COMPARATIVE STUDY OF FAECAL SLUDGE TREATMENT METHODS EMPLOYED IN THREE MUNICIPALITIES OF BANGLADESH

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ABSTRACT

Onsite sanitation and disposal of human wastes are largely unregulated in Bangladesh. According to a field survey, the annual faecal sludge generation in Khulna, Jhenaidah and Kushtia municipalities had been found to be 710000 m3, 58705 m3, and 104581 m3, respectively. In order to reform the way that human waste is being disposed of safely in these municipalities, faecal sludge treatment plants (FSTPs) have been constructed and already started their operations. The main aim of this study is to identify and compare the methods adopted in these treatment systems. In Khulna & Jhenaidah FSTPs, constructed wetland systems comprising vertical flow followed by subsurface horizontal flow treatment process have been adopted. Moreover, unplanted drying beds are used to collect dry sludge for bio-energy. Nevertheless, Kushtia municipality has developed the FSTP involving sludge settling-drying bed with co-composting facilities and coco-peat filter. Field and laboratory investigation have been carried out for determining the treatment efficiency of these FSTPs. Infrastructural failure has been detected in wetland walls due to settlement of soil and infestation of foxes in Jhenaidah FSTP. While, plantation damages in vegetation system caused by burrowing animals is found in Khulna FSTP. In all three FSTPs, BOD_5 and Total Solids removal efficiency were over 95% and 97%, respectively and fecal coliform never exceeded the allowable limit 1000 N/100ml in final effluent. Kushtia FSTP is earning profit by selling co-compost and now planning to develop a local compost market.

Keywords: Faecal sludge treatment, Constructed wetlands, Drying beds, Coco-peat filter.

1. INTRODUCTION

Sanitation is a vital piece of health and development around the world. The lack of safe sanitation access has profound implications worldwide. The consequences of almost 2.6 billion people in the world using unsafe toilets or practicing open defecation are devastating to their health and to their financial and personal well-being (Chowdhary & Kone, 2012). It also contributes to the fact that 0.7 billion people worldwide do not have access to safe drinking water, as precious water is polluted with the people's own excreta (Harada et al., 2016). In response to the lack of access to sanitation, the United Nations defined the target of Goal 17 of the Sustainable Development Goals (i.e., SDGs) to halve the proportion of the population without access to improved sanitation facilities during the period from 2015 to 2030 (United Nations, 2019). Worldwide there is an increasing interest and awareness of faecal sludge management (FSM) issues, particularly in Africa and Asia (Oxfam, 2016; WRC, 2015). Bangladesh is a striking example of the rapid progress in access to sanitation where open defecation has been reduced from 29% in 2000 to 1% in 2017 (UNICEF & WHO, 2019). However, the inability to sustain use of existing toilets and unsafe disposal of faecal sludge pose the next challenge in improving health and economic situation of urban populations. The national regulatory framework demands the City Corporations/Municipalities to take the responsibility of FSM but it is not being done due to lack of proper understanding of the subject and lack of resources. As a result, accumulated sludge overflows into nearby drain and causes dangerous impact on public and environment health. The water and faecal born disease burden are higher in urban slums than rural areas mostly due to unhealthy and unhygienic conditions from poor sanitation (Stevens et al., 2015).

Faecal sludge (FS) needs to be safely contained onsite, and then the accumulated faecal sludge needs to be safely emptied, transported to a treatment plant, treated, and used for resource recovery or disposed of safely (Harada et al., 2016). There are plenty of technologies available to treat FS; however, the same level of operational information is not available to all of them based on their different levels of implementation. FS treatment technologies that are covered in an operational level of detail are settling tanks, unplanted drying beds, planted drying beds, co-treatment with wastewater, co-composting of FS together with municipal solid waste; co-treatment of FS in waste stabilisation ponds; and deep row entrenchment (Ronteltap et al., 2014). Onsite sanitation and disposal of human wastes are largely unregulated in Bangladesh. In response to this situation, many innovations have been started to contribute to faecal sludge management properly. According to a field survey, the faecal sludge volume generated in Khulna, Jhenaidah and Kushtia municipalities were found to be 710,000 m^3; 58,705 m^3; and 104,581 m^3 per year, respectively (SNV, 2018). In this context, various methodologies have been employed for the establishment of faecal sludge treatment plants (FSTPs) in these three municipalities. Constructed wetland systems along with drying beds have been adopted in Khulna & Jhenaidah FSTPs while sludge settling-drying bed with coco-peat filter technique is used in Kushtia FSTP. The goal of this study is to deliberate in details the different methods implemented in these FSTPs and compare their performance with regards to treated effluent quality as well as operation and maintenance (O & M) aspect.

