sample was collected from the top surface of three different soak pit of Rokeya Hall, KUET. 5-liter wastewater sample was lifted from the soak pit and carried to the laboratory for testing.

Figure 1: A Typical Soak Pit

DEVELOPMENT OF A TRICKLING FILTER

As shown in the Figure 2, the proposed filter has three main parts. In the system there is an influent chamber. Along with this chamber there's a shower which works as a screen. Most of the solid particles are removed at this stage. Then only the liquid is allowed to the filter.

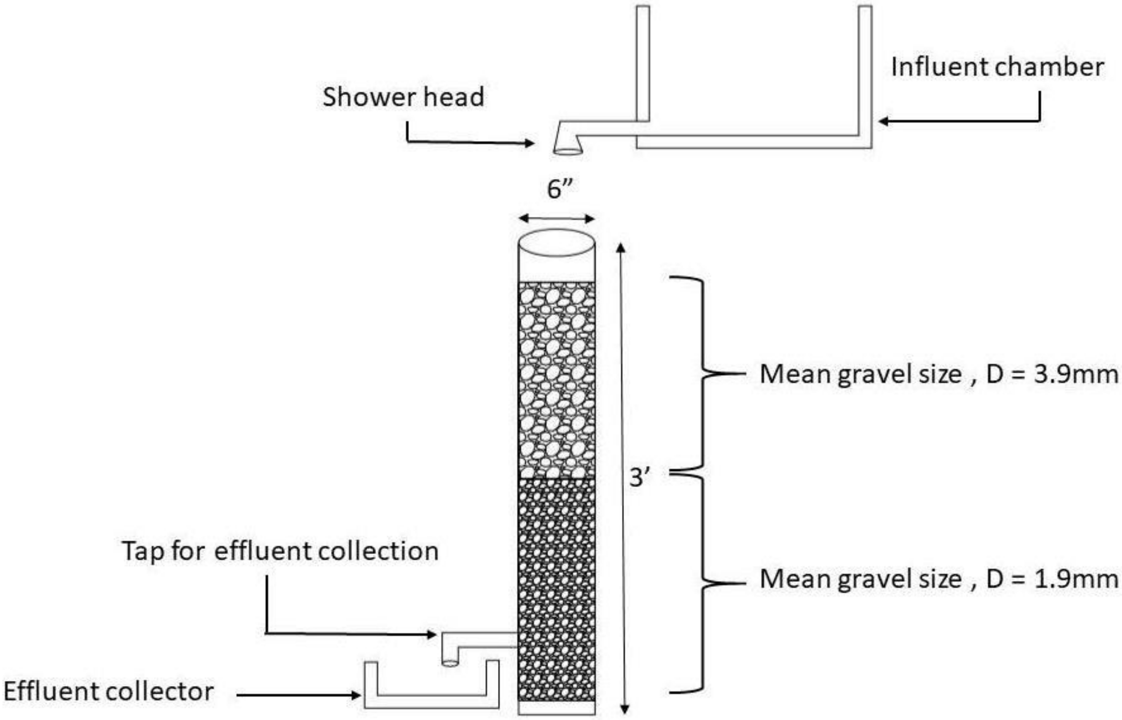

Figure 2: Schematic drawing of the trickling filters arrangement

The filter is made with a PVC pipe. The diameter of the pipe is 6 inch and the length of the pipe is 3 ft. The total length of the pipe was divided into two filter media and a clear space of 4 inch. First part was filled with a mean gravel size of 3.9mm and the 2nd part of the pipe was filled with the mean gravel size of

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1.9mm. The bottom of the pipe is sealed with a plastic cap. A tap is connected at 3-inch depth from the bottom of the filter for collecting the effluent from the filter. The filter is filled with small size gravel. Finally, there is a chamber for collecting the effluent.

Filter media

There is a clear space of 4 inch above the filter media. As described above, there are two layers of filter media in this filter. The length of the bottom layer is 1 ft 5 inch. This layer is filled with gravel with mean diameter 1.9 mm. These gravels are obtained by sieving relatively fine sand. For this layer, the particles passed through #8 sieve (2.38 mm) and retained on #16 sieve (1.19 mm) is used.

