RESEARCH ARTICLE

# Evaluation of the Functionality of GeoTube® based Physicochemical Faecal Sludge Treatment: A Cursory Alternate

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## Abstract

With the rampant boom in faecal sludge (FS) collection and management in line with Indian government's agenda, quite a few urban local bodies (ULBs) in Telangana such as Greater Warangal Municipal Corporation (GWMC) initiated into establishing faecal sludge treatment plant (FSTP) in collaboration with experienced private technology partners such as Banka BioLoo Limited. FSTPs were so designed with minimal mechanical components to regularize it as a popular choice for rural and sub-urban. The GeoTube based technology makes use of an organic flocculant to maximize the floc formation and thereby the water recovery. Post-flocculation the sludge is fed into a semi permeable polypropylene trap (GeoTube®) with a pore size of 0.3 mm. The method of dewatering the septage with the aid of GeoTube was so designed to ensure greater than 98% efficacy. Ultimately, the above effluent gets polished with a series of tertiary units such as pressure sand filter, activated carbon filter, UV disinfection, etc. The permeate meets the inland water disposal standards and is used to maintain the green belt in and around the plant. The trapped biosolids are self-composted for more than two months inside the filled tubes. Further, the debagged material is analyzed to ensure compliance with physico-chemical, metallic, and pathogenic limits. Afterward, the final materials pulverized, packed, and distributed amid the local farmers to be used as a soil conditioner. The FSTP has been successfully running for about two years now and has to date treated more than 2 million liters of septage of which recycled almost 1500 kL of water and 35 tons of biosolids.

**Keywords:** Faecal sludge, GeoTube, Physico-chemical treatment, Soil conditioner, Water recovery.

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## Introduction

Sanitation is a reflection of hygiene and public health by ensuring access to basic amenities such as potable drinking water and pertinent treatment and disposal of sewage and septage. Septage constitutes of human urine and feces which is collected separately from grey water. Despite lower generation rate, high nutrient load and pathogenic interference make the chunk vulnerable for easy disposal. Inadequate sanitation leads to the spread of diarrheal diseases (Lalander *et al*., 2013; Singh *et al*., 2017), whereas improved sanitation is known to have significant positive impacts such as gluttony, women menstrual and urinal hygiene, water, and biosolid recovery, etc. (Mara *et al*., 2010; Tan *et al*., 2015; Andrade *et al*., 2017).

Globally, sanitation needs of 2.7 billion people are met by onsite sanitation technology such as pit latrines and septic tanks (Cairns-Smith *et al*., 2014; SNV Netherlands Development Organization, 2017). These storage cum semi-treatment technologies serve a large amount of FS. The limitations include odor, overflow, periodic cleaning, environmental and health interventions etc. Contrarily, onsite sanitation technologies offer an adequate and affordable solution for faecal sludge management (FSM), with modules such as collection, transport, treatment, and safe end use or disposal of FS (Dodane *et al*., 2012; Strande *et al*., 2014, 2018; Talekar *et al*., 2018; Urban Sanitation Working Group, 2019).

Presently, the majority of FS in low-income countries are discharged inadequately or untreated into the urban environment. In Kampala, Uganda, around 46% of excreta (Schoebitz *et al*., 2017), in Dar Es Salaam, Tanzania and Nakuru, Kenya, 57% and 64% (Brandes *et al*., 2015; Furlong *et al*., 2015) of the excreta and more than 80% of excreta in Indonesia (Nisaa and Hajrah, 2018) and Vietnam (Katerina *et al*., 2015) are left untreated. Nationally, in major cities of India like Coimbatore, Tamil Nadu 76% (GIZ, 2019), Bansberia, West Bengal 72% (Datta *et al*., 2016; Rohilla *et al*., 2017a), Bijnor, Uttar Pradesh 98% and Siddipet, Telangana 100% (Rohilla *et al*., 2017b,c) of the human excreta remains untreated. Such unsafe practices significantly impact on the public and environmental health and has severe economic implications (Hutton and Haller, 2004; Boschi-Pinto *et al*., 2008; Bartram and Craincross, 2010; Mara *et al*., 2010; Zhang *et al.,* 2011).

