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Performance Evaluation of Faecal Sludge Treatment Plant: Efficiency, Compliance, and Operational Challenges

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Abstract:

In today's world, the Faecal Sludge Management (FSM) is an important issue needed to be addressed in a sustainable way. Faecal sludge has both solid and liquid matters and its management (FSM) refers to the emptying, transportation, treatment and safe disposal. Many plants of FSM are being designed and constructed but are not working effectively as designed. To know about the actual field performance to designed components, this study was conducted at Charali Faecal Sludge Treatment Plant. This plant consists of Screening Chamber, Drying Beds (DB), Anaerobic Baffle reactor (ABR), Anaerobic Filter (AF) and Planted Gravel Filter (PGF) in series respectively where, solid is separated in drying bed and rest treats the effluents. Liquid effluent is treated in ABR and AF anaerobically then PGF provides the final treatment aerobically through plant uptake. The raw sludge sampled in inlet of the plant shows low alkalinity with average pH of 8.1. Average individual Biological Oxygen Demand (BOD) removal efficiency of the ABR and PGF were found 20.42%, and 57.83% respectively whereas overall BOD removal efficiency of plant was found 79.71%. But in accordance to design report, average removal efficiencies of the ABR and PGF were 64% and 84.33%. This variation suggests that the plant is working inefficiently contrary to design expectations. BOD of final effluent from treatment plant was found 117 mg/L that exceeds the standard limit for discharge to on water bodies or land. BOD removal efficiency of DB and AF were also analyzed and found 17.68% and 26.55% respectively with 79.71 % overall removal efficiency of treatment plant. For Total Nitrogen, removal efficiencies of DB, ABR, AF and PGF were found 26.78%, 17.73%, 24.09% and 35.16% respectively.

Keywords: *Faecal Sludge, Removal Efficiency, Faecal Sludge Management, Biochemical Oxygen Demand, Total Nitrogen.*

1. Introduction

Nowadays, discoveries of new technologies and innovations are leading the world in greater pace. Some developed countries are being advanced based on their new research and findings. In the field of environment, such countries are doing great jobs. But there are some nations which are far behind in technology and even awareness about environment and sanitation. With the greater population, waste generation is increasing. But they are not being managed properly. Direct disposal of waste to water bodies is being major cause for water borne diseases and endemic.

In developing and under developed countries, governments are failing in effective collection and centralized treatment of waste enforcing people to dispose their waste in their locality. For human waste management, people have constructed toilets or latrines connected to different type septic tanks. Faecal Sludge (FS) accumulated in septic tanks and onsite sanitations systems may be liquid or semi liquid. These are several times more concentrated in suspended and dissolved solids than normal wastewater. (Sandec: Department of Water and sanitation in developing countries). In many urban areas river pollution has become major concern as people are directly connecting their toilets. Even the tankers that collect FS in urban areas are disposing it in rivers. Some are directly using them in agricultural fields leading to higher risk to farmers in terms of their health.

In the whole world, 2.7 billion people depends on onsite sanitation and more than 4.5 million are far away from managed sanitation services. (Blackett & Hawkins, 2017). In Nepal, 11% household are connected to sewer and 89% are still adopting on-site sanitation resulting accumulation of 2925 cubic meter of sludge per day in septic tanks and emptied without record and transported, and disposed of without proper treatment in rivers and fields which is not a sustainable and safe (Adhikari & Suman , 2021). This emphasizes on immediate need of Faecal Sludge Management (FSM) plans and policies and also use of FSM plants in many locations of Nepal. First FS treatment plant was constructed in Nepal in 1998 at Teku, Transfer Station, and Kathmandu with Technical support from Environment and Public Health Management (ENPHO). The existing FSTPs in Nepal have designed capacity of approximately 252 m^3 per day, but only about one third of the sludge transported in the plant is being treated, indicating the FSTPs are not operating at its full designed capacity (Buddha Bajrachraya, 2025). This is because of the unwillingness of private desludging service providers to transport to the FSTPs and prevalence of direct application of emptied Faecal Sludge (FS) to the farmland (Buddha Bajrachraya, 2025).

