Faecal Sludge Management in small towns: BRAC WASH Initiative

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Abstract

Faecal sludge management is the second generation challenge of sanitation. Households of the small towns of Bangladesh mostly depend on single pit latrines. A research was done to find suitable solutions for reuse of this latrine content and ensure safe sanitation. The aim of this research was to provide scientific evidence to support the commercial viability of collecting and composting faecal sludge for use in agriculture. This research includes analysis of appropriate pump options to clean single pits and mode of transportation. The second step was to find proper drying and co-composting procedure for pathogen inactivation and nutrient enrichment to reuse the sludge as organic fertilizer or soil conditioner. Pathogen-free fertilizer was produced following the developed drying process. This study also includes the preparation of pellets and biochars from the sludge. This study reveals the idea of the users about reuse of sludge and willingness to pay for that. The study was concluded with a field trial on spinach to check the capacity of faecal sludge to be used as organic fertilizer. For this study, sludge sample was collected from 5 sub-districts of Bangladesh. The trial composting plant was established in an organic fertilizer production facility near Dhaka. This study revealed the opportunity of faecal sludge reuse in the agricultural sector of Bangladesh. At the same time it also exposed different administrative and technical limitations to popularize sludge-based fertilizer. Based on the findings of this research a hypothetical model of faecal sludge management was projected. Sub-district town (small administrative area) based faecal sludge collection, treatment and reuse model was proposed and hypothetically analyzed in this paper.

Key words: faecal sludge, organic fertilizer, pit latrine, field trial

Introduction

Progress in reducing open defecation and use of improved sanitation in Bangladesh has been impressive. Between 1990 and 2012 rates of open defecation in rural areas of Bangladesh fell from 30 percent to 3 percent and access to improved sanitation rose from 30percent to 57 percent[i].

In 2006, BRAC initiated a comprehensive intervention on water, sanitation, and hygiene (the BRAC WASH Programme). The main focus is on behavior change that impacts on people's health and welfare: sustainable use of sanitation, safe use of water and the adoption of hygienic practices. The programme originally covered 150 upazilas (sub-districts) and subsequent phases expanded to 250 upazilas out of a national total of 488. During the period 2006-2013, the programme reached 63.5 million rural people with hygiene education. The second phase of the programme (2011-2015) focused on sustaining progress, with special attention on low cost and sustainable sanitation in areas that are geographically remote, geologically difficult or socially deprived.

The programme has promoted the use of sanitary latrines that separate faeces from human contact and do not cause contamination of water sources. In intervention areas30.7 million people can now access sanitary toilets. Construction was supported through grants and by promoting demand. Repair of unhygienic latrine was helped by loan support. In the same areas 1.9 million more people can access water free of arsenic and faecal contamination[ii].

Access to single pit latrines reduces open defecation, which is associated with numerous health and environmental issues. Human excreta contains bacterial, viral, and protozoan pathogens, along with helminths, that cause diseases such as cholera, amebic and bacterial dysentery, diarrhea, typhoid, dracunculiasis, and schistosomiasis[iii]. The disease burden from water, sanitation, and hygiene at the global level is estimated to be 4% of all deaths, and 5.7% of total diseases[iv]. It is suggested that most of these deaths and diseases can be avoided through low-cost proven interventions[v]. Single pit latrines have become an important sanitation option for lowering this disease burden, as they are a low-cost solution for containing excreta in the ground; without requiring any extensive engineering or expertise to install.

However, simply improving access to single pit latrines is not likely to be enough. As pits fill up, owners will either: move back to open defecation; seal old pits up and install new ones; or empty the contents to reuse the pit. Moving back to open defecation would unravel the gains that have been made from containing excreta. Sealing old pits is also likely to create health losses. When groundwater is the primary drinking water source, pit latrines can microbiologically impact groundwater[vi]. In the absence of waste management systems, emptying pits for reuse would entail dumping untreated faecal sludge into the environment, negating the gains achieved through the containment of excreta. Thus, preserving the gains from improved latrines may entail installing better lined latrines to minimize seepage into groundwater, while also designing waste management systems that periodically extract sludge, and transport them for safe disposal.