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The rising numbers indicate that the issue can only be resolved if addressed at a micro-scale through decentralized in expensive and local technology. Treatment technologies like DEWATS, Soil Biotechnology, drying beds are in vogue. But technologies that are easy to establish, operate and economical to maintain are in a real upsurge in the tier two category towns and suburban areas (Mara, 1996, 2003; Niwagaba *et al*., 2014; Ojo *et al*., 2019; Roy Choudhury *et al*., 2020). Dewatering is the crucial component for such FSTPs and can seriously influence the performance and economics. Tayler (2018) has exclusively highlighted the increase in popularity of geobags in the recent past as a dewatering media.

Geobags (*i.e*., fiber woven polypropylene) are commercial products sold by several manufacturers either in a tube or in bag form and have been used in many countries for the dewatering of sludge from various sources (*e.g*., wastewater treatment, aquaculture) at different scales (Fowler, 2002; Howard *et al*., 2008; TenCate, 2008; Wei *et al*., 2015). During operation, the bags or tubes are filled with sludge. Following filling, the free water drains through the semipermeable material within hours or days. Geotextiles operate by gravity, have no mechanical parts, produce no noise and are modular in operation. This makes them potentially suitable for decentralized FS treatment. However, the product involves a major disadvantage related to reusability. The used geotube have found very little reuse/recycling potential once the bag fills up and the biosolids are discarded.

Limited information is available for the dewatering of septic tank FS with GeoTube. TenCate (2014) reported TS tolerance of up to 40% for dewatering of FS in Canada. Shi and Kone (2010) reported the use of tubes for dewatering of septic tank FS in Malaysia without providing details about their performance. According to the GeoTube® manufacturer, solid-liquid separation efficiencies can be greater than 99% in terms of total suspended solids (TSS) removal, while the total solids (TS) in the dewatered sludge may vary in the range of 25-30% (TenCate, 2014). The claimed efficacy is further supported by Fowler (2002) and Pawar *et al*. (2017).

The main objective of this paper is to analyze the efficacy of GeoTube® in dewatering moderately old or partly digested septic tank faecal slurry. Also, to assess the effluent and biosolid quality of GeoTube® to conclude on the further set of treatment required.

## MATERIALS AND METHODS

The Faecal sludge treatment plant is located at Sanitation Park, Ammaveripeta at Warangal at an intercept of 17.93°E and 79.55°N (India). The non-complexity of design and minimal mechanization is the profound leverage of the present study. The process begins by quantifying the incoming mass and ends by reusing the treated effluent and distributing the stabilized and dried biosolids (Fig. 1). Additional descriptions are delineated below.

### Sludge Quantification

Partly digested sludge is primarily quantified upon entering into the facility. The process of quantification involves a weighing based mechanical approach. The weight of the influent chunk is precisely measured by subtracting the empty vehicle load from the combined initial load.

### Screening and Homogenization

The Faecal Sludge and Septage transported by the de-sludger are received at the Screening Chamber which aids in removing coarse objects such as rags, paper, plastics, and metals to prevent the damage and clogging in the following downstream process. The screened sludge (*i.e*., mainly organic matter) is then taken into a holding tank and recirculated over 24 h to achieve homogenization. The process prevents shock loading.

### Flocculation

The homogenized sludge is then pumped into the static mixer wherein an organic biodegradable polymer is dosed and flocculation begins. The flocculated slurry is then pumped into the GeoTube for the dewatering process to occur. Each GeoTube bag is so designed to withhold 65 kL of sludge.

### Dewatering

The principal component of an FSTP is the dewatering. The present study has opted for a Geobag based dewatering technology to separate the biosolids and the water. Separated liquid is stored in an underground aeration chamber for about 30 min and later forwarded to the tertiary treatment unit. The quality of the treated effluent is regularly analyzed following the