In comparison to wastewater sludge, FS exhibits greater variability in its characteristics based on the region, city, district, household, and source. (Charles B. Niwagaba, 2025). This variability have made the design and operation of FS quite difficult for low income countries with little resources. FS also have potential of water and nutrient recovery but improper handling of the sludge may also poses potential public health and environmental threats (Akalu Melketsadik Woldeyohans, 2025). In 2015, Department of Water Supply and Sewerage Management (DWSSM) with the support from Asian Development Bank (ADB) initiated two FSM projects in eastern part of Nepal in Mechinagar Muicipality of Jhapa District.

Table 1: General Characteristics of Faecal Sludge

Parameters	Public Toilet Sludge	Septage	Reference
pH	6.55-9.44		(Niwagaba, 2014)
COD (mg/L)	20000-50000	<15000	(Strauss, 2002)
COD/BOD	5:1-10:1	5:1-10:1	(Strauss, 2002)
TN (mg/L)		190-300	(Niwagaba, 2014)
TP (mg/L)	450	150	(Niwagaba, 2014)

2. Research Objective

The main objective of this study is to examine the current treatment capacity of FSTP to treat Faecal Sludge. Specific objectives are to determine Biological Oxygen Demand (BOD), Total Nitrogen (TN) removal efficiencies of Charali FSTP and compare the theoretical efficiency of units of treatment plant with actual efficiencies.

3. Methodology

The treatment plant has its own de-sludging tanker. After the request from the people, the tanker collects the sludge from septic tank. The collected sludge is brought to the treatment plant and poured to the screening chamber located at elevated position. The sludge moves through treatment unit with gravity flow.

The treatment plant was build up with capacity of 27 KLD. It consists of screening chamber with clear spacing of 200 mm followed by 28 planted drying beds of size (6m*10m). In planted drying beds solid part of sludge remains on top surface and dried on natural open environment and liquid part gets percolated to inlet of Anaerobic Baffle Reactor (ABR). ABR has the dimension of 1 meter in length and 4 m in width with expected peak flow rate of 4 cum per hour. It is followed by AF and PGF. Final liquid effluent is collected at polishing pond after being treated at PGF. Final effluent is discharged to the Hayadi River. Sometimes the effluent is also used in farms by the local farmers.

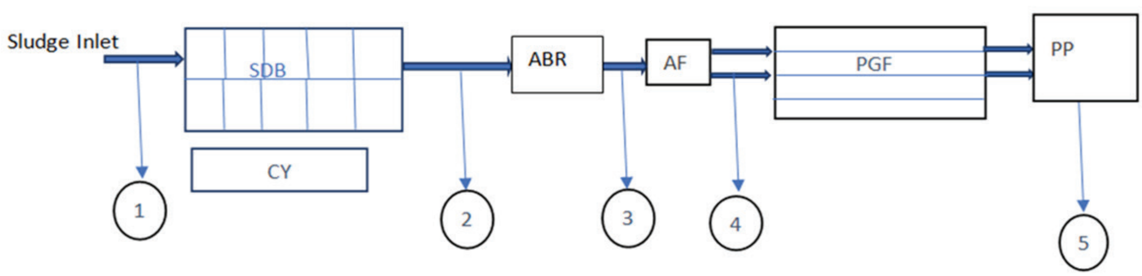

Figure 1: Schematic Diagram of Charali Faecal Sludge Treatment Plant

SDB - Sludge Drying Bed, CY - Composting Yard, C - Collection Tank, ABR - Anaerobic Baffled Reactor, AF- Anaerobic Filter, PGF - Planted Gravel Filter, PP- Polishing Pond

Table 2: Experimental Parameters of FSTP

1	2	3	4	5
• pH • BOD • TN	• pH • BOD • TN	• pH • BOD • TN	• pH • BOD • TN	• pH • BOD • TN

Samples name with numeric number as shown on Table 3.1 were taken from respective location represented in Figure 1.

Samples were collected in plastic sampling bottles and preserved in icebox. In lab, samples were stored at 4^{0}C temperature. Laboratory works were done on environmental lab of Pulchowk Campus, Institute of Engineering, Tribhuvan University. Total six samples were collected from each sample points. Raw sludge was filtered and only liquid portion was analyzed in lab. Methods used for the experimental analysis are

Table 3: Experimental Parameters with their methods

Parameters	Units	Analysis Method
pH	-	pH meter
TN	mg/L	APHA 4500
BOD	mg/L	APHA 5210

Results And Discussions

3.1 pH

The pH value of raw sample collected from tanker was with low alkalinity showing 7.76 average value and 0.266 standard deviation. Overall pH of the system ranges from 7.76 to 7.37. pH value at outlet of drying bed seems to be decreased slightly because of some biological action. The pH of final effluent ranges from 7.7 to 6.92. It indicates that the effluent is safe for discharge on water bodies or land. in terms of pH.

