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Research Article

The Status Quo of Fecal Sludge Treatment Plant at Khulna and Its Future Prospective About Biomass Energy (Briquette)

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Abstract

As many developing countries are moving towards increased sanitation coverage, Bangladesh has been striding successfully towards full sanitation coverage with the proper management of fecal sludge city-wide. Following the situation, Khulna City Corporation built a Fecal Sludge Treatment Plant (FSTP) with six units of CW (constructed wetlands) and six units of drying beds in 2017. The main objective of this study is to discuss the current situation of Khulna FSTP based on treatment efficiency and its future perspective on biomass energy (briquette). In Khulna FSTP, the collected fecal sludge from septic tanks and pits is treated, and finally, its effluent is discharged into the environment, satisfying the disposal standards. The removal efficiency of final effluent for Biochemical Oxygen Demands (BOD_5) and Total Solids was found to vary between 97.8% - 97% and 98% - 93% in the previous year to the present, respectively. Total Suspended Solis and Fecal Coliform never exceeded the allowable limit 100gm/L and 1000 N/100ml in final effluent. Furthermore, dried sludge is used as handmade processing biomass energy (briquette) without further treatment, which has some procedural problems such as loose compaction and pathogenic contamination.

1. Introduction

As many developing countries are moving towards increased sanitation coverage, the safe handling of sludge has emerged as an important and challenging issue of concern. Sanitation is one of the most important aspects of community well-being because it protects human health, extends life spans, and is documented to benefit the economy. Yet, globally, 946 million people still open defecate (9 out of 10 live in rural areas), 2.4 billion people lack access to basic sanitation (7 out of 10 in rural areas), 663 million lack access to basic water sources, and diarrhea is the second leading cause of death in children under five much of which is preventable by clean water and sanitation [12]. Therefore, the 2015 United Nations (UN) Sustainable Development Goal (SDG) 6 for 2030 aims to achieve equitable access to safely managed water and adequate sanitation for all and end open defecation [10]. FSM (fecal sludge management) is currently rapidly developing and gaining acknowledgment. FSM is important because although over a billion people in urban and peri-urban areas of Africa, Asia, and Latin America are served by onsite sanitation technologies, fecal sludge is poorly managed. In many cities, onsite technologies have much wider coverage than sewer systems. For example, in Sub-Saharan Africa, 65-100% of sanitation access in urban areas is provided through onsite technology [8].

Bangladesh strides towards full sanitation coverage with the proper management of fecal sludge citywide. According to the Bangladesh Bureau of Statistics (BBS) 2017 publication, the percentage of improved sanitation facilities is 75%, whereas open defecation is 2.7% and other toilet users are 22.3%, as reported by Bangladesh Sample Vital Registration System [13]. In most cases, there is hardly any effective or safe collection, transportation, treatment, or disposal of sludge. Much of it ends up in water bodies or polluting nearby land. On the other hand, the Bangladesh Joint Monitoring Programme (JMP) Report 2019 of UNICEF claims that open defecation is now down to 1% of the population [11].

Fecal sludge treatment, its safe disposal, and the reuse of sludge materials are very important components of FSM to ensure a healthier life for every citizen. FSM coverage is currently low and problematic, causing environmental and public health [9]. On the other hand, developing sustainable energy systems is one of the top priorities for global development and the driving force for major political and societal reforms in the 21st century. Biomass briquetting presents an energy-efficient solution by managing dry fecal sludge in this context. Biomass briquettes can be an excellent energy source for households and commercial sites and are ideal for replacing continuously depleting fossil fuels [3-5]. Khulna Division is in southwestern Bangladesh, leading the FSM program through various project activities [4]. In Khulna, basic trenching ground and household sanitation are predominantly onsite technologies, with 61.7% septic tanks and 38.3% pits requiring regular emptying [1-6].

Table 1. Fecal sludge generation in Khulna City [4-7]

Item of Information	**Khulna City Corporation (KCC)**
Year of Establishment	6 August, 1990 (City)
Area, km^2	45.65
Population	15,00,689
Population Density per km^2	67,994
No of wards	31
HH with soak-well in septic tank	7.4
Fecal Sludge Volume (Actual Field Survey) m^3/yr	7,10,000
Fecal Sludge Volume (Theoretical) m^3/yr	7,21,213
Number of treatment plant	1

Like other local contexts, in the city of Khulna, the disposal of fecal sludge is unusual as most are directly connected to surface water drains or water bodies; consequently, accumulated sludge overflows into nearby drains and low-lying lands, which causes dangerous impacts on public health and environment. Mostly, sweepers have been employed to provide manual emptying around 81% of total desludging services, and recently mechanical emptying has been brought together using vacutugs. Besides, City Corporation Community Development Committee (CDC) has three smaller ($1m^3$) vacutugs that are popular in services. Table 1 shows that the annual fecal sludge generation was estimated to be around 7,10,000 m^3 [1].