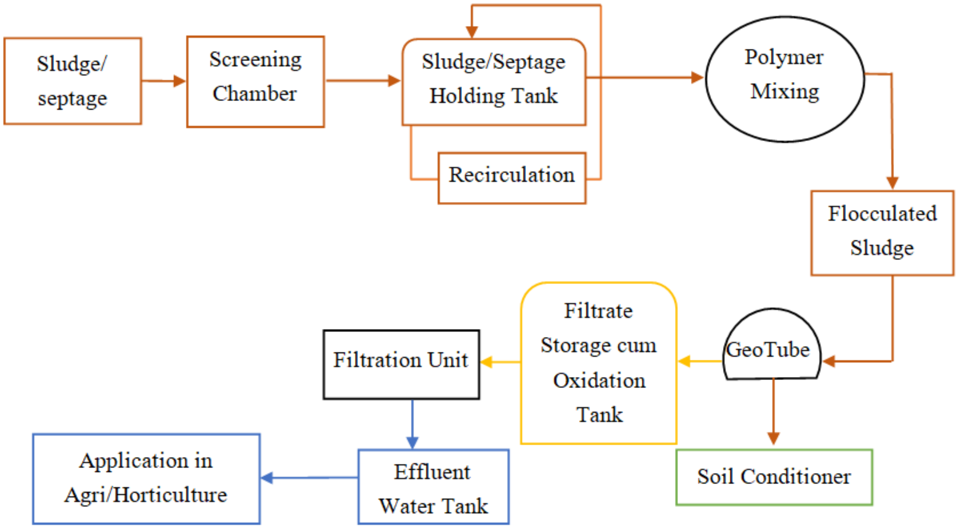

**Fig. 1:** Process Flow Diagram

APHA method prior to reuse (APHA, 2003). While the separated biosolid is self-composted in the same bag.

### Filtration

The GeoTube effluent is further treated with pressure sand and activated carbon filters and finally disinfected through UV treatment. The water obtained suffices the In land disposal water quality norms as per CPCB standards (Akolkar *et al*., 2012, 2015). The water is generally reused for developing and maintaining the green belt within the facility premises.

### Stabilization of Biosolids

The Bio-Solids are retained in the GeoTube for 6 to 8 weeks. During the tenure, it undergoes a considerable reduction in the moisture content and pathogen. Recession in moisture is the direct outcome of combined impact from external compaction and natural curing. While microbial stabilization gets obtained due to escalation in temperature resulting from the heat liberated during the composting exothermic phase. Post debagging, biosolid is further cured for 2 to 3 days to attain the moisture level of 22 to 25%and is pulverized using a batch pulveriser. The dried nutrient-rich mass is later distributed amid local farmers.

## RESULTS

The FSTP at Ammaveripetta was established and came into active treatment process since October 2018. Since then it has been receiving loads of septage at an average of 10000 liters per day. It is often ascribed to be an old and oxidized sludge typically stabilized over a period of a few months to several years. The variation in the concentration of major parameters after each set of unit operations is portrayed below (Fig. 2-8)

Studies showcased a remarkable reduction again stall the above parameters during each stage of unit operation. The received septage which has an average TS of 29615 mg/l, consequently gets reduced to 2000 mg/l in the GeoTube effluent and ultimately to a range of 1300 mg/l for the final effluent.

The mean TDS value of septage of 8500 mg/l gets initially reduced to a range of 1400 mg/l in the GeoTube effluent and further drops near to 1000 mg/l for the polished effluent. Reported efficiency is almost on par with that of TS. But the efficacy depicted a proportional correlation with the influent concentration. The efficiency value was found to be gradually increasing between 70% to 92%, subjected to higher influent concentration. Contrary to the sewage stream, the concentration of TDS and TSS portrays an inverted trend for septage. The TSS value in the receiving septage is nearly greater than two times of TDS and the major removal takes place in polypropylene geobags.

The existing FSTP effluent is anyhow meeting the desired dilution disposal value for TSS but intricate understanding indicates towards the requirement of continual improvement to meet the inland surface water disposal or land irrigation limits. It is also advantageous to monitor TSS in conjunction with BOD and COD as part of the BOD/COD is in the TSS form. The average BOD for septage as received is around 3000 mg/l which is reduced to a range of 100 mg/l in the GeoTube effluent and finally to about 30 mg/l. Moreover, an average COD of 15000 mg/l in FS is quite common; it gets reduced to around 150 mg/l