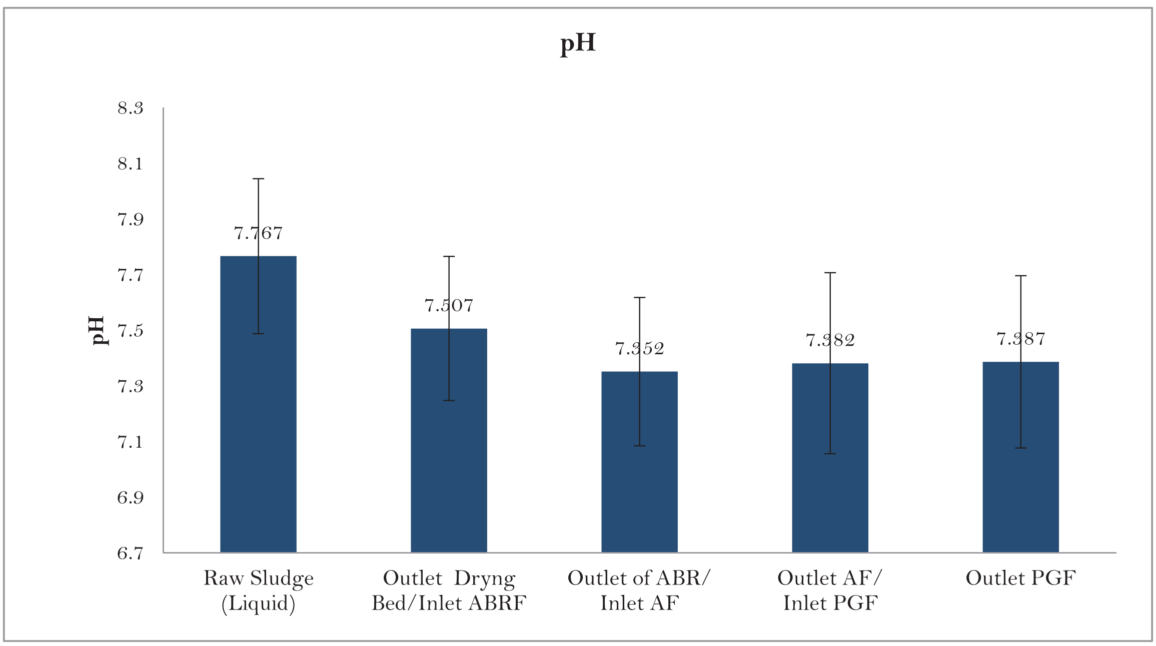

Figure 2: pH of samples of CFSTP with average value

3.2 Biological Oxygen Demand (BOD)

BOD of raw FS (liquid only) collected from desludging tanker was found with variability ranging from 700 mg/L to 450 mg/L with average value of 500 mg/L. Final outlet of liquid from treatment plant (outlet of PGF) was found ranging from 160 mg/L to 40 mg/L with average value of 117 mg/L. This value exceeds the standard limit <50 mg/L for discharge. This indicates that the final effluent is unsafe for discharge on water bodies or land.