70% of the people of Bangladesh live in the villages of Bangladesh. This people are out of any kind of fsm service. As most of the latrines in this area are single pit latrine, thus based on the findings of the single pit latrine research, a model of sludge management was formulated here. Sub-districts are small administrative area of Bangladesh. There are 59000 villages in Bangladesh. They are segregated among 488 sub-districts. Technically Union is the smallest administrative unit of Bangladesh which is 4550 in number and villages are considered as ward of one union. Usually one union consists of 12-13 villages. One sub-district contains 9-10 unions. Being small towns, these sub-districts are closely associated with the villages. This research focused on these towns that a huge population can have the fsm service and villages can come under the reach of fsm service as well[vii].

Methods

Bhaluka, Upazila of Mymensingh district was selected as the location for a sample survey whose aim was, to understand how households behave when their pit latrines are full. Around 8% of rural households in Bhaluka received single-pits under the BRAC program, amounting to ~19 BRAC households per square kilometer. Bhaluka Upazila was selected as it has a large number of households whose latrines had been installed by the BRAC program.

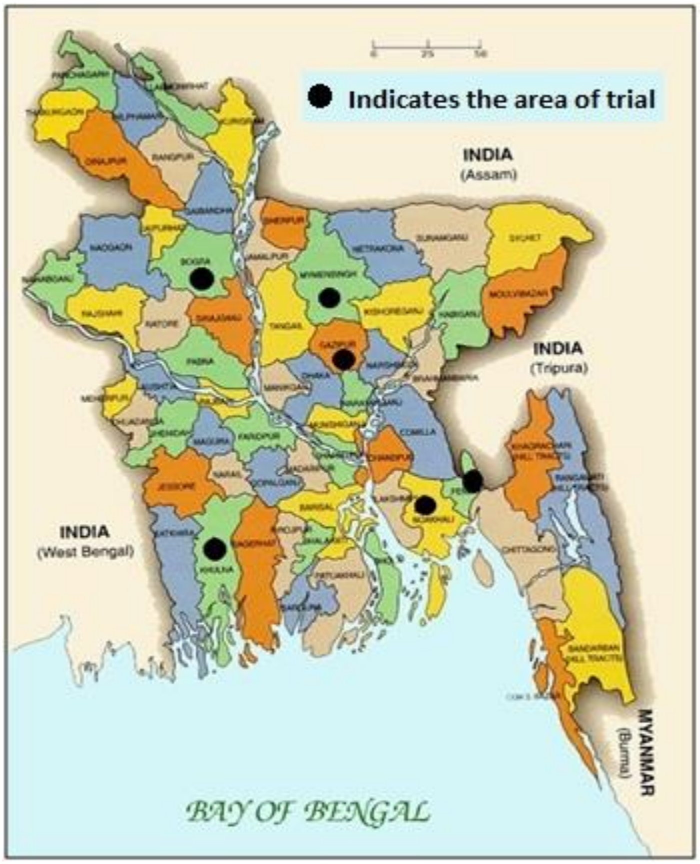

Figure 1: Locations of trial areas in Bangladesh

A questionnaire was implemented to understand what households did when their pits filled up; whether households emptied their pits themselves or hired sweepers to do so; and whether the faecal sludge was transported away, dumped or buried nearby. If a household was yet to empty its pit, they were asked what they intended to do when their pits filled up. Information on household demographics was also collected. The questionnaires were administered to the male head of the household.

In addition to the household survey, a literature review of emptying tools and technologies was undertaken. Technologies were classified into three categories: manual, semi-mechanized, and mechanized.

- Manual emptying is defined as the use of buckets, shovels and ropes, but no machinery.
- Semi-mechanized processes involve using a small hand-held pump to empty the pits. This reduces the likelihood of laborers coming into contact with faecal sludge. .
- Mechanized processes involve, using machines (e.g. a Vacutug or Vacuum tanker) to empty pits; therefore there is minimal contact with faecal sludge.