Following the situation, Khulna City Corporation built a Fecal Sludge Treatment Plant (FSTP) with six units of CW (constructed wetlands) and six drying beds in 2017 at Rajbandh. In Khulna FSTP, the collected fecal sludge from septic tanks and pits is treated, and finally, its effluent is discharged into the environment, satisfying the disposal standards. In the present study, a field survey and laboratory investigation were done to know the existing situation of Khulna FSTP, and the data from another year was collected from another survey report. Furthermore, dried sludge is used as handmade processing biomass energy (briquette) without further treatment, which has procedural problems such as loose compaction and pathogenic contamination. The main aim of this study is to discuss the current situation of Khulna FSTP based on treatment efficiency and its future perspective on biomass energy (briquette).

2. Materials and Methods

The FSTP of Khulna is located at 22°47’39” latitude and 89°29’32” longitude outside Khulna municipality**,** 10 kilometers away from the city center. It is located at Rajbandh-2, which is 4 kilometers distance from the “Zero Point” of KCC (Figure 1). The plant covers an area of 4500 m^2 and adopts a constructed wetlands system and drying bed (Figure 2). Figure 3 shows the present view for Khulna FSTP. Khulna Fecal Sludge Treatment Plant (FSTP) has been designed to treat up to 15% of total fecal sludge [7].

Figure 1. Location of Khulna fecal sludge treatment plant (FSTP) at Rajbandh

The constructed wetland at Khulna FSTP is identical to natural systems. The CW for FS is designed for six VF (vertical flow) type units that can receive 30 m^3 (average) FS per day per bed. Solid particles are removed by filtration and gravitational settlement in planted CW. Leachate from the constructed wetland flows under gravity to the planted filter bed for further treatment.

Raw FS from CW is discharged into the unplanted sludge drying beds. After the sludge is dried, it is collected for briquette production. Briquette is ready with handmade processing without further treatment, containing rice husk, cow dung, and water. Further treated leachate from UPDB and CW in the planted filter bed post-treatment is discharged into the canal in Khulna FSTP.