2. METHODOLOGY

2.1 Study area

The location of study FSTPs are in Khulna, Kushtia, and Jhenaidah. Khulna is the third largest industrial city of Bangladesh with a density of 32,859 persons per square km (KCC, 2019). Khulna FSTP is located at Rajbandh-2 which is 4 kilometers distance from the "Zero Point" of KCC. The plant covers an area of 4500 m^2 and adopts constructed wetlands system. Kushtia Municipality is a Class 'A' Municipality with 42.79 sq.km area and 3, 75, 149 population. Kushtia FSTP is located at Baradi and adopts faecal sludge settling-drying beds system. Jhenaidah Municipality is a Class 'A' Municipality with nine wards and an area of 32.4 square km. The population of Jhenaidah is 157,822 with a density of 3,987 per square km (FSM Survey, 2014). Jhenaidah FSTP is located at Nagarbathan and adopts constructed wetlands system with drying beds. The location of the study area is presented in Khulna division map.

Figure 1: Khulna Division Map

2.2 Case scenario

2.2.1 Scenario 1- Khulna FSTP:

For faecal sludge treatment, there are constructed wetlands and drying bed system Faecal Sludge Treatment Plant (FSTP) at Khulna which has been designed to treat up to 15% of total generated faecal sludge (SNV, 2018). Khulna FSTP built in 2017 with 6 units CW (constructed wetlands) as pre-treatment, 2 units of percolate CW as post-treatment and 6 units drying beds. The CW for FS is designed for 6 units of VF (vertical flow) type that are planted with emergent macrophytes. It has capacity to receive 30 m^3 (average) FS per day per bed, which is collected from septic tank and peat latrine. At first raw FS is emptied from the tanker into the screening chamber to remove any grit and debris. FS from the chamber enters into the respective constructed wetland. Leachate from the constructed wetland then flows under gravity to the planted filter bed for further treatment. Then raw FS from CW is discharged into the unplanted sludge drying beds. Leachate from the unplanted drying bed is then flows into planted filter bed for further treatment. The bed is filled to its full capacity and is kept for drying for 2-3 weeks. After the sludge is dried, it is collected for composting or briquette production. Further treated leachate from UPDB and CW in the planted filter bed post treatment is discharged into the canal in Khulna FSTP. Figure 2 illustrates a flow diagram of treatment mechanism of constructed wetland process in FSTP.