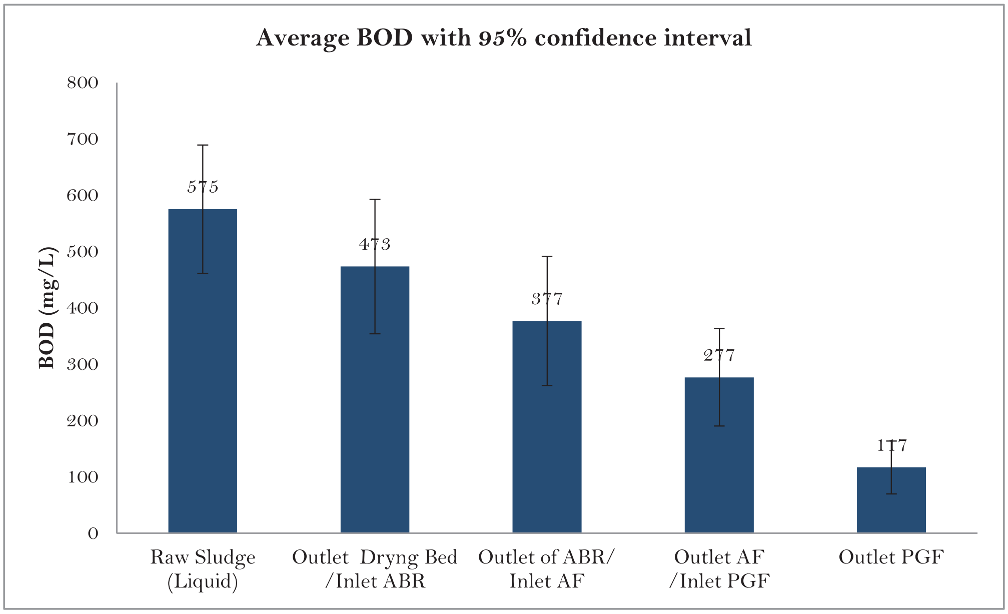

Figure 3: BOD of Charali Faecal Sludge Treatment Plant

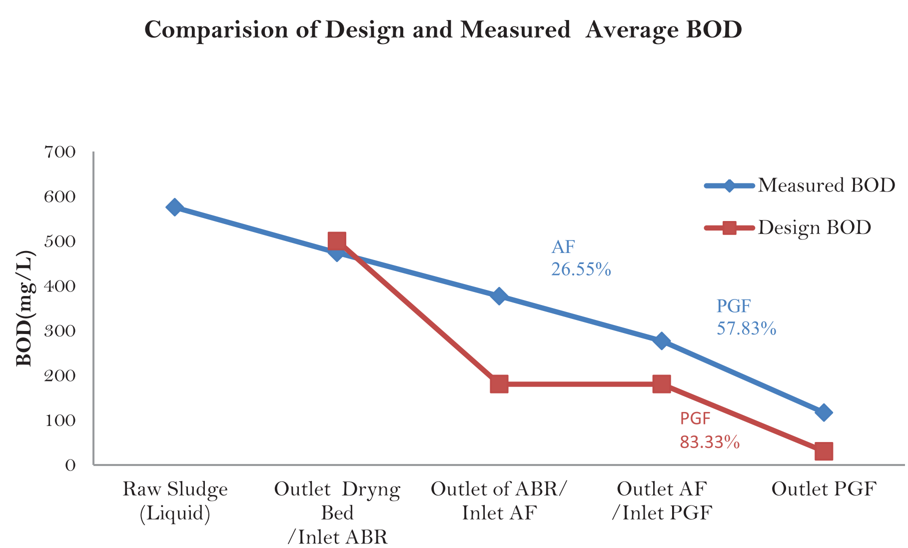

Figure 4: Comparison of design and measured average BOD

For BOD, Figure 3 shows design efficiency of 64% of ABR and 83.33% PGF estimated in design report with final effluent value of 30 mg/L and overall removal efficiency of 94% of treatment plant. But in the study, average treatment efficiencies of planted drying bed, ABR, AF and PGF were found 17.68%, 20.42%, 26.54% respectively and 57.83% and average overall removal efficiency of treatment plant a 79.91%. A study done on pilot scale FSTP in Kamapala had also found the BOD removal efficiency of ABR (39%), AF (29%) and PGF (74%) (George Otaka, 2019).

These lower efficiencies might be the result of lower temperature than the system need to work efficiently. Also, negligence in timely desludging of ABR have resulted in lower efficiency. In design report, removal efficiency of AF has not been considered showing straight horizontal line in AF portion. However, in study BOD removal efficiency of AF was found 35.06%.

3.3 Total Nitrogen (TN)

TN of raw FS (liquid only) collected from desludging tanker was found with variability ranging from 573 mg/L to 295 mg/L. with average value of 420 mg/L. Final outlet of treatment plant was found to be ranging from 148 mg/L to 54 mg/L with average value of 96 mg/L. This value is within the standard limit of 10-100 mg/L for discharge. Figure 4.7 shows average Total Nitrogen removal efficiencies were found 26.78% and 17.72% for planted drying bed and ABR respectively. Among all units PGF had highest removal efficiency of 33.16%. Overall removal efficiency of treatment plant was found 76.97%.