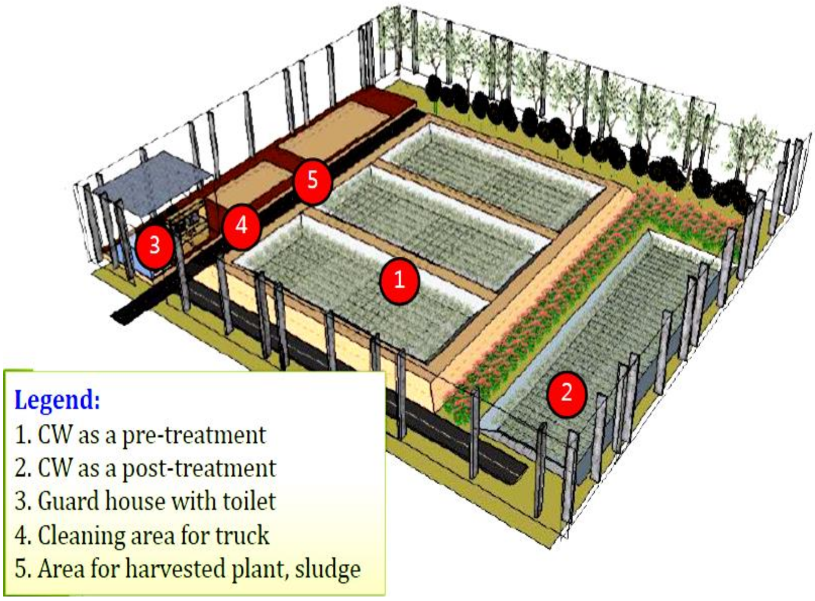

Figure 2. 3D-View of Khulna FSTP at Rajbandh

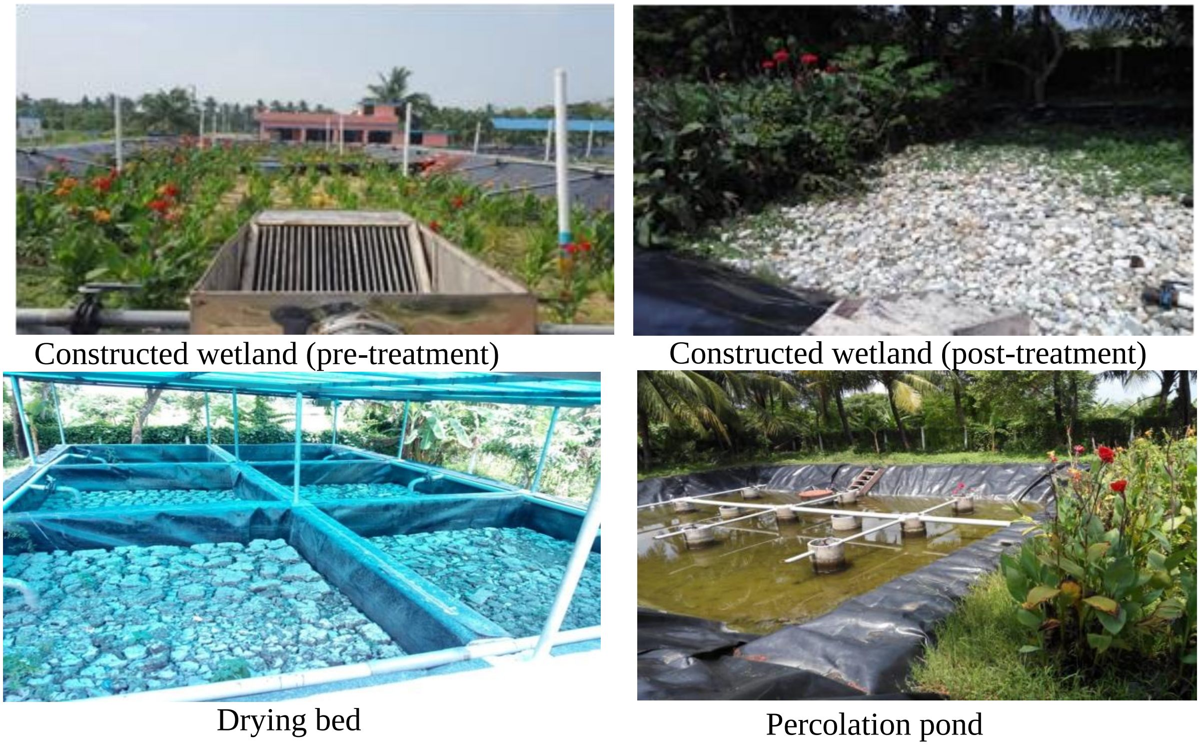

Figure 3. Present view of Khulna Fecal Sludge Treatment Plant

The generated wastewater must be managed appropriately for a clean, hygienic, and environment-friendly city. Inlet and outlet samples were collected from Khulna FSTP to justify the current situation—clean plastic water bottles collected percolate effluent from the receiving tank after the primary and final treatment. Samples were transported to the 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 analyzed concerning various water quality parameters such as BOD_5, NO_3, PO_4, TS, TSS TC, and FC following standard methods, as shown in Table 2.

Table 2. List of Water Quality Parameters for Laboratory Analysis

#	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	Phosphate (PO_4)	SM 4500-P E
6	Total Coliform (TC)	SM 9222 B
7	Fecal Coliform (FC)	SM 9222 D

*Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF)

3. Results and Discussions

The operational chain of fecal sludge management in Khulna FSTP is represented in Figure 4. Khulna City Corporation has one vacutug of 4 m3, and the Community Development Committee has three vacutugs of 1 m3, transporting fecal sludge to a treatment plant. The average demand per month in Khulna per vacutug is 5. The Vaccutug is a simple portable machine that extracts human excreta from septic tanks and pit latrines for safe transport to a sewage disposal site where wastes can be discharged safely.