Figure 2: Trial of different types of pumps

In order to identify the main characteristics of raw FS in typical pit latrines in the study area, samples were collected from single pit latrines in the following sub-districts: Mirzapur, Gazipur (samples collected from 4 pit latrines in Feb 2014 and from another 4 pits in Jul 2014); Phultola, Khulna (6 pits, Feb 2014); Senbagh, Noakhali (6 pits, Aug 2014); Bhaluka, Mymensingh (6 pits, Jun 2014); and Chagolnaiya, Feni (6 pits, Jun 2014).

Vacutug trial

Vacutug operation trial was done in Bogra. Three surrounding sub-districts were the subject area called Bogra sadar, Gabtoli and Sariakandi. A vacutug with capacity of 700 liters was rented from jhinedah City Corporation for the trial. The model Vacutug MK IV (figure 3) had a 700 liter tank (storage capacity) mounted on a 3 wheeler country made vehicle known as Nashimon that Runs by a 16 HP diesel engine with a 30 km per hours moving speed. In alternate mode, the diesel engine drives a centrifugal suction pump for emptying pit latrines or moves the vehicle to cover short distance at low speed.

Figure 3: Vacutug operation trial in Bogra

Two different types of composting was subjected to collected sludge. Sand bed drying was applied for dewatering and composting. For speeding up the process bio-drying was applied which used aerobic bacteria as agent for digestion. This process was fast and can be used even in the rainy season as well. Pelletizing was done on the compost to prepare an user-friendly product. The advantages of pelletizing compost include reduction in volume/bulkiness which in turn helps to reduce transport costs and make handling of the end product easier. There are also benefits in terms of optimizing nutrient release which due to the disintegration of the pellets over time may allow a steady nutrient release. In order to achieve these objectives the characteristics of the pellets should be such that they are durable and therefore do not get crushed during transportation and they should also have suitable disintegration and nutrient release properties.

The main objective of the crop trials was to identify the performance of faecal sludge co-compost (FSC) (including nutrient-enhanced and pelletized versions) compared to other alternatives such as municipal solid waste (MSW) compost, synthetic fertilizer and other cheap alternatives such as poultry manure. The different treatments included:

- Control 1: No fertilization
- Control 2: local common practice (Urea + TSP + MOP)
- NPK alone
- Commercial compost – MSW based compost
- Faecal sludge compost – from windrow 3
- Faecal sludge compost + NPK
- Pelletized faecal sludge compost + NPK

The findings of the above analysis used to develop the model of fsm in sub districts. Beside that logistic information from different sources was analyzed to check the feasibility of fsm system based on small towns.

Results

Four types of pumps were tested during the research. These pumps were tested in two different sub-districts as these sub-districts are larger in area and population than the other sub-districts of this study. The sub-districts were Bhaluka (Mymensingh) and Fultola (Khulna). Seven sweepers were hired to test the protocol of these pumps from these two sub-districts. Three sweepers from WSUP in Dhaka were hired to demonstrate the use of the selected pumps to those seven sweepers in rural areas and to test the selected pumps by using them to empty the pits of rural households, who had volunteered to take part in this study. The findings collected from these ten persons are shown in table 1.

Table1: Comparing different pumps to gauge feasibility of use in rural areas

	Gulpher	Diaphragm	Diesel	Electric
Capital costs/ Purchasing costs (BDT)	10-15K	25-30K	20-25K	10-15K
Energy requirements	None	None	Diesel	Electricity
Maintenance costs (annual, BDT)	1-2K	1-2K	3-5K	2-3K
Ease of use in rural areas	Difficult	Easy	Difficult	Easy
Ease of handling	Difficult	Easy	Difficult	Difficult
Minimum labor requirement (per pit)	2	1	2	1
Van needed for transporting pump	Yes	No	Yes	No
Ideal pit depth	3-5ft	3-10 ft	10-15 ft	3-10 ft
Pit emptying charges (per pit; BDT)	0.5-1.5K	0.5-1.5K	1.5-2K	1.5-2K