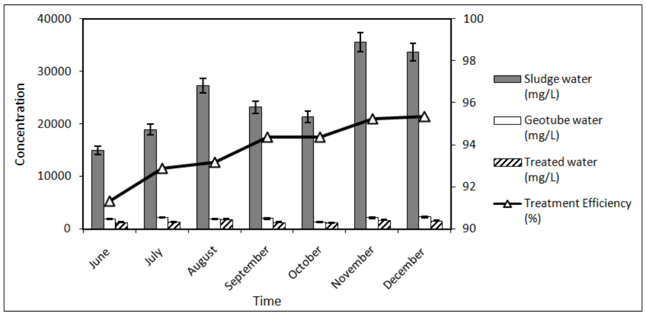

**Fig. 2:** Average Total Solids Removal Efficacy

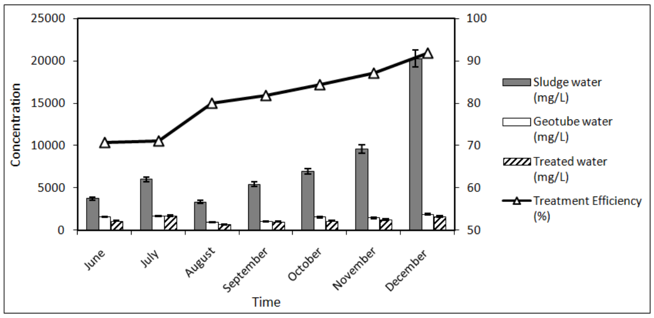

**Fig. 3:** Average Total Dissolved Solids Removal Efficacy

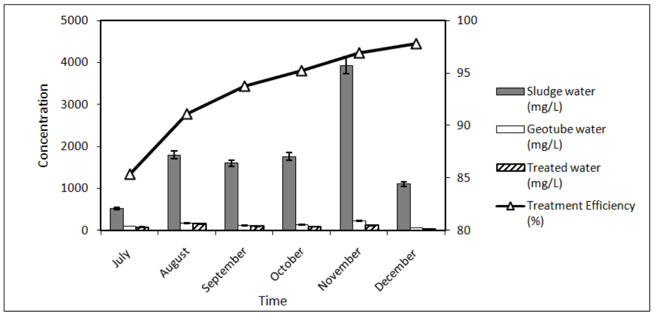

**Fig. 4:** Average BOD Removal Efficacy

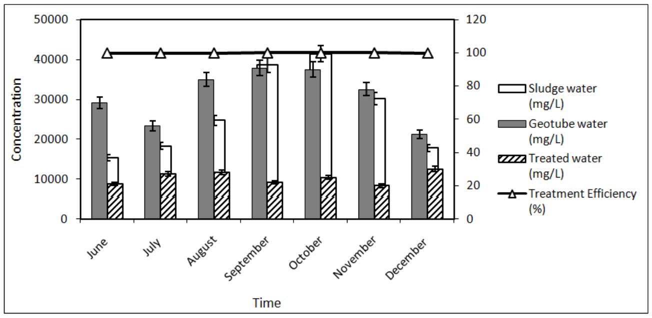

**Fig. 5:** Average COD Removal Efficacy

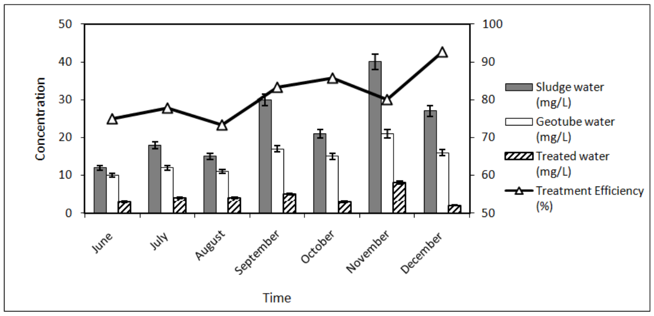

**Fig.6:** Average Nitrate Removal Efficacy

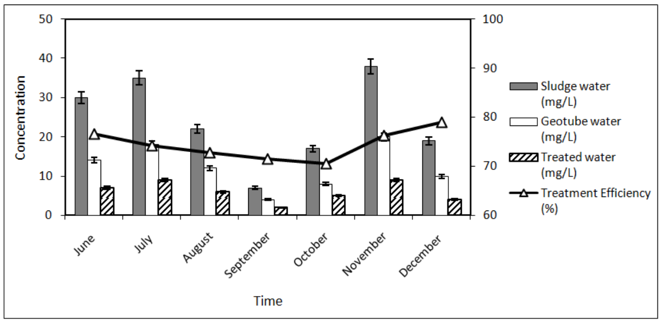

**Fig. 7:** Average Phosphate Removal Efficacy

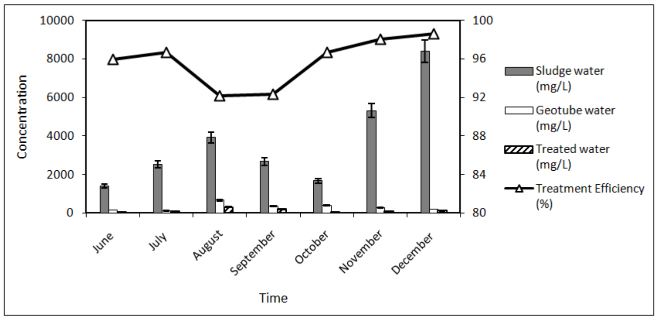

**Fig. 8:** Average Total Kjeldahl Nitrogen Removal Efficacy

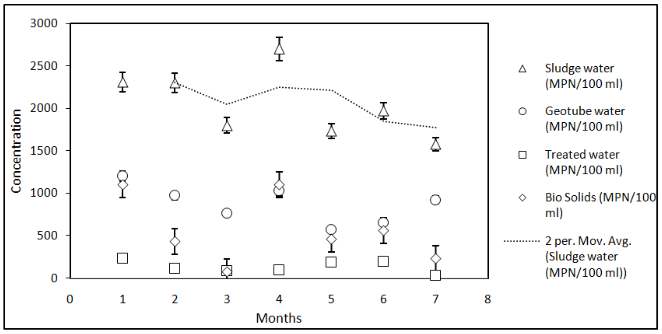

**Fig. 9:** Average Total Coliform Removal Efficacy

in the case of GeoTube based physical treatment unit and finally to below 100 mg/l. Assessing the BOD/COD ratio of 0.2, lately, a diffused aeration system has been incorporated in the GeoTube effluent storage tank as a process enhancement.

BBL's GeoTube dewatering process also shows great potential in the removal of TKN from the septage received (Fig. 8). The major TKN composition of the septage received is generally organic nitrogen in the suspended form which gets entrapped due to the flocculation and then inside the GeoTube. It renders the value of TKN to a range of below 200 mg/l during each batch. Phosphates (P) and Nitrates ($NO_3^-$) are also seen to be drastically reducing in their content once the water is leached through GeoTube (Lopez-Vazquez *et al.,* 2013; Deng and Wheatley, 2018) (Fig. 6-7).

**Table 1:** Biosolid analysis report

| *Sl. No.* | *Parameter* | *Unit* | *Values** |
|---|---|---|---|
| 1 | pH | --- | 7.43 |
| 2 | EC | dS $m^{-1}$ | 0.87 |
| 3 | C/N Ratio | --- | 9.16 |
| 4 | TKN | mg/l | 48.74 |
| 5 | Phosphates | kg/ hectare | 360 |
| 6 | Metals | | |