The upper length of the filter is 1 ft 3 inch. This layer is filled with gravel with mean diameter 3.9 mm. For this layer the particles passed through #4 sieve (4.75 mm) and retained on #8 sieve (2.38 mm) is used. This coarse sand allowed to pass the wastewater relatively faster than the lower layer. But the purification capacity of lower layer is better than the upper layer.

Figure 3: Materials for filter bed

Experimental Setup

As shown in the schematic diagram of trickling filters arrangement, a bucket was used as influent chamber attached with a shower head. The water was fallen into the pipe to flow through the filter media. As it flows through the filter media, the containments and solid particles were trapped into the media and reduce the BOD_5, COD, TC, FC, TS, TDS, TSS, and other parameters to the endurable limit to discharge to the environment. A tap was fixed below the pipe containing filter media by which the effluent was collected to the effluent collector. The collected effluent was tasted in the laboratory. The major parameters of wastewater were checked before and after the treatment process.

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Figure 4: Setup of Trickling Filter

Monitoring the treatment efficiency of the Filter

Different wastewater parameters of the effluent passing through the proposed trickling filter were tested in the laboratory by following proper guideline. BOD, COD, TS, TDS, TSS, Fe and other parameters were tested and compared with the standard for disposal of wastewater in the environment.

Result and discussion:

The suitability of treated water is being tested by analyzing different water quality parameters of treated and untreated water. BOD_5, COD, TC, FC, TS, TDS, TSS, TVS, VSS, Fe, NO_3^- and $PO_4^{3-}$of 3 waste water sample and treated water was measured and compared with the standard of the disposing water to the environment.

BOD Removal

A chart is given below for analyzing BOD removal and for checking the suitability for disposal of treated water into water bodies based on BOD_5. Standard biological oxygen demand in 5 days for safe environmental disposal is 40mg/L. Wastewater from soak pit contains high amount of BOD.

Table 1: BOD of the Samples

Sample No.	Before Treatment	After Treatment	Standards for Disposal	% of BOD Removal
Unit	**mg/L**	**mg/L**	**mg/L**	**%**
Sample-1	132	45	40	65
Sample-2	138	33	40	76
Sample-3	147	36	40	76

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After treatment of this wastewater from soak pit, BOD gets removed by a significant value. Using the proposed trickling filter, three (03) wastewater samples were treated. Among these three cases, minimum percentage of BOD_5 removal was 65%. But the BOD_5 of remaining two wastewater sample was reduced more than 75% and the wastewater became safe for proper disposal to the environment.

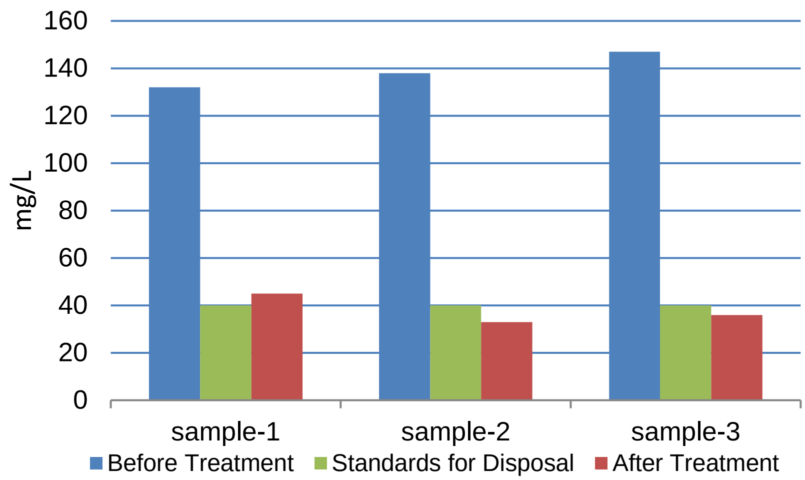

Figure 5: Variation of BOD for Samples before treatment and after treatment.