Spillage during emptying	Yes	No	Yes	Yes
Probability of damaging latrine during use	High	Low	Med	Low
Preparation time (minutes)	15-20	10-15	20-30	15-20
Pit emptying time (minutes)	20-30	15-20	5-10	101-5

In order to identify the main characteristics of raw FS, representative samples were collected from single pit latrines in the following sub-districts, districts: Mirzapur, Gazipur (samples collected from 4 pit latrines in Feb 2014 and from another 4 pits in Jul 2014); Phultola, Khulna (6 pits, Feb 2014); Senbagh, Noakhali (6 pits, Aug 2014); Bhaluka, Mymensingh (6 pits, Jun 2014); and Chagolnaiya, Feni (6 pits, Jun 2014).Table 2 illustrated the properties of the faecal sludge collected.

Table2: Physical and chemical characteristics of FS samples from single pit latrines

District	Moisture (wt%)	pH	Conductivity (mmho/cm)	TVS (wt%)	TOC (wt%)	TN (wt%)	C/N	PO_4-P (wt%)
Gazipur	83.68	7.35	3.34	68.56	36.38	3.7	9.52	2.1
Noakhali	88.1	7.08	5.02	68.65	37.23	3.91	10.09	2.13
Khulna	91.34	7.94	4.76	74.37	39.32	3.66	10.91	2.25
Mymengsing	90.54	7.73	3.51	68.09	54.34	3.15	12.83	1.67
Feni	90.54	7.81	4.58	77.88	41.19	3.98	11.12	2.49
Mean	88.84	7.58	4.24	71.51	41.69	3.68	10.89	2.13

TVS = Total volatile solids; TOC = Total organic carbon; TN = Total nitrogen; C/N = carbon to nitrogen ratio

Microbiological characteristics reported in table 3 confirmed the actual challenge for the stabilization of FS material, particularly when strategies for reuse/recycling of resources including handling, transportation and recovery of materials into agriculture. In particular the prevalence of helminth eggs in FS material was targeted as the main concern regarding the quality of any final product with the potential to compete in the fertilizer market.

Table3 : Microbiological characteristics of FS samples from single pit latrines

District	Total coliforms, cfu/g	*E. coli*, cfu/g	Helminth eggs	
			egg/g	Group
Gazipur	5.20E+06	3.50E+06	20	*Ascaris lumbricoides*
Noakhali	7.90E+04	2.30E+04	119	*Ascaris lumbricoides, Trichuris trichiura, Enterobius vermicularis, Hymenolepis nana*
Khulna	1.40E+05	9.80E+04	32	*Ascaris lumbricoides, Hymenolepis nana,*
Mymengsing h	1.90E+05	9.00E+04	13	*Enterobius vermicularis, Taenia spp*
Feni	1.80E+06	7.60E+05	23	*Enterobius vermicularis, Ascaris lumbricoides,*
Mean	1.50E+06	9.00E+05	41	

Pre-treatment units for FS dewatering were develop at pilot scale in an existing composting facility at Purbapara, Gazipur, Bangladesh, which is located approximately 50 km away from Dhaka city centre .At the project site, two identical sand drying beds with mix media (i.e., dry rice straw, sand and gravel) were constructed with a surface area of 12 m^2 and designed to operate with a maximum solid loading rate of 450 kg m^{-2} yr^{-1}. The primary purpose of these drying beds is to dewater and dry FS collected from single pit latrines before co-composting. Considering the potential to utilize exothermic energy released during the biological stabilization of organic matter under anoxic conditions, it was envisaged that the use of bio-drying beds would help to reduce drying cycles; particularly during wet seasons with added benefits such as faster FS stabilization during composting. Pilot-scale bio-drying beds were constructed at the experimental facility in Purbapara, Gazipur. Table 4 showed the physical, chemical and microbiological composition of the final product from each of the 6 windrows together with concentrations for various parameters taken from the national standards for organic fertilizer in Bangladesh.