| | $K_2O$ | kg/ha | 763 |
| | Cu | mg/kg | 4.88 |
| | Mn | mg/kg | 27.4 |
| | Fe | mg/kg | 37.2 |
| | Zn | mg/kg | 58.43 |
| 7 | Helminths | cells/g | 0.9 |
| 8 | Viruses | --- | Not Detected in any of the samples |
| | Hepatitis Virus | | |
| | Human Papilloma Virus | | |
| | Human immunodeficiency Virus | | |

*So far, no standard to compare and validate the values

## Biosolidstabilization

BBL's treatment process quite effectively addresses and stabilizes the trapped biosolids. The gradual rise in temperature due to the digestion of the organic content in the presence of the inherent microbes serves a key role here. This exothermic biochemical reaction reaches a peak of about 50°C which is good enough to kill most of the pathogens and the helminths (Ova and Eggs). Exposure to temperatures over 45°C for at least 5 days is known to inactivate *Ascaris* eggs. Higher temperatures speed up the desiccation rate of *Ascaris* cells and destroy the cells' ability to slow down desiccation (Feachem *et al.*, 1983; Gaspard and Schwartzbrod, 2003; Capizzi-Banas *et al.*, 2004). Apart from temperature, a decrease in moisture content (final moisture content in GeoTube yield: 16-20%) in the living environment (*i.e.*, compost heap) reduces helminth larvae's mobility and movement, thus accelerating the decay rate (Wharton, 1979; Stromberg, 1997; Sanguinetti *et al.*, 2005). A nearly alkaline pH also triggered the decay of helminth eggs in biosolids (Gaspard and Schwartzbrod, 2003; Capizzi-Banas *et al.*, 2004). The matured mass got further investigated for physicochemical parameters such as C/N ratio, pH, moisture content, electrical conductivity, TKN, phosphates and bacteriological parameters like total coliforms, helminths, viruses as well as metals. The findings of the above analysis are showcased in Table 1.