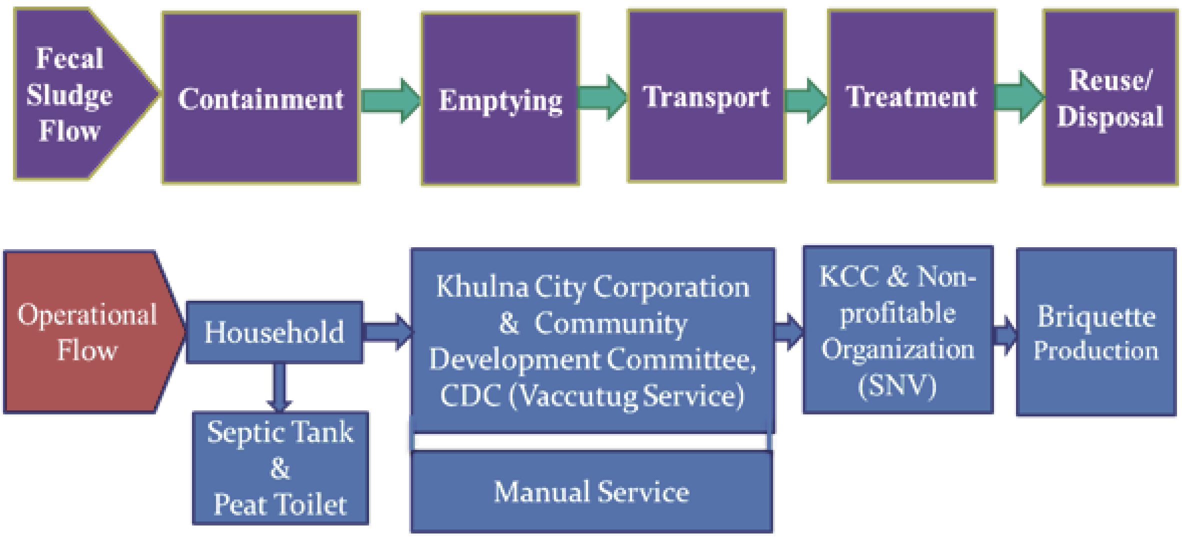

Figure 4. Operational models for Khulna FSTP

Constructed wetland systems and drying beds have been adopted in Khulna FSTP for treatment purposes. The laboratory test results reveal the present condition of the fecal sludge treatment plant and its level of treatment efficiency. Table 2 represents the quality of inlet and outlet samples collected from Khulna FSTP. It also reveals the present condition of treatment efficiency by comparing previous laboratory data analysis in 2017, the starting level of Khulna FSTP. The raw fecal sludge (influent) was very high in organic load, nutrients, and pathogens. To check the treatment condition, the allowed standard value for disposal into inland surface water bodies of these water quality parameters are also listed in Table 3 for comparison (ECR, 1997), and it shows that all important parameters are within the ECR‟97 limits. Figure 5 shows the treatment efficiency of Khulna FSTP to evaluate the effectiveness of the adopted treatment methodology. Biochemical Oxygen Demand (BOD5) was 42 mg/L in 2022, slightly exceeding the allowable standard limit. It would occur due to operation and maintenance problems such as over-loading, clogging infiltration, and infrastructure failure. Figure 5 also shows that after the treatment of raw fecal sludge, the removal efficiency of BOD5 varied over 93-98.5% from the previous to the present. Further from Table 3, total solids and total suspended.

Table 3. Results of influent and effluent water quality from Khulna FSTP

Parame-ters	Units	Khulna FSTP 2022		Khulna FSTP 2017 [2]		Standard limit (*ECR 1997)
		Inlet/ Raw sludge	Outlet/ Final treated	Inlet/ Raw sludge	Outlet/ Final treated	
BOD_5	mg/L	615	42	1662	25	40 mg/L
Total Solids	mg/L	52680	1490	44560	960	---
Total suspended solids	mg/L	29020	95	30060	80	100 mg/L
NO_3	mg/L	94	0.8	270	2	250 mg/L
PO_4		80	0.5	2808	1	35 mg/L
Total coliform	N/100 mL	180000	1100	444000	1500	---
Fecal coliform	N/100mL	120000	760	390000	100	1000N/ 100mL

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

Solids in treated water had decreased remarkably after treatment in each case. Total solids concentrations were approximately 97% reduced after the final percolate treatment. Nevertheless, total suspended solids were found to be 95 and 80 mg/L, which also satisfied the standard limit of 100 mg/L (ECR, 1997) for disposal into inland water bodies, but it is very close to the standard limit. For nitrate (NO3) and phosphate (PO4), after the final treatment, the removal efficiency was found to be over 99%, and they are also within allowable limits according to ECR'97.

According to Environmental Conservation Rules, 1997, coliform counts must be within 1000 per 100 mL of disposing water, and FSTP final treated samples always meet the standard limit. Figure 5 indicates that the treatment efficiency of FSTP is still in good condition and is carrying out full-fledged treatment properly.