Table 4: Final characteristics of sludge in different windrows

Parameter	Windrow1	Windrow2	Windrow3	Windrow4	Windrow5	Windrow6	
Faecal Sludge	Sand beds		Bio-dried				Bangladeshi standards
EC (mmho/cm)	1.76 ± 0.17	1.98 ± 0.08	2.82 ± 0.23	1.29 ± 0.08	1.54 ± 0.12	2.08 ± 0.14	-
pH	7.10 ± 0.19	7.40 ± 0.14	7.36 ± 0.25	7.35 ± 0.22	7.70 ± 0.26	7.56 ± 0.04	6.0-8.5
Moisture (%ww)	37.22 ± 2.29	39.36 ± 1.55	41.30 ± 3.12	52.52 ± 2.34	56.15 ± 1.57	54.65 ± 1.78	10-20
TVS (%dw)	42.33 ± 3.03	45.21 ± 0.78	36.32 ± 0.59	36.52 ± 3.13	34.97 ± 2.78	33.81 ± 1.19	-
TOC (%dw)	25.08 ± 1.70	23.91 ± 1.17	24.71 ± 2.13	19.85 ± 1.79	18.99 ± 1.50	18.22 ± 1.20	10-25
C/N	15.12 ± 0.20	15.52 ± 0.45	15.83 ± 2.12	11.15 ± 0.77	12.17 ± 0.16	10.80 ± 0.41	<20:1
Total N (%dw)	1.66 ± 0.13	1.54 ± 0.04	1.57 ± 0.13	1.78 ± 0.11	1.56 ± 0.12	1.69 ± 0.16	0.5-4.0
PO4-P (%dw)	1.12 ± 0.06	1.21 ± 0.11	1.26 ± 0.09	1.38 ± 0.08	0.97 ± 0.07	1.21 ± 0.06	0.5-3.0
NO3-N (%wt)	0.12 ± 0.00	0.09 ± 0.01	0.07 ± 0.01	0.11 ± 0.03	0.13 ± 0.01	0.13 ± 0.01	-
NH4-N (%dw)	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	-
Total Coliforms (cfu/g)	nil	nil	nil	nil	nil	nil	-
***E. coli* (cfu/g)**	nil	nil	nil	nil	nil	nil	-
Helminth (eggs/g)	nil	nil	nil	nil	nil	nil	-
Si (% dw)	21.96	19.04	16.42	18.71	15.98	18.25	-
Ca (% dw)	6.49	6.85	5.57	5.23	6.78	8.69	-
Fe (% dw)	2.77	3.30	2.95	3.58	3.48	3.14	-
K (% dw)	2.57	3.01	2.61	2.73	2.49	2.85	0.5-3
Mg (% dw)	1.59	1.50	1.15	1.24	1.18	2.05	-
S (% dw)	1.14	1.12	1.00	1.21	0.92	1.27	0.1-0.5*
Mn (% dw)	-	0.24	0.00	0.00	0.00	0.30	-
Zn (% dw)	0.11	0.11	0.08	0.15	0.18	0.16	< 0.1**
Cr (% dw)	0.03	0.00	0.03	0.00	0.03	0.00	< 0.005%***
Cu (% dw)	0.02	0.02	0.02	0.02	0.02	0.02	< 0.05%
Ni (% dw)	0.01	0.01	0.02	0.00	0.02	0.00	< 0.003%****
As (ppm)	0.37	0.54	1.18	0.38	1.02	0.43	20 ppm
Pb (ppm)	11.40	22.12	18.24	17.66	19.32	50.88	30 ppm
Cd (ppm)	1.10	0.71	0.76	2.26	0.76	1.44	5 ppm

Figure 4 showed the trial result of compost on spinach. Faecal sludge based compost with NPK has given best result on the spinach.