The results in Table 1 depict that the pathogen content is quite minimal while no viable/dormant helminth egg or ova are observed. However, considering the Nitrogen, Phosphorus, and persistent pollutant levels in the dried biosolids it is very evident that this could be very luxuriantly used as a soil conditioner. During the process, almost 435 bags of biosolids (25 kg each) were taken away by the nearby farmers and had been utilized to grow plants such as cotton, fodder grass, and also was used in certain fruit orchards. The received feedback was absolutely overwhelming with visual evidence include higher yield, better root zone development with no sacrifice on safety. Total coliform values were also assessed in MPN/100 ml for the same samples portrayed in Fig. 9.

The two-period moving average trendline in the above figure against the influent load quite explicitly depicted the variation. Though it had meagerly influenced the results, still the existing system managed to renderthe count below 100 MPN/ 100 ml in almost half of the cases. The results highlight the limitation of disinfection assembly while treating effluent derived by purifying wastewater streams and indicate the requirement of a collective disinfection effort.

## DISCUSSION

Okeyo *et al*. (2018) stated that microbiological quality of water is currently evaluated by the use of indicators of faecal contamination (total coliforms, *Escherichia coli* and faecal streptococci) in the water environment. Faecal contamination of water is a strong indication of the presence of human pathogens. Some studies have depicted that these indicators do not provide adequate information about viruses, particularly in terms of their fate in the environment and their resistance to treatment (Tchobanoglous *et al*., 2003; Shar *et al*., 2007; Getachew *et al*., 2018). Studies have already indicated the need to monitor not only the classical pollution indicators, *i.e.*, culturable total or faecal coliforms, but also viral pathogens, toxigenic *E. coli*, and highly infectious bacterial pathogens such as *Vibrio* (Okeyo *et al*., 2018; Roy Choudhury *et al*., 2019).

CPCB has no specific limits prescribed exclusively against those individual bacteriological categories neither anything explicitly portrayed in National Policy on Faecal Sludge and Septage Management (MoUD, 2017). Moreover, the inland disposal standards are vaguely being followed for greenbelt development without considering the consequences (Diener *et al*., 2014; Cheng *et al*., 2017). In fact, the current observation directs, sewage farming in controlled farmland would extend to be more promising.

Guo and his colleagues (Guo *et al*., 2018) explored the removal efficacy of multi soil layering (MSL) and reported nutrients removal was strongly affected by the Hydraulic Loading Rate (HLR). Removal efficiencies of ammonia-N, TN and TP were escalated with the increase in HLR from 80 to 160 L/m$^2$/day, and stretched to the peak values of 94.2%, 94.4%, and 92.5%, respectively. Whereas, the excessive HLR reduced the independent capability of the MSL bioreactor in anaerobically digested swine farm effluent treatment (Guo *et al*., 2018).

Alleviation of major problems of water resource shortages and water environment pollution may be achieved by using reclaimed water as a resource for landscaping. Although the safety of the reclaimed water and the risk of eutrophication caused by the reclaimed water is unclear to the public and to the research community. However, Li and his colleagues (Li *et al*., 2020) showed a significant difference caused by the addition of reclaimed water as was found in the microbial diversity and community structure. They hypothesized that the combination of 80% reclaimed water and 20% natural water was a feasible solution that could be used for supplying river water. The researchers also suggested the keen monitoring on the sedimentation part to evade early dredging requirements (Li *et al*., 2020).

The dried Geobags mass yields a C/N ratio below 10 which indicates the abundance of nitrogen. Pawar *et al*. (2017) as well reported an equivalent result and claimed its potential as a soil conditioner. Further, the author goes on explaining the process of detoxification of the solid by attributing it with temperature stabilization. Their research findings showcased a gradual rise in temperature inside the Geobags up to 50$^{o}$C which attenuates the pathogenic activity and diminishes the same over prolonged exposure. The above statements are at par with the current findings and the same is portrayed in Table 1.

## CONCLUSION

The results of this pilot study potentiate the possibility of using the GeoTube based dewatering technology for decentralized dewatering of FS. Due to the non-affordability and scarcity of land, presently the technology is best suited for rural and suburban outsets. Also, the non-reusability of the bags left the operator with no option other than recycling. Onsite recycling for such a limited quantity is also unadvisable while transportation incurs additional expenses on the operators. Despite a few drawbacks, the discussed technology offers a great range of advantages including time efficiency, optimum recoverability, premium effluent quality, composting ability, and above all scalability. Continual research is on progress at BBL's end to overcome the challenges listed above. Models such as vertical dewatering solutions with various filtration media have been experimented and proved their potent during bench-scale experiments. This will lead the pathway of future research in this domain and shall help the novel technology to thrive and flourish even in highly critical urban situations.

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