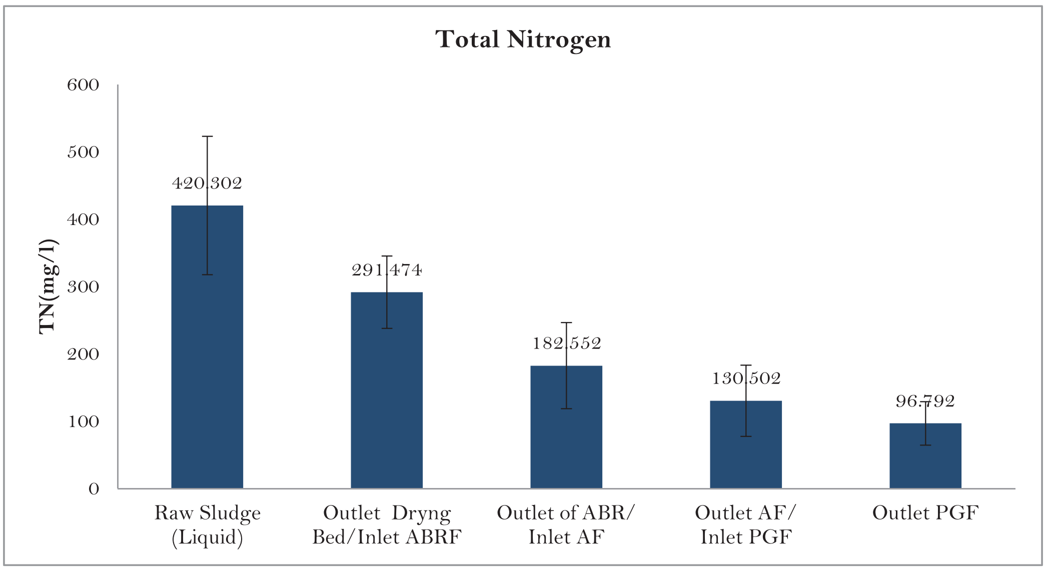

Figure 5: TN of Charali Faecal Sludge Treatment Plant

3.4 Characteristics of Faecal Sludge (solid + liquid)

In the experiment, the raw sludge (solid + liquid) collected at inlet of treatment had average TSS value of 20296 mg/L and average VSS value of 13196 mg/L. BOD and COD were found 1533.33 mg/L and 7722 mg/L respectively with 5.037 COD/BOD ratio. Sludge was found with low alkalinity with average pH value of 8.01. The volatile suspended solid was found. 65.02% of TSS on average.

Table 4: Characteristics of Faecal Sludge of Charali FSTP

Parameters	Raw Sludge (solid +Liquid) (average Value)	Units
pH	8.01	
TSS	20296.667	mg/L
VSS	13196.667	mg/L
VSS% of TSS	65.019	%
BOD	1533.333	mg/L
COD	7722.667	mg/L
COD/BOD	5.037	

Conclusion

The experiment was conducted on Charali Faecal Sludge treatment plant with the objective of exploring the working efficiencies of all units of the treatment plants. Average individual BOD removal efficiency of the DB, ABR, AF and PGF were found 17.68%, 20.42%, 26.55% and 57.83% respectively whereas overall BOD removal efficiency was found 79.71%. As per design report, ABR and PGF had individual BOD removal efficiency of 64% and 84.33% with overall plant BOD removal efficiency of 94%. For Total Nitrogen, removal efficiencies of DB, ABR, AF and PGF were found 26.78%, 17.73%, 24.09% and 35.16% respectively. In comparison with the design report, the actual measured average removal efficiencies of the ABR and PGF were found low suggesting that the plant is not working as efficiently as expected. Final effluent was found exceeding standard limit of discharge on water bodies or land for BOD where as it was under standard limit for TN. Provision of tertiary treatment before discharge and some changes in operations like unloading of dried solid sludge from DB in regular interval of time need to be done immediately. For anaerobic treatment unit (ABR and AF), treatment efficiencies are low. It suggests that ABR and AF had failed in efficient degradation of organics. There should be special considerations for protecting ABR, AF and PGF to protect them from heavy rain and proper drainage for draining collected rainwater in the surrounding area. This seems to have some kind of difference in the design considerations and the actual performance of the units and thus causing the inefficient treatments. This study also helps to draw the attention of the designers and all stakeholders for the new considerations and that could be applied in the new designs for the betterment of the FSM.

4. Acknoledgement

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