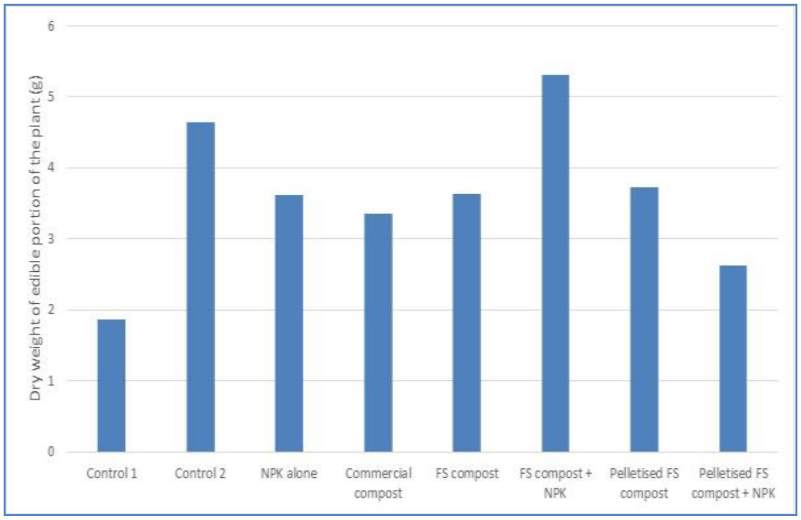

Figure 4: Yield of plant in different treatments

Discussion

In Bangladesh improved sanitation in small and emerging towns consists largely of latrines and septic tanks. A major part of the human waste from these facilities is dumped untreated in waterways or on marginal land, harming the livelihoods and health of the poorest. Without proper faecal sludge management improved sanitation and hygiene is unattainable. This is not only an environmental problem, but also an equity problem. It is the richer and middle classes that construct septic tanks, but most sludge are emptied manually, posing a health risk to some of Bangladesh's most dispossessed communities who carry out this work. Sludge largely ends up being dumped untreated in drains, waterways and on marginal land, where it pollutes and poses a huge health risk, again mostly affecting the poorest communities[viii]. In the small towns most of the latrines are consists of single pits. Thus this study focused on the collection, transport and reuse of single pit contents. It also intended to develop the process to reuse the septic tank content as well. The study started with a trial of different pumps to collect the content of single pit latrine. The diaphragm pump emerged as the most feasible option for reducing contact with sludge while emptying rural pits. Debriefing conversations with sweepers in Bhaluka and Fultola revealed that they were unlikely to purchase the pump of their own accord due to its high capital costs. Therefore, the government/municipality would need to provide subsidy/incentives to facilitate the purchase of these pumps. However, this is a one-time subsidy, and not a recurring one. The cost of the pump will likely be recovered over the lifetime of the pump. The Vacutug, being driven by belt and pulley, faced another challenge. While carrying a full load on an Uneven and rough rural road, especially on sandy soil, the belt often breaks and requires immediate Replacement. This is an additional cost of operation. The logistics test has taken this as the basis for computation, as the Vacutug vehicle did not have any device whatever either for measuring consumption or for measuring the distance travelled. Therefore, for each kilometer traveled, Vacutug suction and the lifting operation consumed 0.62 liters of diesel oil for lifting of one full tank load of 700 liters of faecal sludge. Water to solid ratio was 75:25. The outreach of the Vacutug is a 50 feet suction pipe. However, most pit latrines in research area are from 100 to 200 feet from the road. Therefore, the Vacutug operation could only service a limited number of pit latrines. Physical, chemical and microbiological characteristics of FS per district are reported in tables 2 and 3. For the stabilization of FS via composting processes, it is required that pre-treatments units developed in this study should be able to reduce moisture content from 90% to 50%. On average, the