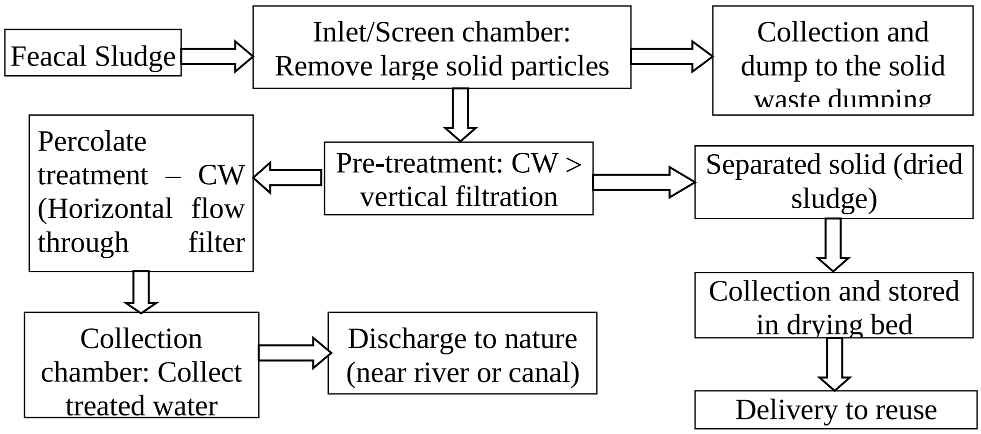

Figure 2: Flow chart of FS constructed wetland plant

2.2.2 Scenario 2- Jhenaidah FSTP:

Another planted wetland system for fecal sludge treatment was built at Jhenaidah municipality in 2012 but never been operated. Furthermore, this FSTP was renovated with 5 units CW (constructed wetlands) and 3 units drying beds in 2016 which has got the capacity to treat up to 18% of total generated faecal sludge (SNV, 2018). CW enables to receive 36 m^3 FS per day in average. Solid particles are removed by filtration and gravitational settlement in planted CW. Percolate from CW treating FS is further treated by unplanted CW. Finally treated effluent from UPDB and CW in the planted filter bed post treatment is discharged into a stream of Nabhaganga river in Jhenaidah FSTP. The tratment technology used for Jhenaidah FSTP has been mentioned in Figure 2.

2.2.3 Scenario 3- Kushtia FSTP:

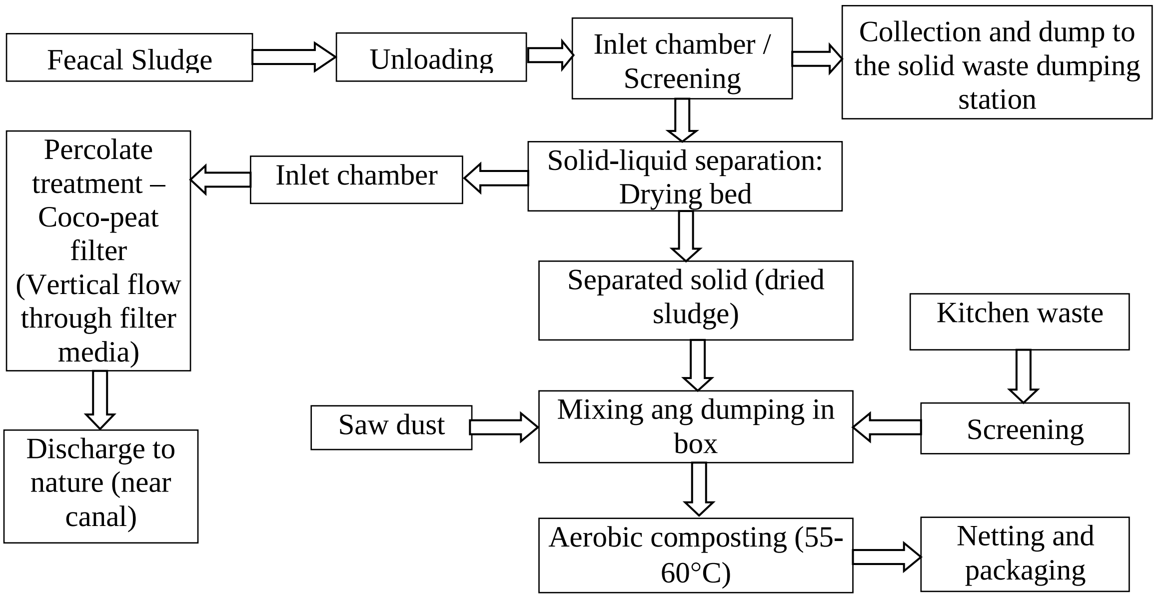

Figure 3: Flow chart for FS and Kitchen waste co-composting process

Kushtia municipality started managing faecal sludge though co-composting technology since 2012. FSTP have two drying bed and capacity of the two bed is about 18 m3 (9*2 m3) per day in 2 drying bed as input and 9-ton compost as output per month. Faecal sludge collected by vacutugs from municipality area is taken to FSTP for its proper treatment. Faecal sludge which is dumped to the drying beds is used for dewatering. After dewatering process, the percolate is transferred into the connected percolate tank. The percolate is pumped into the cocoa peat filtration unit for further treatment. On the other hand, municipality also collects kitchen waste from individual household and dumping at FSTP site. After screening of kitchen waste, it is dumping with semi dry sludge and other materials for co-composting in a box. Ratio of compost production materials is 40% faecal sludge, 55% kitchen waste and 5% saw-dust of each dumping box. It was needed to take 40-45 days for decomposition of biodegradable organic matters and in this process different layer had been overturned @ 10-15 days interval for ensuring better aeration. Temperature around 55-60°C had been maintained for the removal of pathogen and finally the end product was collected. Figure 3 shows the flow chart of scenario-3.