COD Removal

Chemical oxygen demand is another important parameter for wastewater and usually greater than the value of BOD. The amount of oxygen required by the chemical oxidizing agent to decompose the organic matter in acidic condition is defined as COD (Chemical Oxygen Demand). Collected samples were treated by the proposed trickling filter and found out very efficient to reduce the COD.

Table 2: COD of the Samples

Sample No.	Before Treatment	After Treatment	% of COD Removal
Unit	**mg/l**	**mg/l**	**%**
Sample-1	402	90	78
Sample-2	930	278	70
Sample-3	295	70	76

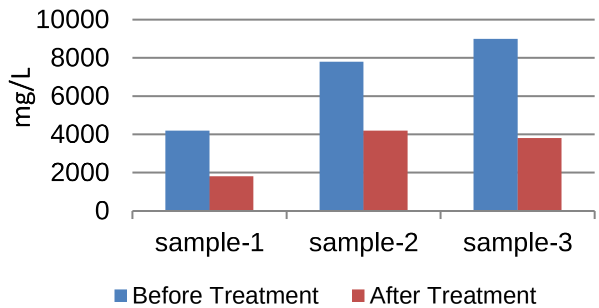

Figure 6: Variation of COD for Samples before treatment and after treatment

After treating the wastewater by proposed trickling filter, more than 70% COD has been removed. This significant change occurred due to filter media used in the trickling filter.

Total Coliform and Faecal Coliform Removal

Total coliform and faecal coliforms are important parameter for identifying the water quality. The less the number of total coliform present in water, the more the water is suitable for disposal into environment.

Faecal coliform comes from the faeces of warm-blooded animals. The presence of faecal coliform in the water shows that the water is pathogenically not safe to drink. This is a common parameter to detect the removal of pathogens.

Table 3: Total Coliform and faecal coliform in the Samples

	Total Coliform			**Faecal coliform**			
Sample No.	**Before Treatment**	**After Treatment**	**% of TC Removal**	**Before Treatment**	**After Treatment**	**Standards for Disposing**	**% of FC Removal**
Unit	**N/100ml**	**N/100ml**	**%**	**(N/100ml)**	**(N/100ml)**	**(N/100ml)**	**%**
Sample-1	4200	1800	57	3200	800	1000	75
Sample-2	7800	4200	46	2200	600	1000	73
Sample-3	9000	3800	58	2400	800	1000	67

Normally the water having faecal coliform more than 1000/100ml should not be disposed in environment. Faecal coliform is removed by adsorption process. Faecal coliforms are adsorbed in the surface of sand. The finer the size of the sand, the greater the surface area which causes more adsorption. As the wastewater percolates slowly through the filter media, coliform stick to grain surfaces or get caught in crevices or voids on grains or in spaces between grains. Most of the coliform is adsorbed by the sand gravel. Graph shows that TC have been decreased about 57%, 46% and 58% for sample-1, 2 and 3 respectively. A chart is given below for analyzing total coliform and faecal coliform removal and for checking the suitability for disposing the treated water into water bodies based on total coliform and faecal coliform.

Total Solid, Total Dissolved Solid, Total Suspended Solid Removal

Total solid available in wastewater can be broadly divided into two parts. Relatively bigger solid particles which is suspended in the wastewater can be defined as total suspended solids and the remaining part which is dissolved in the wastewater can be named as total dissolved solid. The proposed trickling filter have a layer of filter media containing sand of different sizes. As the wastewater percolates slowly through the filter media chemical process takes place in the filter. Particles stick to grain surface or get caught in voids on grains or in spaces between grains. Some of the negatively charged grain surfaces can attract positively charged waste particles and bond with them through adsorption. The solid particles of comparatively large size are removed while passing through the shower head.