carbon to nitrogen ratio found in FS samples (10:1) presents the potential for co-composting FS with other organic wastes locally available, in order to improve the nutrient content and value as fertilizer. The prevalence of helminth eggs in the FS material was targeted as the main concern regarding the quality of any final product with the potential to compete in the fertilizer market. One particular FS sample from the Noakhali district had the highest number of helminth eggs (511eggs/g), which made a strong influence on reported mean values. Also it is important to highlight that, 12 out of the 32 FS samples did not contain helminth eggs. FS dewatering and drying was initially carried out under direct sunlight during the dry season February-March, 2014 (i.e., □5 hours of sun per day). Results reported in Figure 6 shown that the designed drying beds are able to reduce initial moisture content from 85% to 50% within a 15-day drying cycle. An extended drying cycle of 30 days in total provided further moisture reduction, resulting in a drier FS with only 36% moisture (see Figure 6 (a)). Along with moisture removal, drying and dewatering pre-treatment processes contribute to pathogen inactivation in dry FS with 40% helminth egg inactivation, and 90% *E. Coli* and 70% total coliform removals in 15 days (94% removal for *E. Coli* and Total Coliforms in 30 days). It was noted that the percolate from each drying bed does not contain helminth eggs, which confirms the excellent performance and efficiency of the filtration system. Unlike septage, FS from a matured single pit (i.e., 2 years pit) contains lesser amount of water and hence, its percolate from a sand drying bed is not as demanding in terms of post-treatment requirements. Temperature increased considerably during bio-drying with single readings varying between 30 and 47°C. Moisture removal did not improve when compared with results obtained from sand drying beds; and the removal achieved was only 25% with a longer drying cycle. Total coliforms and *E. coli* removals were both 99% and with regard to helminth eggs inactivation, it was only 16%. Also, higher temperatures favored additional nitrogen losses due to ammonia volatilization (i.e., remaining total nitrogen was 1.84%, while total nitrogen from sand beds was 2.63% after 15 days and 2.45% after 30 days during the dry season. Total nitrogen figures for sand beds during wet season experiments were 2.57% on average. It can be seen that for the majority of the parameters measured, where there is a corresponding standard in Bangladesh, the material produced meet the required standard. However for sulphur, zinc, chromium and nickel, the end products for some of the windrows fell outside the standards given. The data would suggest that sulphur is almost certainly coming from the faecal sludge. However, it is not clear what the source of the heavy metals is, as elemental analysis was not carried out on the raw sludge or the bulking agents.