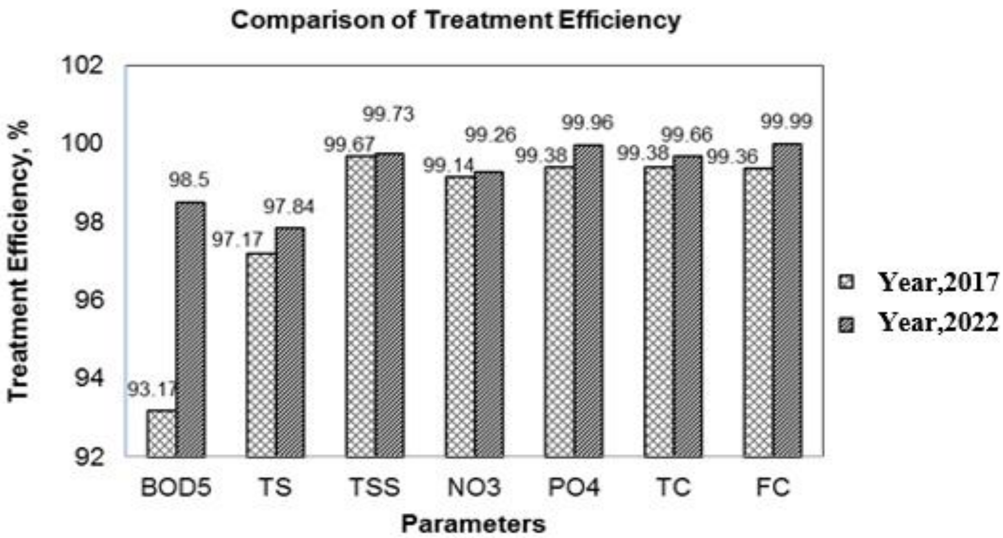

Figure 5. Comparison of current treatment efficiency of Khulna FSTP

Figure 6. Hand-made briquette production in Khulna FSTP

Another major concern about a fecal sludge treatment plant is its solid waste (dry fecal sludge). To save the environment, a large quantity must be managed to avoid solid waste pollution as if left unused, such residues are usually burnt inefficiently. Biomass briquette presents an energy-efficient solution by managing solid waste like dried fecal sludge, waste paper, sawdust, poultry litter, broken green jute sticks, and maize leaves. Moreover, dried sludge is used as biomass energy (briquette) with a combination of rice husk, cow dung, and water in Khulna FSTP (Figure 6). After making the briquette, they are kept in the house. As briquette is being ready with handmade processing without further treatment, it has some procedural problems like loose compaction and pathogenic contamination.

In contrast, dried sludge is collected for carbonized briquetting, and they are willing to start the procedure as soon as possible. If they can make the biomass briquette successfully, it can be an excellent source of energy for households and commercial sites and is ideal for replacing continuously depleting fossil fuels. Displacing LPG with renewable biomass (briquettes) will reduce carbon emissions, cooking time, and kitchen air pollution, resulting in health safety.

4. Conclusions

The above study reveals that Khulna FSTP still has good treatment skills and is conducting full-fledged treatment properly. Khulna City Corporation (KCC) and SNV Netherlands organization have both taken the responsibility of Khulna FSTP to execute the proper management of fecal sludge in Khulna City. The removal efficiency of final effluent for Biochemical Oxygen Demands (BOD5) and Total Solids varied from 97.8% - 97% and 98% - 93% in the previous year to the present, respectively. TSS of final treated sludge ranges within disposal limits into inland surface water bodies (ECR‟97) is 100 mg/L. The nitrate and phosphate concentrations in treated effluent were always far below the acceptable limit of 250 mg/L and 35 mg/L, respectively. Total coliform (TC) removal efficiency in the treated effluent was found to be approximately 99%. Fecal coliform (FC) in final effluent never exceeded 100 N/100ml, while the acceptable limit was 1000 N/100ml.

Furthermore, dried sludge is used as handmade processing biomass energy (briquette) without further treatment, which has procedural problems such as loose compaction and pathogenic contamination. In contrast, dried sludge is collected for carbonized briquetting, and the procedure is intended to begin as soon as possible. If Khulna FSTP can make the biomass briquette successfully, it can be an excellent energy source for households and commercial sites and is ideal for replacing continuously depleting fossil fuels.

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Declaration of Competing Interest The author declare that she has no known competing interests.

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