2.3 Sample collection and laboratory tests:

Inlet and outlet samples were collected from each of three municipalities FSTPs. After collection, samples were transported to laboratory following standard methods for testing different water quality parameters. Detailed laboratory tests were done to determine the effectiveness of the treatment unit. The performances of the treatment unit were analysed with respect to various water quality parameters such as BOD_5, NO_3, TS, TSS TC and FC following standard methods as shown in table 1.

Table 1: List of Water Quality Parameters for Laboratory Analysis

Serial No.	Water Quality Parameters	Standard Methods (SM) of Analysis
1	Biochemical Oxygen Demand (BOD_5)	SM 5210 B
2	Total Solids (TS)	SM 2540 B
3	Total Suspended Solids (TSS)	SM 2540 D
4	Nitrate (NO_3)	SM 4500 NO_3 E
5	Total Coliform (TC)	SM 9222 B
6	Fecal Coliform (FC)	SM 9222 D

3. RESULTS AND DISCUSSION

The laboratory test results reveal the present condition of faecal sludge treatment plant and its level of treatment efficiency. Table 2 represents the quality of inlet and outlet samples which is collected from Khulna, Jhenaidah and Kushtia FSTPs. The raw faecal sludge (influent) was very high in organic load, nutrients and pathogens. One of the objectives of this study is to check the removal efficiency of the harmful contaminants from wastewater before discharging it to nearby watercourses. To check this, the allowed standard value for disposal into inland surface water bodies of these water quality parameters are also listed in Table 2 for comparison (ECR, 1997) and it shows that all important parameters are within the ECR'97 limits. Figure 4 shows the treatment efficiency of the three FSTPs to evaluate the effectiveness of the adopted methodologies. Biochemical Oxygen Demand (BOD_5) is employed to determine the removal of biodegradable organic substances due to microbial decomposition. The standard value of BOD_5 for disposal to inland water bodies is 40 mg/L. From figure 4, it is clear that after the treatment of raw faecal sludge the removal efficiency of BOD_5 in all cases was found to be over 95%. Further from table 2, it is clear that total solids and total suspended solids in treated water had been decreased remarkably after treatment in each case. Total solids concentrations were found to be approximately 97% reduced after final percolate treatment in three FSTPs. Nevertheless, total suspended solids in Kushtia FSTP was found to be 90 mg/L which also satisfied the standard limit 100 mg/L (ECR, 1997) for disposal into inland water bodies but it is very close to standard limit.

Table 2: Results of influent and effluent water quality from FSTPs

Parameters	Units	Khulna FSTP		Jhenaidah FSTP		Kushtia FSTP		Standard limit (*ECR 1997)
		Inlet/ Raw sludge	Outlet/ Final treated	Inlet/ Raw sludge	Outlet/ Final treated	Inlet/ Raw sludge	Outlet/ Final treated	
BOD_5	mg/L	615	22	895	32.5	844	37.5	40 mg/L
Total Solids	mg/L	72870	484	47260	410	48420	1140	---
Total suspended solids	mg/L	29010	40	18904	50	19368	90	100 mg/L
NO_3	mg/L	94	2.96	176	1.8	163	22	250 mg/L
Total coliform	N/100 mL	180000	460	174000	760	152000	430	---
Fecal coliform	N/100 mL	120000	140	121000	240	105000	210	1000N/ 100mL

* ECR 1997: The Environmental Conservation Rules (1997) for Wastewater Disposal into Inland Surface Water Bodies