This study reveals the opportunity to develop a faecal sludge management model based on the sub-district towns of Bangladesh. There are 488 sub-district towns in Bangladesh that are considered as small urban areas. These towns act as nucleus of the unions (smallest administrative areas of Bangladesh). Unions could be an option for the centre of management as well. But weak administrative capacity and lack of space for treatment made this unit out of considerations. Sub-district towns established its position as a strong competitor for being the centre of FSM in small towns because of its strategic position. This study trialed the feasibility of using different types of pumps along with Vacutugs in this regards. As these types of towns have both well constructed and muddy roads thus both manual pump and vacutug can be of use. Vacutugs with long suction pipe can serve the surrounding union households as well. For interior areas diaphragm pump can be of great use. According to that model the treatment facility will be outside the town and the sub-district council can have the authority of it. As the unions are in close proximity thus the final valorized product can be easily distributed to the farmers. The final pellet produced from faecal sludge showed good prospect to be used as organic fertilizer or soil conditioner. Thus developing the supply chain based on sub-district towns may create cost effective solution from the consideration of transport cost of the product. Research findings have showed that compost production certificate and regulations are complicated and time-consuming. So developing fsm system following this model needs to ease the process. Figure 5 stipulates usual distances of unions from Upazila (sub-district) towns.

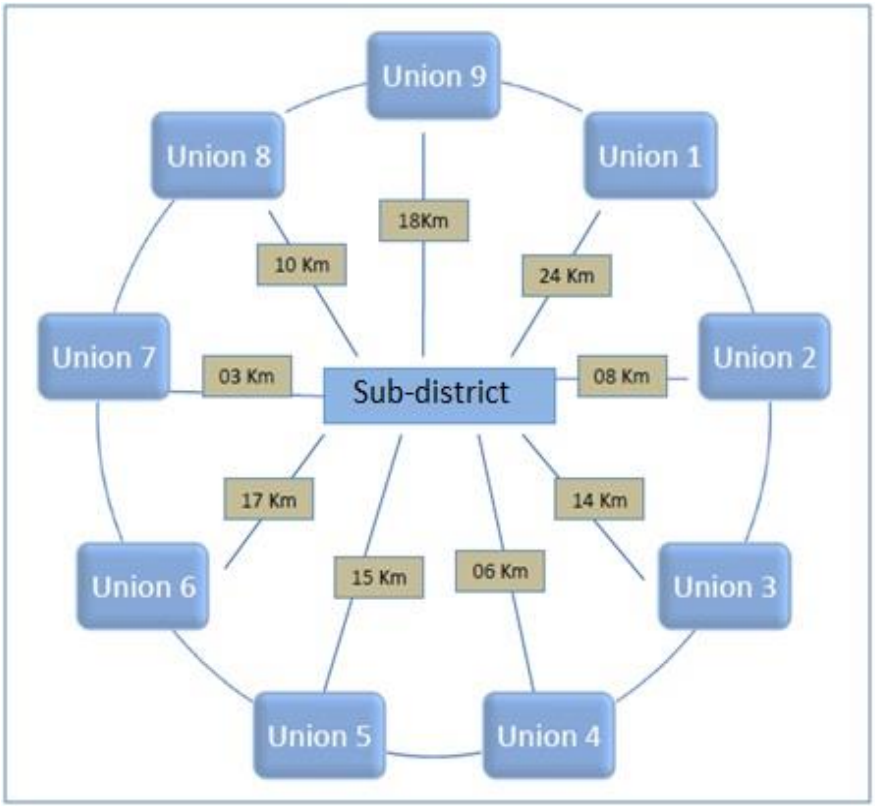

Figure 5: Usual union to sub-district distance of Bangladesh

Sub-district Council is the authority of sub-district towns and they have to play the lead role here. But it will also need private partnership and social participation. Vacutug trial showed that, sludge collection part can be outsourced by private entrepreneurs where they will have the profit on incentive, based on the amount of sludge they will deliver to the treatment plant. Also for the retail of the fertilizer, engagement of private entrepreneurs can play a good role. As there are some nuisance issues thus social participation is very important. Figure 6 explains a hypothetical model of fsm in sub-district towns.

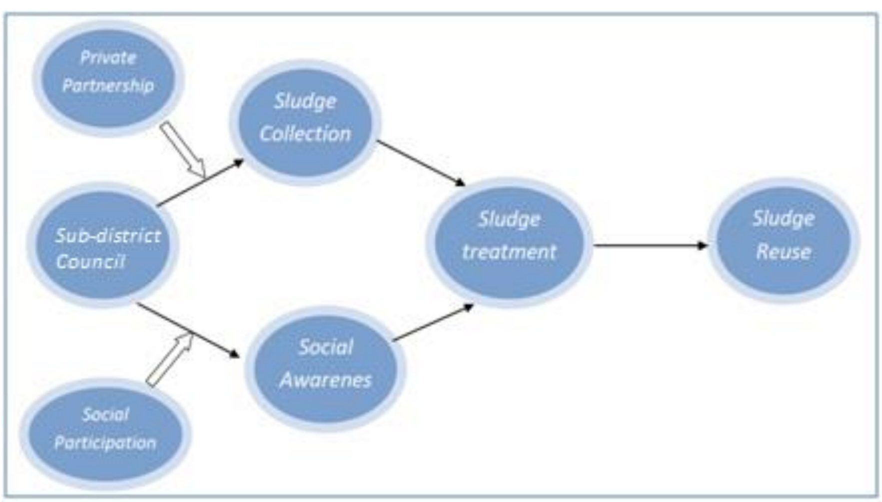

Figure 6: Hypothetical model of FSM in sub-district

The research findings of this study unveil the opportunity of establishing a small town based fsm system. Although there are many more challenges exist in establishing a full proof management system, this study identified some significant parts of them and discovered possible solution for that.

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