Table 4: Total Solid, Total Dissolved Solid, Total Suspended Solid in the Samples

	Total Solid			Total Dissolved Solid			Total Suspended Solid			
Sample No.	Before Treatment	After Treatment	% of TS Removal	Before Treatment	After Treatment	% of TDS Removal	Before Treatment	After Treatment	Standard for Disposal	% of TSS Removal
Unit	mg/L	mg/L	%	mg/L	mg/L	%	mg/L	mg/L	mg/L	%
Sample-1	3705	3165	15	3280	3148	4	425	70	100	96
Sample-2	3960	3400	14	3420	3360	2	540	40	100	93
Sample-3	3100	2820	9	2990	2750	8	110	35	100	68

Chemical contaminant Removal

The amount of iron, nitrate and phosphate available in wastewater before and after treatment by trickling filter was determined by following proper guideline. It was found that proposed trickling filter was more efficient to remove iron from the wastewater. About 65% of iron was removed by the treatment process. But average nitrate and phosphate removal was less than 30%. Even than the iron, nitrate and phosphate content is acceptable with respect to the standard for disposal in the environment.

Table 5: Total Solid, Total Dissolved Solid, Total Suspended Solid in the Samples

Contaminant	Sample	Before Treatment (mg/L)	After Treatment (mg/L)	Standard for Disposal (mg/L)	% of Removal
IronI Iron	Sample-1	0.89	0.32	-	64
	Sample-2	1.1	0.38	-	65
	Sample-3	0.74	0.26	-	65
Nitrate	Sample-1	2.9	2.0	250	31
	Sample-2	1.8	1.5	250	17
	Sample-3	2.3	1.7	250	26
Phosphate	Sample-1	2.8	1.92	35	31
	Sample-2	2.48	2.06	35	17
	Sample-3	2.69	2.22	35	17

Conclusions

The first objective of this study was to develop a trickling filter for wastewater treatment. A trickling filter was developed with a PVC pipe of diameter 3 inch and the length of 3ft. At the lower half of the filter gravel of mean size 1.9mm is used as filter media and the upper half gravel of mean size 3.9mm is used as filter media. A bucket connected with a shower head is used as influent chamber. At the bottom of the filter a tap is connected for collecting effluent. For monitoring the efficiency of the proposed filter average efficiency for BOD, COD, TC, FC, TS, TDS, Fe, NO_3^- and PO_4^{3-} is shown below.

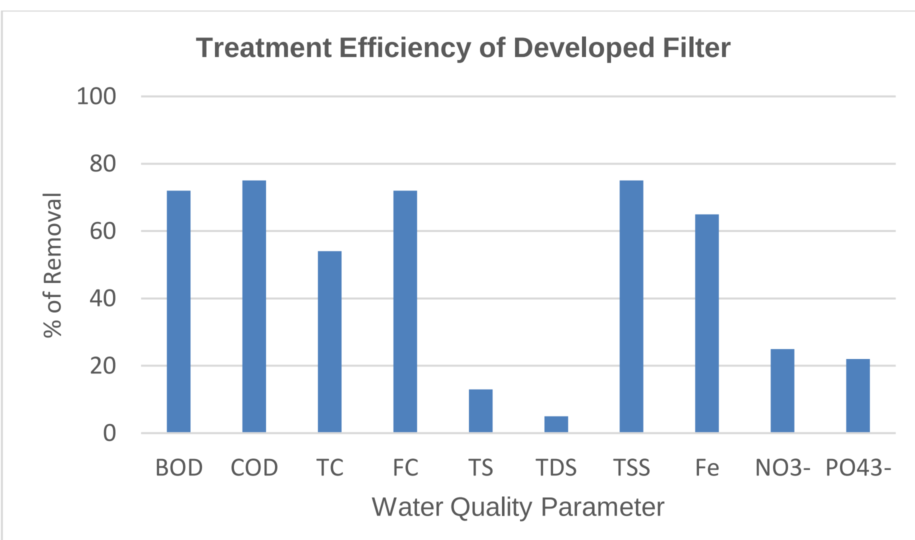

Figure 7: Average treatment efficiency of developed filter

It has been found that the vital parameters of wastewater like BOD, COD, TC, FC, and TSS etc was removed very efficiently by the developed trickling filter and made the effluent suitable for environmental disposal. For total dissolved solid removal the developed filter wasn't found as a good solution because the filter wasn't capable of mitigating the dissolved matters available in wastewater.

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