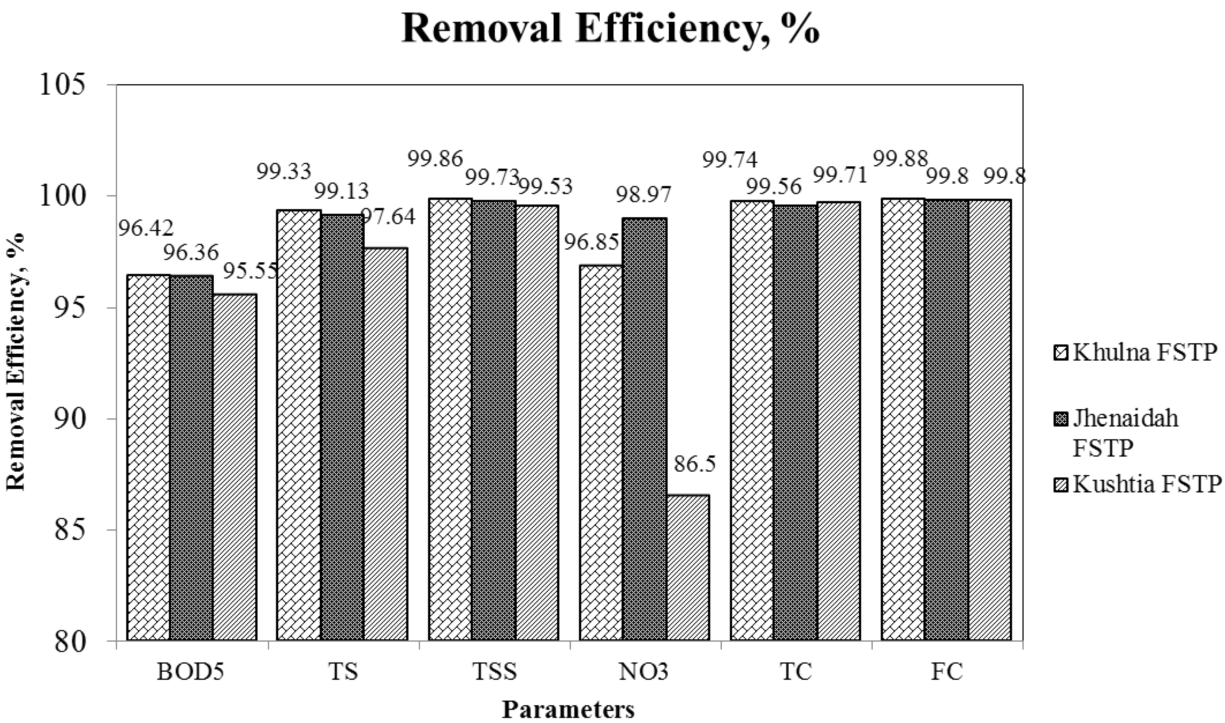

Figure 4: Treatment efficiency of three FSTP

Table 3: Operation and maintenance assessment of three FSTPs

Operation and Maintenance	Action/Notice		
	Khulna FSTP	**Jhenaidah FSTP**	**Kushtia FSTP**
1) Screening/ unload			
Racking of garbage	Yes (Irregularly used). Bar screening is irregularly used to separates garbage from influent. However, sometimes screening is not used because of clogging due to highly concentrated faecal sludge and other pollutants.		Yes Locally made plastic container screen is used to separate garbage from influent
Collection of garbage	Yes. Garbage entrapped in screening are collected. If garbage is not collected, it clogs the filter media.		
Cleaning	Yes. Collected garbage is cleaned before use.		
2) Storage and Mixing			
Mixing condition	No. Mixing is not done at FSTP	No. Mixing is not done at FSTP	Yes Dry sludge is mixed with kitchen waste.
Pumping condition	Yes. Influent discharges to the CWs by pumping.	Yes. Influent discharges to the CWs by pumping.	Yes. Influent faecal sludge is pumped to settling tank.
3) Feeding for CW	Full capacity is not utilized due to receiving small volume of faecal sludge.		X
4) Feeding for Unplanted CW/DB	Depending on concentration of influent	Unplanted CW is using as primary percolator due to CW infrastructural failure	Exceed the feeding capacity in drying bed
5) Plant monitoring	Canna and Heliconia have plenty growth.	No plantation right now because of CW infrastructural failure and clogging of filter media	X
6) Retaining of percolate water	Meet ECR'97 standards	Clogging occurs in CW	Meet ECR'97 standards
7) Plant harvesting	Cutting and taking the debris out	Replantation is required	X
8) Nuisance of animal	Burrowing animals have been identified in cutting down HDPE sheet.	Foxes are making hole in CW walls	No infestation of animals
9) Sludge harvesting			
Drying Bed	Yes For briquette production	Yes Collecting for reuse	Yes For co-composting

For nitrate (NO_3), after final treatment, the removal efficiency was found to be 96%, 86% and 98% respectively, in Khulna, Kushtia and Jhenaidah FSTPs. The acceptable limit for nitrate disposal is 250 mg/L (ECR'97). Although, the treated effluent for all three FSTPs had far less nitrate than the standard value but Coco-peat filter process in Kushtia FSTP showed lower removal percentage with 22mg/L nitrate in final effluent. Furthermore, all three FSTPs had remarkable performance for the removal of microorganisms (TC & FC). According to Environmental Conservation Rules, 1997, the number of coliform counts must be within 1000 per 100 mL of disposing water and FSTPs final treated samples always meet that the standard limit. Treated final effluent from all three FSTPs clearly denoted that the water quality parameters have been improved significantly. The removal efficiency in both constructed wetland methods and coco-peat filter was over 90%.

A field survey was done to illustrate and compare the operation and maintenance of the treatment technology used in three FSTPs. Based on field observation; it seems that clogging is the most common problem due to irregular/avoiding screening operation before loading into constructed wetlands. Therefore, the influent does not well settle with primary treatment before flowing into the wetlands. Infrastructural failure and soil settlement took place frequently within 2-3 years. That's why proper maintenance deemed very important for fruitfully carrying out the treatment methods. Composting is the most common resource recovery method from faecal sludge as an organic fertilizer and soil conditioner; as the organic matter increases the water retaining capacity of soil and contains essential plant nutrients (Cheng et al. 2017). There is other resource recovery scheme like briquette production in Khulna FSTP which needs to explore proper market channel.

The initial operations of all three FSTPs have to be confirmed by unobstructed flow of sludge which is free of grit or garbage. In Khulna and Jhenaidah FSTPs, bar screening is irregularly used because of clogging due to highly concentrated faecal sludge and other pollutants. In Jhenaidah FSTP, unplanted constructed wetland is used for primary treatment of raw sludge and replantation is required in constructed wetlands due to infrastructural failure. In present condition, the estimated volume of faecal sludge is not coming to Khulna and Jhenaidah FSTPs that's why all beds cannot be used equally. On the contrary, in Kushtia FSTP, the capacity of raw sludge treatment is exceeding and the rest of the faecal sludge is being released into a pond near the plant. Moreover, maintenances of all operations in FSTPs are very important to hold on which would confirm the long-term sustainability.

4. CONCLUSIONS

Two different cases of faecal sludge treatment plants (FSTPs): Constructed Wetlands (CWs) and Drying Beds systems, in three municipalities have been studied from different viewpoints. Infrastructure failures and settlement of earthen embankment had been visible in Khulna and Jhenaidah FSTPs within 2-3 years. Moreover, Khulna FSTP was designed to treat up to 15% of total generated faecal sludge while Jhenaidah FSTP had the capacity to treat up to 18% of total generated faecal sludge; but so far, only a small portion of its capacity is in use. Treatment efficiency of these existing treatment plants are good and still providing their services. From laboratory experiment it is also seen that; the treated effluent was within the standard limit with satisfactory level for releasing into inland water body. In all three FSTPs, BOD_5 removal efficiency was varied in the range of 95%-97%. Furthermore, total suspended solids in final effluents were found to be 40mg/L, 50mg/L and 90mg/L respectively, in Khulna, Jhenaidah and Kushtia FSTPs which fall within the acceptable limit 100mg/L as per ECR'97. Kushtia FSTP showed lower removal percentage with 22mg/L nitrate in final effluent. Microbial (TC & FC) removal efficiency in the treated effluent was found to be approximately 99% in all three FSTPs. Fecal coliform in final effluent never exceeded the acceptable limit 1000 N/100ml. From the entire study, it seems that the adopted methodologies in all three FSTPs achieved the safe use of final effluent and productive to support human well-being and broader sustainability of the environment.

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